Title:
**Shape Acquiring and Editing through an Augmented Reality based CAD System**

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Introduction:
Most presently used Computer-aided Design (CAD) systems remain to be based on traditional interface such as monitor, mouse and keyboard. By using these interfaces, designers cannot freely explore shapes in three-dimensional (3D) space, which limits the designers' creativity. The traditional interface is also difficult to use. For example, it is tedious and time consuming to edit a NURBs surface using a mouse or a keyboard by specifying the shape of its silhouette.

There is a large number of research focusing on adopting AR techniques in CAD systems. Van Krevelen and Poelman [1] provided a comprehensive survey of AR technologies, applications and limitations. In recent years, more research was conducted to adopt virtual and augmented reality (VR/AR) in Computer-aided Design. Some approaches such as advanced realism CAD environment (ARCADE) [2] and Construct3D [3] connect existing VR/AR framework to CAD core. Various approaches differentiate from each other by using different 3D input/output interfaces and targeted applications such as shape acquisition and design reviewing. Using similar CAD operations developed for traditional CAD systems, none of the systems adopt 3D physical objects in their system to provide users visual and physical guidance. In this research, shape exploration operations based on the AR integrated CAD system are discussed. Its application in designing customized dental device is demonstrated. Validation in terms of usability and time efficiency from several users is also presented.

Main idea:
A novel augmented reality (AR) based CAD system is presented to provide designers with intuitive and convenient design experience. The desk-top size system consists of a stereoscopic display and two types of 3D input devices, one for each hand. Figure 1 shows a prototype of the AR-based CAD system. The stereoscopic display used as the visual output helps to create an AR environment for the CAD system; the 3D input devices are able to execute positioning function to directly capture user inputs in 3D space. Details about their implementations are described in the paper.

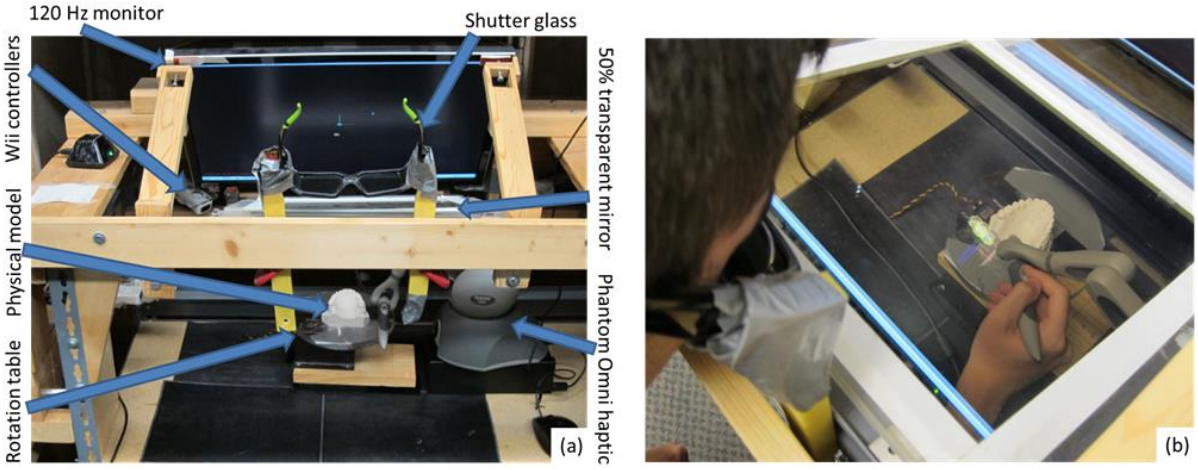


Fig. 1: A prototype AR-based CAD system. (a) Overview of the system; (b) a user can see both physical and virtual objects in the system. In addition, the display of a virtual object is aligned with the related physical object positioned in the system.

The presented 3D interface can potentially change the way of future designers in using CAD systems to design engineering products. That is, instead of mentally converting between 3D shapes and their two-dimensional (2D) projections displayed on a monitor, designers can directly explore 3D shapes by displaying and touching of physical objects. Thus, the new interface would allow designer to focus more on the product shape design itself. Future CAD software systems need to be redesigned to enable creating and editing 3D geometries in a simple and intuitive way. However, how to design CAD operations based on the new interface such that a CAD system can intelligently capture user intention is still an open problem. Our initial investigation of some CAD operations is discussed in the paper.

An interesting feature of the new 3D interface is that it allows designers to use physical objects as visual and physical feedback during the design process. Such physical objects may already exist, or can be created using various 3D printers. For any physical object in our CAD system, its digital model may be displayed based on a user-specified viewing mode. In addition, the physical and digital models are kept aligned with each other during model manipulations such as rotation or translation.

A stereoscopic technique based on a 3D monitor is used to display virtual models in the working space of the CAD system. A beam splitter is used to superimpose virtual models with physical objects that are positioned in the working volume. Thus, a user can easily verify his/her design by using the physical objects as a reference. Figure 2 shows an example, in which the user needs to design a customized dental brace wire for a physical teeth object. The physical teeth object can be created by the dental impression of a patient. In addition to the visual feedback, the physical object can also provide physical guidance for user's 3D input. For instance, the dental braces wire as shown in Figure 2 can be directly created by sliding an input stylus on the physical teeth object along the desired path. In comparison, using a traditional CAD system to design such a customized wire for a patient would be a tedious job taking a long time.

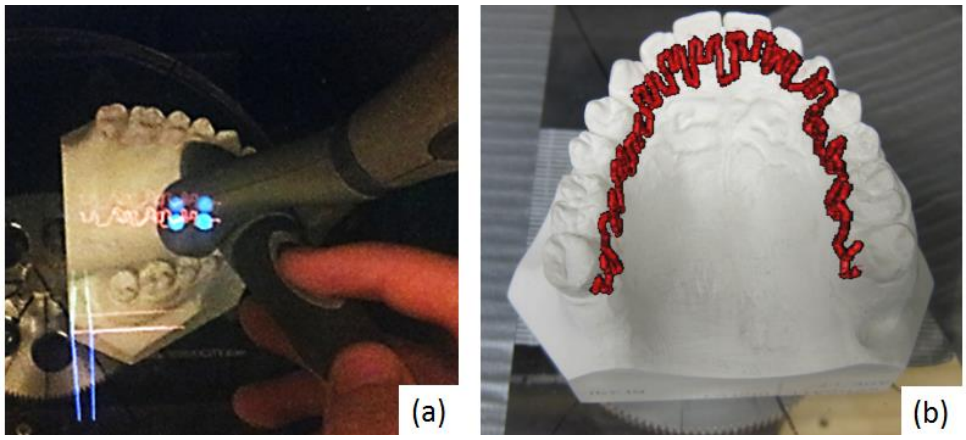


Fig. 2: An example of dental brace wire design. (a) A picture showing the design process of a dental braces wire. A user can directly draw lines on the physical teeth object; (b) a rendering image of the resultant design as shown through the 3D shutter glasses in the AR environment.

Conclusions:

An augmented reality-based CAD system has been presented in the paper. It uses stereoscopic display for visual feedback, and two position tracking devices for 3D user input. Physical objects are used in the system to provide visual and physical guidance in the AR environment. Analysis has been made on the proposed system in the aspects of visual feedback and designer input. A set of displaying and CAD operations have been developed to capture user's intention in shape creation and editing. The implementation of a prototype CAD system has been described. Several test cases are shown to demonstrate the intuitiveness and effectiveness of the AR-based CAD system. The system can potentially be used for the customized dental appliance design.

References:

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