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An Immersive Online Shopping System Based on Virtual Reality

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Abstract. *This paper proposes an immersive online shopping system based on virtual reality (VR). The background of the developed VR mall is for cross-border e-commerce. In particular, the architecture of this VR-based prototype is designed, which is composed by six modules, i.e., virtual mall, item display, online pay, interaction, gaming and advertisement. Among these, the former there modules are essential, and the latter three are integrated elaborately in the system for shopping experience enhancement. The used commercial VR system is HTC Vive, which contains a headset, two independent controllers and two base station for localization. Wearing the headset, customers can roam in the mall freely. Based on controllers, they can pick up items and even compare when two different items are picked up by two controllers. In addition, the customer's position can be real-time tracked and localized, which is benefited from the support of base stations. All the content are stored in a VR-ready backpack PC, in this way the customer can walk in a space (e.g., 3×4 square meters) at will. Extensive experimental results and practical usage proves the validation of this system.*
Keywords: Online shopping, Virtual shopping, Virtual reality, Real-time localization.

1. Introduction.

(1) *Virtual reality.* As an emerging technology, VR has drawn a lot of interest among academia and industry in recent years. Generally, VR is defined as a realistic and immersive simulation of a 3D environment, created by interactive software and hardware, and experienced or controlled by movement of the body or as an immersive, interactive experience generated by a computer. In other words, it refers to using software (e.g., 3D engines) to generate realistic graphics, sounds and other sensations that replicate a real environment, and simulate a user's physical presence in it, by enabling the user to interact with this space and any objects depicted therein using specialized display screens or projectors and other devices. A person wearing a VR headset is typically able to look around the artificial world, move around in it and interact with features or items that are displayed on a screen close to eyes. Some of VR artificially creates sensory experiences,

TABLE 1. VR headset classification

Category	Typical products
PC VR	Oculus Rift [2], HTC Vive [3]
Mobile VR	Google Cardboard [4], Gear VR [5]
Console VR	PlayStation VR [6]
All-in-one VR	Intel Alloy [7], Sulon Q [8]

which can include sight, touch, hearing, and even smell. VR plays an important role in sophisticated human-computer interfaces (HCI). It usually refers to a computer simulated environment that can simulate physical presence in places in the real or virtual worlds. It can recreate various sensory experiences thanks to its capability in providing immersion, interaction and imagination to end users.

The underlying idea for stereoscopic visualization is that it is close to the way we naturally see the world. Nowadays, a number of visualization technologies have been developed for immersive exploration of complex scenes. Two mainstream examples are the Computer Assisted Virtual Environment (CAVE) and Head-Mounted Displays (HMD) which provide a much larger field of view (FOV) into a virtual environment in comparison with traditional desktop systems, and use stereoscopic pairs of images to improve the perception of spatial relationships. The classification of some mainstream commercial VR headset is shown in Table 1. In particular, totally four categories are invented, including those based on PC, mobile, console and all-in-one headsets. In addition, some other kinds of VR headsets are developed.

For example, a 3D multimode visual immersive system with applications in telepresence is presented in [1]. Most VR equipments are displayed either on a computer monitor, a projector screen, or with a headset (also called head-mounted display or HMD). HMDs typically take the form of head-mounted goggles with a screen in front of the eyes. VR headset actually brings the user into a digital world by cutting off outside stimuli. In this way user is solely focusing on the digital content. Note that VR environment also can be produced by 360^o stereoscopic spherical videos and 360×360 surround sound from professional VR cameras. The users can emerge in the VR environment using HMDs. In a word, the immersive environment can be similar to the real world in order to create a lifelike experience.

Research reveals that most information is obtained by human vision from the exterior world, while other physical sensations retrieve a relatively small amount in total. Hence, most of the current VR systems are primarily designed for visual experiences, although a few of them can stimulate one or several sensory experiences such as taste, sight, smell, sound and touch. The HMD based VR system is an emerging technique in recent years. As HMD employs real-time head tracking with six degrees of freedom, the world is displayed to users based on head orientation.

