Application of Augmented Reality in Engineering Graphics Education

Heen Chen,Kaiping Feng,Chunliu Mo,Siyuan Cheng, Zhongning Guo,Yizhu Huang
Faculty of Electromechanical Engineering
Guangdong University of Technology
Guangzhou, China
chheen@gmail.com; fengkp@gdut.edu.cn

***Abstract*—Engineering graphics (EG) is the subject of transferring information from design into manufacture. Developing ability to create and read graphical representation of engineering structure is essential for individual. Therefore, training engineers able to use the graphical language to communicate is vital in every engineering college. However, in the classroom, where lecture time is limited, it is hard for the instructors to illustrate clearly the relationship between the 3D geometry and their 2D projection using only one kind of presenting technique. This work gives a brief insight into the potential and challenges of using Augmented Reality (AR) in Engineering Graphics Education. An AR-based system specifically designed for EG instruction were studied and developed. The system aims at improving the spatial awareness and interest of learning. Our own interest is to apply the AR system to Engineering Graphics instruction and provide the students with their own unique discovery path. The AR application enables faster comprehension of complex spatial problems and relationships which will benefit the students greatly during their learning processes. The AR-based method is proved to be effective teaching aids for engineering graphics courses and applying AR technology to support learning activities may become a trend in the future.**

Keywords-Engineering Graphics Education; Augmented reality; Computer vision; Teaching reform

I. INTRODUCTION

Engineering graphics (EG) is the subject of transferring information from design into manufacture. Developing ability to create and read graphical representation of engineering structure is essential for individual. Therefore, training engineers able to use the graphical language to communicate is vital in every engineering college. Besides understanding the relationship between three dimensional (3D) objects and their 2D projections, Graphics education aims at comprehending geometric relationships of lines, sides, planes, angles, developing their ability to make sense of visual information, and motivating logical thinking and cultivating logical skills. However, in the classroom, where lecture time is limited, it is hard for the instructors to illustrate the relationship between the 3D geometry and their 2D projection using only one kind of presenting technique. The research presented herein aims to develop a teaching aid: an augmented reality (AR) model presentation system, to help students better understand the relationship between 3D objects and their projections.

According to Azuma [1], Augmented Reality is a variation of Virtual Reality (VR), allowing the user to see the real world, with virtual objects or information superimposed upon it. Therefore, AR supplements reality, rather than completely replacing it. Nowadays, AR applications have become portable and available on mobile devices. AR is desirable for entertainment, game, travel, maintenance, and marketing to get more exciting experience. In education and training, AR has the potential to make ubiquitous learning a reality, allowing learners to gain immediate access to a wide range of information from various sources. Research in conceptual learning in immersive augmented scene has recently seen great progress. As suggested by several authors VR and AR can contribute to provide opportunities for more authentic learning and motivation in students with a high potential to enhance the learning experience and engage them in a way that have never been possible before[2][3][4]. The 2010 Horizon Report also predicts that the use of simple AR in education will be widespread within 2 to 3 years on US college campuses [5]. However, the practical potential of AR is still being explored. How to use AR technology to support learning activities offers considerable challenge for the designers and evaluators. This paper concentrates on the use of Augmented Reality for Engineering Graphics educational purposes.

AR application attempted at presenting the assembly process of specific equipment to date has limited result due to poor interaction. Traditional virtual assembly system uses mouse and keyboard to operate assembly objects which leads user feel difficult to grasp or move the 3D virtual object in the virtual environment [6]. A virtual system was developed for assembly training using data glove and do have some intuitive performance. However, this work has been unavailable to regular users due to the expensive and cumbersome of data glove. In the last decade, the advances in computer vision technique allows user to communicate directly with computer without applying any supplementary devices [7]. Computer vision-based technique needs only one or more cameras to analyze the user's gesture and intention, thus the cost become much lower than other methods. Therefore, this paper investigates the realization of an Engineering Graphics Education system using computer vision-based AR technology.

In the next section, techniques for designing educational AR applications will be discussed. Afterwards the architecture of AR-based Engineering Graphics System will be addressed. Our experimental results are illustrated in section IV. Furthermore, comparisons between AR application and traditional presenting method are made. Finally, we summarize our work with a few further comments.

