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APPLICATION OF VR TECHNOLOGY IN DESIGN EDUCATION

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ABSTRACT
In the era of globalization, design education is playing vital role in design of products and systems. Designers conceive products which are in their imagination and many a times these are virtually prototyped but need to be converted into tangible products. Design education is facing the challenge of teaching theory and application to bridge the gaps between solution of a design problem and its conversion to a tangible product. Virtual prototyping facilitates to visually realize the size and form of a product and physical products can be realized through Rapid Prototyping (RP). However the product may require further modifications in absence of haptic feedback during virtual prototyping process since designers may not be able to perceive characteristics such as textures, elasticity, weight, depth, perception etc. Advancement in three dimensional visualization technologies and increasing demand for innovative methods in design education has made it imperative to use wide range of teaching and training materials involving virtual environments. Virtual Reality (VR) technology provides with realism and interactivity. The VR technology with haptic device integrated with Virtual Prototyping may reduce the gap between imagination and reality of virtual prototyped model, which can provide reality like perception of the conceived products and significantly enhance practice based teaching in design education and learning experience. If VR can be successfully combined with CAD to provide haptic feedback, space and form perception, it will bridge the existing gap to some extent between imagined/conceived and tangible products realized through RP.

Keywords: Virtual reality, design education, virtual environment, education, technology

1 INTRODUCTION

Current 'Industrial Design' and 'Engineering Design' students are entering higher education with significant computing knowledge and higher expectations from academic institutions that introduce them to appropriate technologies for their successful transformation into industry. Due to those reason, academic institutions are challenged to adopt appropriate strategies to meet the innovative educational demand [1]. In addition to this, industries are challenged by their customer's requirement, since customers have more focus on the ergonomic characteristics (e.g. comfort, appearance, texture, ease of use etc.) of the products. These characteristics of product are generally adopted at the early stage of product design, which consequently affect the manufacturing process and products performance. Thus, virtual reality and augmented reality technology are appropriate to speed up and give the wide option in a decision making activities in early stage of design process. VR has enormous potential to help in visualizing and understand the complex concepts and theories, lead to new product design, to motivate and encourage designers/design instructors in immersive three dimensional environments for teaching learning and design practice [1, 2]. Virtual reality is being used for industrial design, military training, automotive and aerospace design, medical (surgery, dental, and for phobia & autism treatment), maintenance, repair, and entertainment [1, 3, 4, 5, 6]. Virtual reality also provides a suitable environment for design reviews helping to reduce the development time and costs and to improve the quality and usability of new products. Above factors has made it almost compulsory for VR to be integrated with design education curriculum to be globally relevant. This requires design application based research in this domain. This research is in this direction undertaken by doctoral research scholars, where actual application of VR is used to evaluate product performance in terms of various ergonomic characteristics e.g. comfort, appearance, texture, ease of use, weight of the designed product etc. Particular product considered in this research is a battery powered tea leaf plucking machine designed in-house in the Department of Design [7], IIT Guwahati by doctoral research

scholar forming a part of design education to evolve a proper methodology for VR application in Design education.

2 AIM AND OBJECTIVE

Until recently, most of the applications of VR research are associated with design, entertainment, maintenance, repair, military & medical training purpose, product evaluation, educational tool applied for the science, art, mathematics etc. while limited information is available on its use as design educational tool. The aim of the present research work is to highlight existing scenario of VR applications in design education sectors for various purposes such as interior design, product design, ergonomics studies, and usability by integrating with haptic devices which allow interaction with virtual model and sensing the object with more realism. An attempt has also been made to highlight advantages, as well as identified reasons behind less adoption of this technology in design education disciplines. Aim of this research work was to evolve a method that can be easily adopted by design students and thereby facilitate integration of VR in design education.

3 VIRTUAL REALITY AND ALLIED SYSTEMS

3.1 Virtual Reality

Virtual reality has been defined in many different ways with respect the context of use, in general Virtual reality defined according to William and Craig [8] as a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more sense, giving the feeling of being mentally immersed or present in the simulation (a virtual world). This may display inside a blank room, headset, or other device that allows the user to feel present in the virtual environment [9]. Some virtual reality also offers features like feedback in the form of sound or touch to allow the user to interact with objects and spaces. As it is known, during the product design development, usability tests are usually performed after the physical prototype; now with the integration of CAD-VR with the haptic feedback device during the product design development process it allows to test and evaluate the usability without incurring cost for prototyping [10]. Haptic technology provides new potentials by allowing human operators to interact with digital models using the sense of touch. This aims to develop methods allowing designers to feel the elasticity of the products and to test the function of products with a haptic interface.