(2) *Cross-border ecommerce.* Ecommerce is one kind of booming cross-border trade. As ecommerce is transforming the world into one global marketplace, online Merchants, Payment Solution Providers, Card Processors and Acquiring Banks are learning how to

FIGURE 1. Concept of VR shopping

collaborate and share critical insight and strategic knowledge in a joint effort to overcome technical and business hurdles, in compliance with international laws and local legislation. Cross-border ecommerce is also called international ecommerce, e.g., consumers located in one country buy online from merchants in another one. Note that cross-border ecommerce is not equivalent to online trade. Online trade between consumers and merchants which share one common language and border or which make use of the same currency are not always perceived as cross-border trade. We take an example of China for cross-border ecommerce analysis. As incomes have risen, Chinese consumers have stepped up their purchases of imported goods. But now, impatient for the latest products and better prices, they can buy directly from foreign suppliers at the click of a mouse or the swipe of a screen. Cross-border consumer e-commerce amounted to an estimated 40 billion in 2015, more than 6 percent of China's total consumer e-commerce, and it's growing at upward of 50 percent annually. The country's major e-commerce site, Alibaba's Tmall, has moved into the market with a cross-border site, as have smaller consumer rivals and start-ups, while US e-commerce leader Amazon is increasingly active in China.

(3) *Virtual shopping.* Virtual shopping is an emerging online shopping technique of retail innovation. VR represents a paradigm shift on par with the early days of the Internet when it comes to the retail world. A revolution in personal shopping may be on the horizon, and a company like Alibaba has the resources to pursue it aggressively. In addition to Alibaba, some other international sales juggernauts such as Amazon and eBay are spearheading VR shopping in recent two years. Virtual shopping offer many potential customers the chance to do shopping inside of a VR headset. As shown in Fig. 1, the concept of VR shopping is to wear a VR helmet from and a shopper could take a tour of a 3D digital store. Localization markers are mounted on trolley and customers headset. Customers are sensitive to risk of fraud, logistics, payment processing, etc. In [9], Antonio et al. propose a set of AR and VR techniques for footwear shopping. In [10], a reputation mechanism for e-commerce in VR environments has been proposed. In [11], Udo et al. indicates that virtual trade shows exhibitors' perspectives on virtual marketing capability requirements. In 2016, shopping behavior using virtual and pictorial store representations in a physical store is analyzed in order to investigate whether a virtual supermarket can bring realism into the lab or not [12]. Demirkan et al. developed a framework to improve

FIGURE 2. Concept of Buy+

virtual shopping in digital malls with intelligent self-service systems in [13]. In [14], buyers satisfaction in a virtual fitting room scenario based on realism of avatar is analyzed. In [15], an augmented reality embedded on-line shopping system is evaluated. In [16], Krasonikolakis et al. introduced store selection criteria and sales prediction in virtual worlds. In [17], a real-time virtual fitting technique with body measurement and motion smoothing is proposed. In [18], it is discussed whether music can improve e-behavioral intentions by enhancing consumers' immersion and experience or not. In [19], the authors focused on the virtual shopping and unconscious persuasion, i.e., the priming effects of avatar age and consumers' age discrimination on purchasing and prosocial behaviors.

(4) Main contributions. Since VR systems are able to present information as seen from a user's perspective, they have great potential as an enabling technology for immersive exploration in many domains. This work focuses on a VR shopping system with six parts, virtual mall, item display, online pay, interaction, gaming and advertisement. Here the HTC Vive is adopted as the hardware. Vive's two wireless controllers feature 24 sensors for unobstructed movement. One of the key properties of Vive is lighthouse base station technology. This breakthrough tracking technology lets the headset and controllers know in real time where they are within a room. Freely explore and interact with objects, characters and environments. Room-scale VR puts shoppers at the center of everything. The remained part of this paper is organized as follows. Section 2 reviews the related work. Section 3 extensively describes the proposed system with respect to six components along with some experimental results. Discussions are given in Section 4. At last, a conclusion is given in Section 5.