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II. DESIGNING EDUCATIONAL AR APPLICATIONS

To realize AR-based Engineering Graphics Education system, two key techniques have to be considered: (1) Real-time tracking and alignment technique: computer can render and register a virtual object in the real environment quickly and properly; (2) Interactive technique: user can interact with computer and move virtual object smoothly; (3) Real-time 3D rendering technique: system can generate 3D composites solids that meet the requirements of EG instruction. Software and libraries designed specifically for AR applications are available now. There are several techniques for our rendering purpose. OpenGL is better for mechanical structure simulations with all the geometrical features, e.g. cylinder, cone and chamfer, being added up easily.

Since the graphics education is crucial in cultivating the student's ability, the contents and the process of the AR applications should be set up carefully. Sometimes the journey of solving the problem of Graphics always takes some form of logical deducing. Considering the practical aspects, user interfaces are designed according to the mechanical drawing standards and educational requirement.

III. AR-BASED ENGINEERING GRAPHICS SYSTEM OVERVIEW

As shown in Fig.1, the architecture of AR-based Engineering Graphics System consists of five components: (1) tracking and registration module; (2) gesture computing module; (3) operation instruction module; (4) 3D model database; (5) rendering engine.

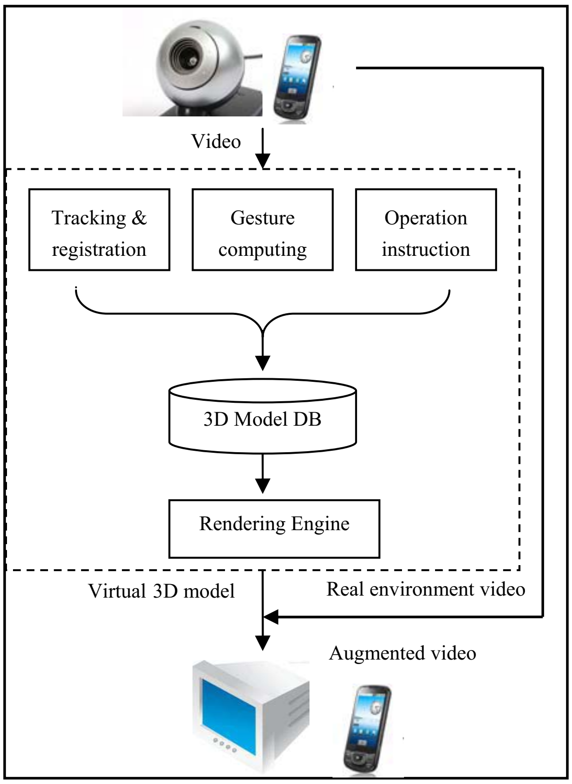


Figure 1. Architecture of AR-based Engineering Graphics System

Tracking & registration module and gesture computing module play an essential role in the AR application system. Video captured by camera are sent to tracking & registration module and gesture computing module. The tracking & registration module is responsible for estimating the position and pose of the camera. The system then generates virtual 3D model which will appear precisely upon the real pages in respect to the position and orientation of the camera or the Smartphone. Our utilization of 2D markers for AR tracking is similar to other vision-based tracking systems. The algorithm employed in calculating the position and orientation of camera is based on literature [8].

Size-known markers serve as the target of the coordinates frame in which Virtual 3D object are superimposed. We refer to the marker frame of reference *m* with respect to the pose of a camera *c* as:

$$T_{cm} = \begin{pmatrix} R_{cm} & C_c \\ 0^T & 1 \end{pmatrix} \quad (1)$$

Where T_{cm} is the matrix describing point transfer between the marker's frame of reference and that of the camera and R_{cm} is the rotation matrix describing directional transfer, and C_c is the location of the center of marker in the frame of reference *c*. The transformation matrix from this marker coordinates to the camera coordinates T_{cm} represented in Eq.1 can be determined by image analysis. Consequently, the generating 3D model will be transforming to align with the target marker.