3.2 Augmented Reality

Augmented reality is a technology, which seeks to enhance the virtual reality environment by integrating the real world with added virtual elements. These can include sounds, sensations, or images generated by a computer system. Augmented Reality brings virtual information or object to any indirect view of user's real world environment to enhance the user's perception and interaction with the real world [11]. Unlike virtual reality, augmented reality does not create a simulated reality. Instead, it takes a real object or space and uses technologies to add contextual data to deepen students' understanding of it.

3.3 Virtual Prototyping

It is process of getting digital out put that represent the imagined model of component or system to be constructed during design process. Virtual prototyping (VP) has great advantage for decision making and modifying the weaknesses during the design stage. The use of physical prototypes is more expensive, they take longer to finish and difficult or impossible to modify it [2, 12]. Tactile feedback is the basis of these applications, in which the need for natural interaction and for the prototype to obtain the same features and properties as the real products, are emphasized.

4 APPLICATION OF VR AND AR IN DESIGN RELATED FIELDS

There is no doubt that usage of VR technology has brought avant-garde changes in many multidisciplinary scientific fields including design education. As large number of the authors have agreed that VR and AR are important and has potential in visualizing and interacting abstract model in three dimensional contexts and to facilitate learning. VR/AR provides the natural and interactive ways to express ideas and overcome the technical gap in the iterative design process by upgrading from traditional computer aided design process to mixed reality aided design space [13]. In addition to this,

Ye et al [12] investigated and explored the potential of VR based technologies into a computer aided product design and evaluation in comparison with traditional techniques. The uses of VR applications in various design education related fields have improved the productivity of teaching and training by allowing engineers to apply theoretical knowledge to real industrial problems with real time experience [1, 14]. The VR is categorized in three different kinds, first is desktop VR, which is by far better, most common and least expensive form of VR; second, a semi-immersive VR system that attempts to give the users a feeling of being at least slightly immersed by a virtual environment and third form of VR is usually referred to as being fully immersed [15, 16]. Desktop VR provide real time visualization and interaction within a virtual world that closely resembles a real world and enhances the learning outcomes [1, 17]. The real time interaction with virtual environment could be achieved through several communication methodologies such as visual (computer screen or stereoscopic display), tactile (force feedback) and auditory (stereo sound) feedback [18].

Nowadays applications of AR are widely used. Unlike other computing technologies AR supplements (combines) the real world with virtual objects (i.e. computer-generated) [19]. The combination of AR technology with the educational content creates new type of automated applications which acts to enhance the effectiveness and attractiveness of teaching and learning process for students in real life scenarios. Actually, AR is a new medium which is combining aspects from ubiquitous computing, tangible computing and social computing. This medium offers unique affordances, combining physical and virtual worlds, with continuous and implicit user control point of view and interactivity [11]. Using AR systems learners interact with the 3D information, objects and events in a natural way. Billinghurst [9] used AR technology in education for support of seamless interaction between real and virtual environments and suggested educator to work with researcher in exploring how this can be applied in school environment. Another interesting application of AR technology is to develop augmented reality textbooks [11], in which books are printed normally but when a webcam is pointed over the book, it brings visualizations and designed interactions on the screen of the device. This is possible by installing special software on a computer or mobile apps on a portable device. This technology allows any existing book to be developed into an augmented reality edition after publication. Through the use of AR in printed book pages, textbooks will became dynamic sources of information. In this way, people can have a rich interactive experience with comparatively less computer knowledge than computer experts.

5 HAPTIC INTERACTION WITH VIRTUAL MODEL

Haptic is the technology of adding the sensation of touch and feeling to computer generated models. This technology allows computer generated virtual objects to be touched and manipulated with one's hands or body [10]. Haptic senses links to the brain's sensing position and movement of the body by means of sensory nerves within the muscles and joints. Haptic feedback information is combination of tactile and kinesthetic information. Tactile information refers to the information acquired by the sensors connected to the body and kinesthetic information refers to the information acquired by the sensors in the joints [20]. In the context of virtual reality applications, haptic is a tactile feedback technology which allows users to use their sense of touch while interacting with a virtual model. By using haptic devices, users can interact with a virtual model by feeding and receiving information through tactile sensation. The possibility of interaction between the user and virtual models extended for Usability evaluation supports designer's decision making that evaluates design appearance (such as the texture, hardness and shape of objects) of product, and reduce revision cost of an inappropriate design, and save time [10,12].

Figure 1. Haptic interaction with Virtual model

6 APPLICATION OF HAPTIC FEEDBACK DEVICE AND VR IN DESIGN EDUCATION

There are certain problems of VR systems which are not integrated with haptic feedback devices. These problems include lack of depth perception, lack of perception of tactual properties etc. of the virtual prototype while designing in a virtual environment. Due to this fact designers/ design students may not able to develop appropriate product prototype for rapid prototyping. Therefore, repeated rapid prototyping is required for taking decision about ultimate product that will be manufactured further. Thus, this ultimately leads to increase of cost of rapid prototyping as more rapid prototype need to be developed for taking ultimate product decision.