2. **Related Work.** One of the VR shopping system, Buy+ [20], was proposed by Alibaba in 2016 as an official debut. The concept is shown in Fig. 2. The company is helping consumers to look into the future by bringing in cutting-edge technologies such as VR. For example, Buy+ allows users to select apparel and accessories with the help of a 360-degree panoramic view and assistance from a robotic shopping assistant. Shoppers wear VR headsets to browse products such as clothes and fashion accessories on a model, with 360-degree view. Shoppers can even call for virtual guides to showcase items. Compared

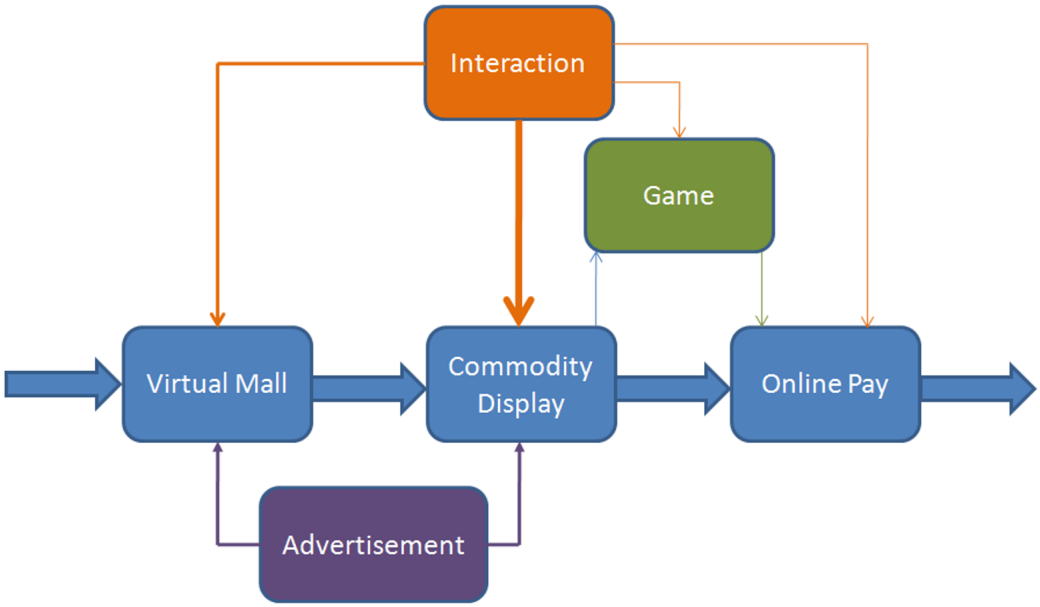


FIGURE 3. Architecture of VR-based immersive online shopping system

to viewing the items via a regular PC, shoppers can look at the products from different angles.

Another system is Mobile VR based shopping prototype developed by eBay. Once the VR Department Store app is downloaded, it works with headsets like Samsung's Gear VR. eBay also offers lots of free shopticals to shoppers, basically just Google Cardboard headsets. The experience works smoothly with a basic, mind map-style interface. Items can be added to the basket in the same fashion, but to check out, users have to take off the headset and return to the eBay app to put through the payment. Building seamless transactions into the product is the obvious next step. That is, the operations of browse, select and buy should be done in a virtual world. In addition, as an experimental JavaScript API, WebVR [21] provides access to VR devices in browser. So far there are several conceptions of WebVR based VR shopping proposed [22, 23, 24].