We use gesture recognition algorithm from [6] for gesture computing. Once the computing modules figure out the intension of the user it then tells the render engine how to generate the graphics. Operation instruction module provides the interaction functions. The learners can move, rotate, zoom or even split the constructed 3D virtual objects under the guidance of operation tips.

The 3D model database was constructed with 3Ds Max Software [9]. The database can be accessed and each 3D model can be retrieved by using a square-sized marker, as shown in Fig. 2.

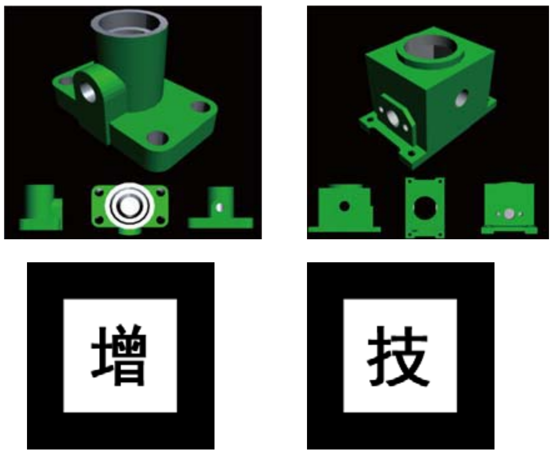
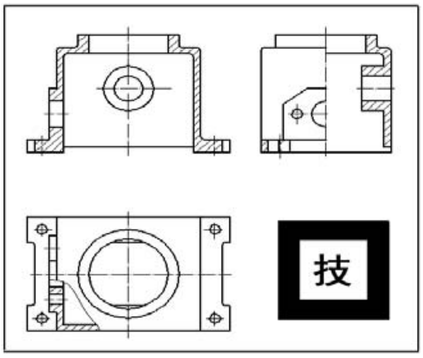


Figure 2. 3D models and markers

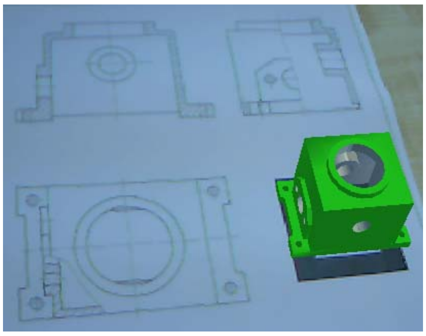
IV. IMPLEMENTATION

The AR-based Engineering Graphics System uses normal books as the interface. Students can turn the pages of these books, look at the problem inside the book, and finish their assignment much the way they are reading and writing on an ordinary sheet. However, if they focus a camera on the marker, a 3D virtual models pop-up in the computer screen over the real pages. The virtual models superimposed upon the real page will serve as the tip for imagining the relationship between the 3D geometry and their 2D projection.

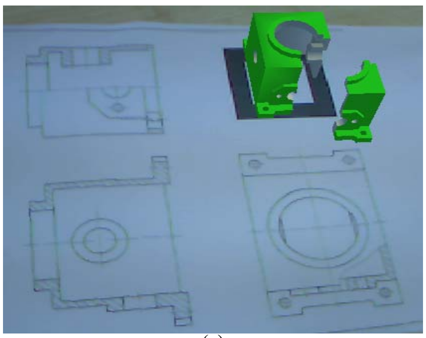
Our AR-based Engineering Graphics System is running in Pentium Dual-Core2 E6300@2.80G CPU with NVIDIA GeForce G210 graphic card, 2G memory and Logitech Pro5000 Camera. The implementation result is shown in Fig.3 and Fig.4.