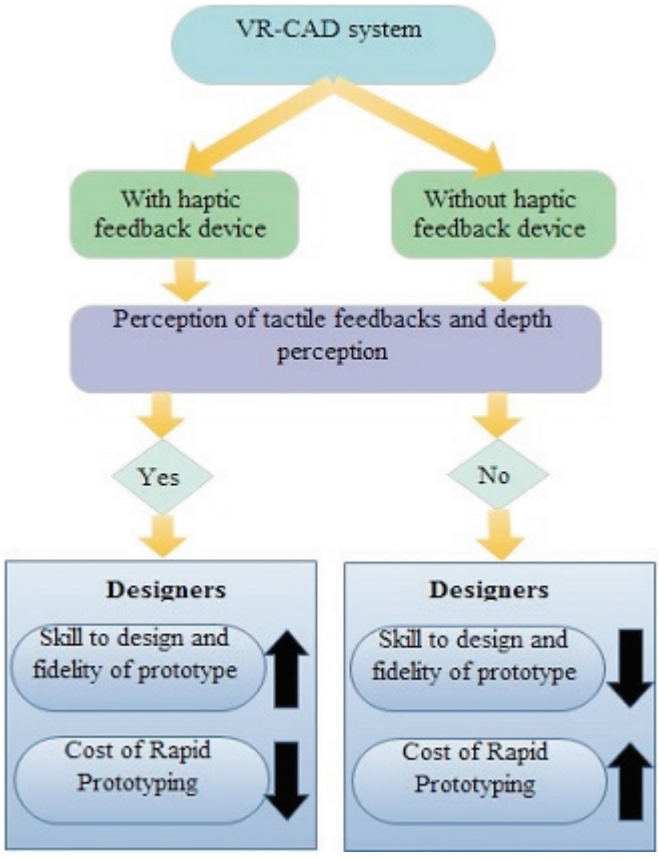

Figure 2. Flowchart the impact of VR with and without haptic on Prototyping

In **Figure 2,** it was depicted how designer may rely on the integrated VR-Haptic system to gain the skills of virtual prototype development and fidelity of the prototype. **Figure 2** is also able to express the importance of tactile feedback and depth perception during prototype development. Actually, haptic feedback system enhances virtual prototype fidelity which ultimately leads to less number of rapid prototyping as well as cost reduction for rapid prototyping. With the present conceptualized

frame work, it is clear that this kind of system may have some impact on design process. Therefore, design faculty may use this kind of system to teach prototype development to their design students for better design outcome. For instance, usability of the virtual model of tea leaf plucking device (**Figure 3**) may be evaluated with VR-Haptic feedback system such as "PHANToM Omni Haptic" which is enabled of tactual feedback as well as depth perception. In this evaluation process it is assumed that VR-Haptic integration will be helpful tool to reduce cost of prototyping, and time to market.

7 METHOD

Authors of this paper have initially studied state of the art in VR application through several research articles, review papers, books and book chapters from various authentic search engines with the help of internet as well as books available in library. The search engines used for this present review include Google, Google Scholar, ACM digital library, IEEE Xplore and other digital libraries. Following thorough study of the available literatures findings were reported systematically.

Based on the study, a method was evolved for using VR in design education as a tool by design students. Design of experiments were undertaken to validate the method evolved by actually taking a virtual prototype in CAD model and evaluating and improving the design prior to actual prototyping. VR program was formulated to evaluate and improve a prior Virtual Prototyped CAD design of a tea leaf plucking machine, **Figure 3**. Improved design was physically prototyped in both formats, prior to application of VR and after application of VR. Physical prototypes were tested in actual use and during the process it was found that physical prototype arrived after VR application was better than the one prior to VR application as assumed and thus a bridge between imagined model and tangible model was possible in terms of design experience.

Figure 3. Battery operated Tea leaf plucking virtual model

8 SUMMARY AND CONCLUSION

This paper briefly discussed about VR and AR technologies and their applications in various design related fields. In addition, present paper also able to discuss about the benefits of integration of haptic feedback device into the VR systems as well as how this integrated systems would help designers/ design students to perform realistically in complex computer aided product design process.

In the recent past, very limited researchers have applied VR/AR for design education. Although, these cutting-edge technologies have potentials to transform and improve design education in various purposes such as interior design, product design, ergonomics, usability engineering, form and shape design etc. by integrating with haptic devices which allow interacting with model and sensing the object with more realism and interactivity. This kind of system may be helpful for students to develop better understanding of complex CAD systems and design process. As stated above that application of these technologies to design education is still in its infancy. There is an urgent need for creating general awareness about benefits offered by these technologies for their wide adoption and very user-friendly methods for VR application by novice designers. There is a need for creation of awareness among tutors, researchers, scientists, engineers, etc. and could be achieved through organizing seminars, conferences, workshops etc. based on actual application case studies as described in this research work.

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