3. **Proposed System.**

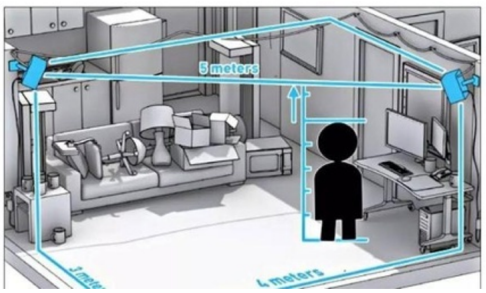
3.1. **Architecture.** Fig. 3 shows the architecture of VR based immersive online shopping system. It is composed by six modules, i.e., virtual mall, item display, online pay, interaction, game and advertisement. The customer shopping is processed from left to right as indicated by the arrow. Among these, the former three modules are essential, and the latter three are integrated elaborately in the system. The arrows indicate the directions of information transmission. The thicker arrow, the more frequently data transmission

As shown in Fig. 4, the HTC Vive is selected as VR headset with outside-in space localization in our system. Once a shopper put on the headset, he or she is immersed in a world full of surprises. The bounds of play area keeps shoppers walk around freely and safely. Meanwhile, stunning graphics make it feel so real and surreal simultaneously.

3.2. **Implementation.** All the modules are implemented. The VR scene is developed by Unity3D engine.

(1) Central hall. This VR mall is tailored for cross-border e-commerce. The central hall of the VR mall is shown in Fig. 5. Several countries' national pavilion are developed for products exhibition. The customer can select one of them and enter it via teleport

(a)



(b)

FIGURE 4. The HTC Vive headset (a) and outside-in space localization principle (b)

FIGURE 5. Central hall of the VR mall

mechanism. The national pavilions have been showcasing new items of their countries. When a shopper enter the virtual mall, various categories of retail items are shown. Users select areas of interest, and the experience is built around the choices.

(2) Item display. The aisle stock of the VR mall and block diagram of item modeling are shown in Fig. 6 and Fig. 7, respectively. First, we take photos from a set of positions carefully selected. Second, these pictures are input the modeling software of Reality Capture. In fact, sometimes we need to manually adjustment the modeling processing, especially when the number of pictures are not enough, or some feature points are not processed accurately. Therefore that block is marked as dash lines. In those cases, the quality of models are not good enough. In other words, software modeling may require human involvement for better decision making. For example, 12 feature points (i.e., from point 0 to 11) marked manually on a item as shown in Fig. 8.

FIGURE 6. Architecture of VR-based immersive online shopping system

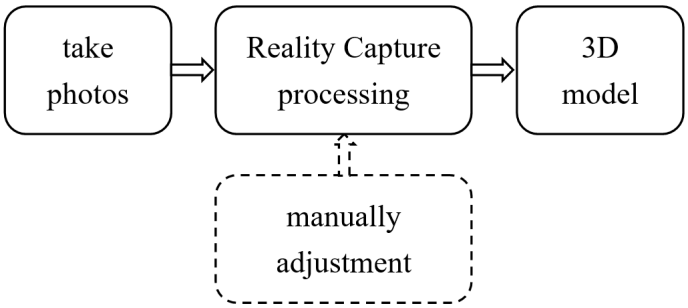


FIGURE 7. The block diagram of item modeling

So far researchers presented various 3D modeling methods. In our case, 3D model of all the items are produced by Reality Capture [25], a software that can convert photos to 3D models. The key technology we used is photogrammetry as shown in Fig. 9. Photogrammetry is method by which Reality Capture is achieved. This type of reality capture uses photographs to reconstruct a 3D image. While this method can require multiple photos to complete a model (typically with a minimum of 2), it can also capture the colors of the subject, translating them into the texture map of the model to further save time in creating assets for games. Photogrammetry can also be used to recreate motion paths of subjects.

In particular, 30-80 pictures are taken for each item. Generally, we take pictures in a ring with the angle of 10 degrees between each two adjacent points. Hence 36 pictures are obtained by equally dividing 360 degrees. The strategy of taking photos of a product from different orientations is shown in Fig. 10, where each white dot represents a camera position during the processing. Specifically, two or three rings photos can produce better quality of model. Item display and two sections of the VR shopping mall are shown in Fig. 11 and Fig. 12, respectively.