(a)



(b)



(c)

Figure 3. Virtual 3D sectioning casing overlay on real page

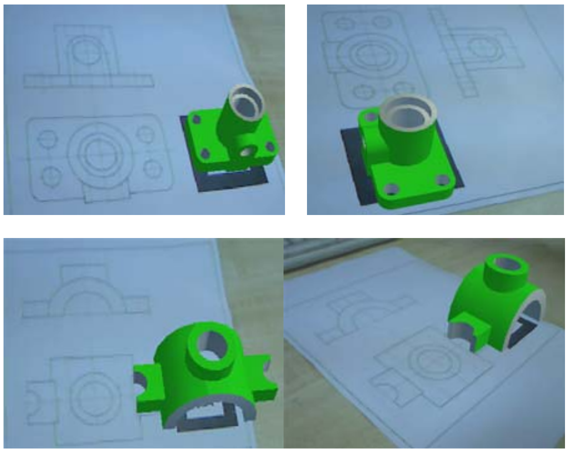


Figure 4. Virtual 3D solids overlay on real page

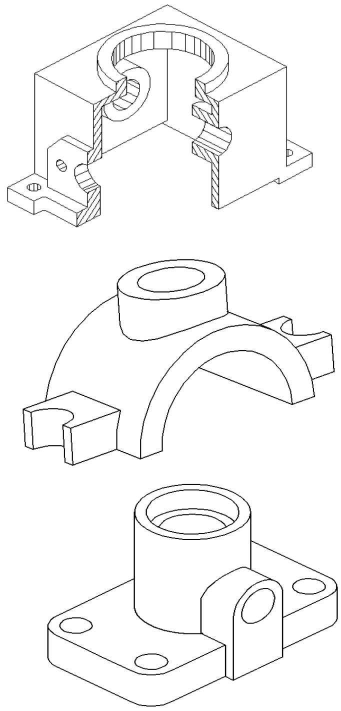


Figure 5. Axonometric drawings of 3D solids

Fig.3 (a) is the drawing of a worms and worming wheels casing. When the students have difficulty in understanding the structure, they can turn to the AR system. The AR system provides modes of Auto learning in our tutorials. Employing computer with a camera or a Smartphone equipped with a camera, students will be able to go through the tutorial themselves. Focus the camera on the markers and the virtual 3D objects will be retrieved from database and the information and graphics are then overlaid onto the screen, as shown in Fig.3 (b). By rotating the real drawing, the virtual object can be rotated accordingly and multi-planar character of the object can be seen. The shape of the interior parts of the wheel casing can be revealed by sectioning operation, as illustrated in Fig.3 (c).

Fig.4 show different 3D virtual superimposed on real 2D three-view drawing. The AR-based learning method enables students to access 3D solid structure and spatial detail information which greatly reduce time spent by the instructors in a classroom. Compared with traditional learning approach, which usually uses axonometric drawings to illustrate 3D composite solids (as shown in Fig.5), the advantages of AR-based learning are obvious. Axonometric drawings can only present one plane projection, while the AR method can reveal all the outer aspect of the 3D models. Since the axonometric drawings are kinds of fixed image, and the rear view of the 3D solids is hidden, it is hard for a beginner to visualize the shape of the 3D object from these drawings. However, in an AR environment, the learner can interact with the 3D virtual model by rotating the markers or using operation instruction, therefore it is very easy to get the spatial visualization of a 3D object. Moreover, in order to overcome the difficulty of interpreting, sectioning instruction can be applied to view the interior part of a complex model. For students attending the EG curriculum, AR-based learning brings flexibility and convenience with self-paced instruction that provides immediate feedback. For many students the aid system may offer an alternative to the classroom situation that did not work for them.

V. CONCLUSION

This paper proposes a general architecture of AR-based system for Engineering Graphics learning. A vision-based gesture recognition method for AR-based educational system is introduced. By focusing a camera on the real page with a specific marker, a 3D virtual model will appear which can be seen from the computer screen. The virtual models superimposed upon the real page will serve as an aid for solving the 3D spatial geometry question. The application provides learner with rich information and more intuitive experience. The simulated experiment results of the prototype system demonstrate the effectiveness of our approaches. Due to advances in the development of computer vision applications and technology, and a simultaneous decline in hardware costs, the use of mobile augmented reality systems running on Smartphone become feasible for educational institutions. Our own interest is to apply the AR system to Engineering Graphics instruction and provide the students with their own unique discovery path. As the AR application enables faster comprehension of complex spatial problems and relationships, students can benefit greatly from it during their learning processes. AR technology is proved to be effective teaching aids for engineering graphics courses. Applying AR technology to support learning activities may become a trend which will post considerable challenge for the designers and evaluators.

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