(3) Interaction. The details of VR shopping are shown in Fig. 13. A shopper can pick up a item with one hand controller to check its details. Furthermore, two items can be picked up with both hands for comparison. The space localization is realized by Valve lighthouse technology. Specifically, two outside base stations are deployed diagonally in

FIGURE 8. An example of feature points manually marked on a item

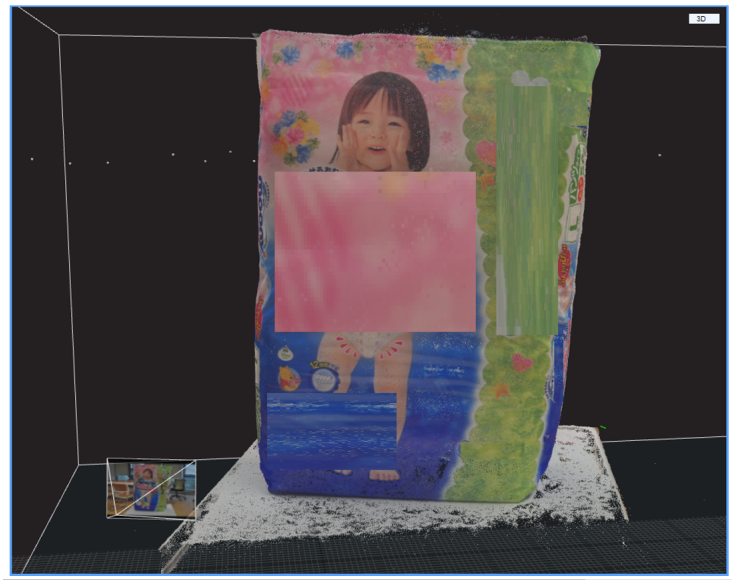


FIGURE 9. Principle of 3D modeling based on photogrammetry

the shopping space, which are used to tracking shopper's position, head orientation and hands movement. The main advantage of this system is providing natural interactions for users. When customers want to shopping in another module, teleport mechanism is used to achieve this instantaneously

(4) Other modules. In addition to the three described modules, there are three auxiliary modules for shopping experience enhancement, i.e., online pay, gaming and advertisement. In the online pay module, for the sake of safety, the payment operation after adding items to the shopping cart is implemented by the popular third party platform, e.g., Alipay. In

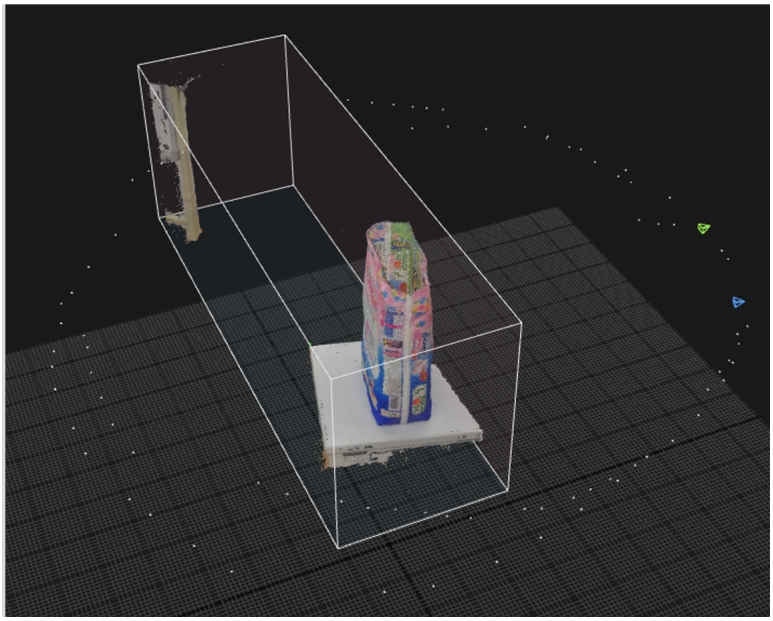


FIGURE 10. Taking photos from different orientations

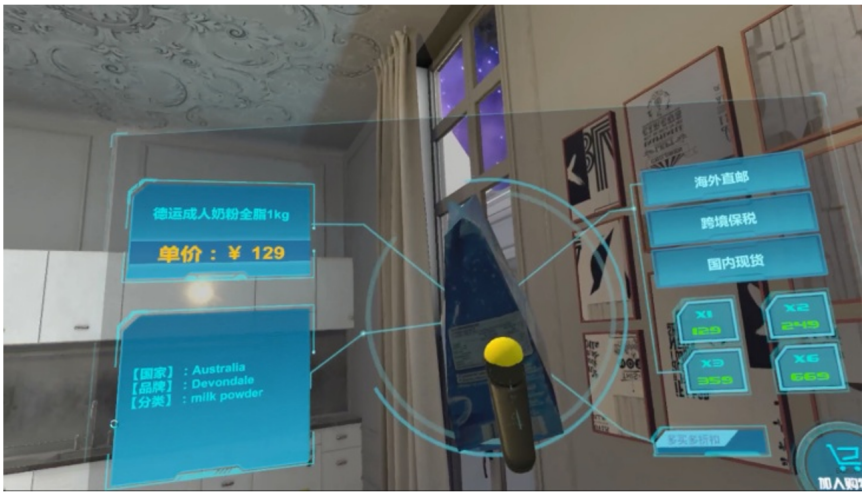
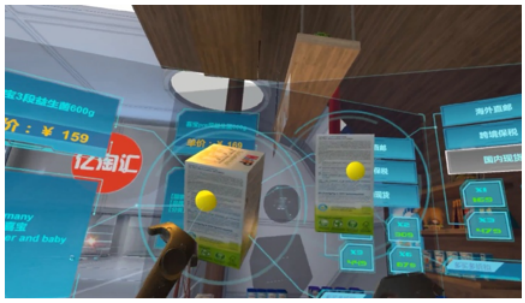


FIGURE 11. Item display

FIGURE 12. Two sections of the VR shopping mall

(a)



(b)

(c)

FIGURE 13. Details of VR shopping, (a) pick up a item with one hand to check its details, (b) pick up two items with both hands for comparison, (c) comparing two items' appearances

the gaming module, an entertainment centre is integrated into the VR mall as shown in Fig. 14. In the advertisement module, some embedded marketing can be introduced into 3D scenes. In our case, all the games are free for players. It has two purposes, one is to provide a relax environment for shopping, and the other is to integrate it with marketing. For example, customer can get promotion codes if they successfully finish some missions when playing games.

4. **Discussions.** Our system is compared with those of Buy+ developed by Alibaba in terms of five aspects, i.e., hardware, item display, space localization, lightweight games, interaction mode. Details are listed in Table 2. Obviously, the proposed system outperforms the previous work in most aspects. The future work focuses on the following three aspects. The first one is WebVR. The second is automatic 3D modeling for items. We are trying to dramatically reduce the cost of 3D modeling and mapping in the future. The third one is natural interaction, which includes voice, inside-out localization technique,

Table 2. VR headset classification

	Buy+	Proposed system
Hardware	mobile VR	PC VR
Item display	image, video	3D model, image, video
Space localization	no	yes
Lightweight games	no	yes
Interaction mode	eye gaze	controller

etc. For example, the technology of simultaneous localization and mapping (SLAM) might be used for localization.

5. **Conclusions.** This paper proposes a VR-based shopping prototype since VR sets to dominate tomorrow's shops in some specific applications. Details of the background and the implementation which include six parts, central hall, item display, online pay, interaction, game and advertisement. A shopper can freely explore in the virtual mall based on a virtual headset and real-time localization mechanism. The commercialization of the prototype has been launched and it satisfies the requirement of cross-border ecommerce scenarios.

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