A Virtual Shopping System Based on Room-scale Virtual Reality

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***Abstract*—In the Virtual Reality (VR) environment, the user needs to input information and achieves interaction with virtual objects. At present, most VR systems provide some input devices, such as keyboard and controller. However, using such devices is not intuitive, especially in the case of VR shopping system. In the real world, we use our hands to handle objects. In virtual world, using hand gestures to interact with VR shopping store will provide us more intuitive VR shopping experience. According to the needs of the room-scale VR shopping activities, we have introduced a new gesture classification for the gesture set, which has three levels to classify hand gestures based on the characteristics of gestures. We have focused on the gestures in level 3. In our research, we have built a room-scale VR shopping system and applied the new hand gesture set for the interaction in the VR shopping system.**

***Keywords*–Room-scale Virtual Reality; Gesture set; Gesture classification.**

I. Introduction

Virtual Reality makes it possible for the user to interact with the virtual environment as if he is in the real world. It is a kind of illusion of “being there” [1].

With the development of the computer graphics, 3D technology and electrical engineering, Head Mount Display (HMD) of VR has been gradually improved in the past few years. Some technology companies have introduced their simple and easy-to-use VR devices for the consumer market, such as HTC Vive and Oculus Rift.

A. VR shopping

People can navigate in the virtual environment through a HMD. Shopping is one of the important activities in our daily life. People have already been familiar with e-commerce or online shopping. We can extend online shopping to the virtual environment.

Over the past decades, many VR shopping environments have been presented. Some works aimed at improving VR shopping experience and some works researched on the interaction in virtual shopping environments. Bhatt [2] presented a theoretical framework which showed how to attract customers through a website with the three factors: interactivity, immersion and connectivity. Chen et al. [3] presented a Virtual Reality Modeling Language - Based (VRML- Based) virtual shopping mall. They analyzed personal behavior of customer in the Virtual Shopping Mall System. They also explored the application of intelligent agent in shopping guidance. Lee et al. [4] designed a virtual interactive shopping environment and analyzed whether the interface of virtual interface had positive affects. Verhulst et al. [5] presented a VR user study. In this study, they applied VR store as a tool to find whether the user in store had intention to buy the non-standard food. Speicher et al. [6] introduced a Virtual Reality Shopping Experience model. Their model had three parts: customer satisfaction, task performance and user preference.

The previous researches have shown some good features of VR shopping. Thus, some retail companies and online shopping companies have become interested in VR shopping. IKEA company [7] presented a room-scale VR environment, in which the user could view a virtual kitchen and interact with the furnitures. Another example comes from inVRsion [8], which provided a virtual supermarket shopping system, Shelfzone VR. In the future, there will be more applications on VR shopping.

B. Room-scale VR and Hand Gesture

When a user is moving his view in virtual world with an HMD, he cannot move his physical body in real world. Thus, there is a huge gap between sensorial moving and physical moving. It will reduce the immersion of VR greatly. This gap will also cause motion sickness for some people [6] [9]. If user’s walking is synchronous in both virtual world and real world, the experience is much better.

Using controllers in the VR shopping environment is not immersive enough. Users will feel a gap when using controllers to catch the virtual objects which are similar to real objects. Besides, the amount and functions of buttons in the controllers are limited, which limits the interaction when using controllers in the room-scale VR environment. To achieve VR shopping activities, we can use the buttons to design interaction methods in the VR shopping system. Comparing with controllers, using hand gestures can improve the immersion of VR shopping experience and also provide the rich interaction vocabulary for the VR shopping system.

Hand gestures have been widely used in human-computer interface. Gesture-based interaction provides a nature, intuitive communication between people and devices. People use 2D multi-touch gestures to interact with devices like smart phone and computer in the daily life. 3D hand gestures can be used by some devices equipped with camera or depth sensor. The most important problem in hand gesture interaction is how to make computers understand the meaning of hand gestures [10]. Wachs et al. [11] summarized the requirements of hand-gesture interfaces and the challenges when applying hand gestures in different applications. Yves et al. [12] presented a framework for 3D visualization and manipulation in an immersive space. Their works can be used in AR and VR systems. Karam et al. [13] used depth camera and presented a two-hand interactive menu to improve efficiency. These previous researches show that hand gestures have many possibilities for human-computer interaction field.

In Section II, we introduce our goal and approach of our study. In Section III, we show the system design, including VR environment, gesture set and gesture classification. In Section IV, we show the hardware in our system. In Section V, we explain how to achieve gesture recognition in our system. In Section VI, we show how to use the gestures in room-scale VR. In Section VII, we show the preliminary evaluation. In Section VIII, we introduce some related works. Finally, in Section IX, we show our conclusion.

II. Goal and Approach

In this research, we aim to present a new hand gesture set which is suitable for room-scale VR shopping system to replace the controllers. We introduce a new gesture classification to make the gesture set more structural. We apply room-scale shopping system to provide a immersive virtual shopping environment, which is a simulation of physical shopping store. In the room-scale VR shopping environment, the user can walk around in his room to view the virtual shopping environment through an HMD. We design the new gestures for the room-scale VR shopping system. The user can interact with VR environment by the natural hand gestures but not the controllers. We introduce a gesture classification for gestures, which has three levels to classify hand gestures based on the characteristics of gestures. Summarizing the hand gestures, we get a new hand gesture set especially for room-scale VR shopping activities. The hand gesture set will improve the convenience and immersion of the room-scale VR shopping system.

We use VR devices to build the room-scale VR shopping system. In the system, there are two sensor stations installed in the room. The two sensor stations create a walking area for the user. When moving in the walking area, user's motion will be captured by the sensor stations. System will get rotation and three-dimensional coordinates of the HMD worn by user. The view in virtual environment will move synchronously with the HMD. Then we use depth sensor to recognize the hand gestures. In the virtual environment, the user can see his virtual hands moving synchronously with his physical hands. The system can realize the special gestures when the user performing gestures near the depth sensor, and achieve the interaction with virtual environment.

III. System Design

The virtual shopping system is composed of a room-scale VR shopping environment and the gesture-based interaction system.

A. Room-scale VR Shopping Environment

In order to achieve VR shopping activities, we design a VR shopping store as the shopping environment, which is similar to the stores in the real world. We place some desks, shelves and goods in the VR shopping store, as shown in Figure 1.

In the room-scale VR shopping system, we use HTC Vive as the room-scale VR device, as shown in Figure 2. We use Leap Motion [14] as the depth sensor to recognize the hand gesture. Leap Motion is stuck on the HMD.

Figure 1. A VR store

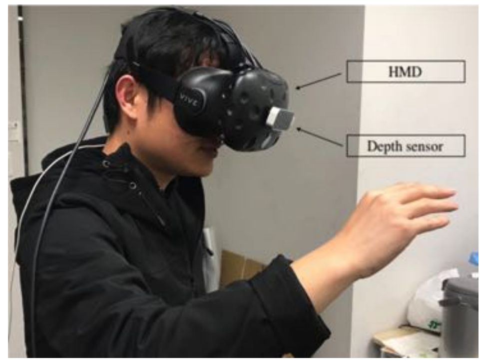

Figure 2. HMD and depth sensor

We prepare an empty area in the real room. The empty area is included in a 3D space. We use two tracking sensors of HTC Vive to capture the motion and rotation of HMD in the 3D space when the user using the VR shopping system. As shown in Figure 3, the length of 3D space is 4 meters, the width of 3D space is 3 meters and the height of 3D space is 2 meters. The 3D space contains walking area of the room.

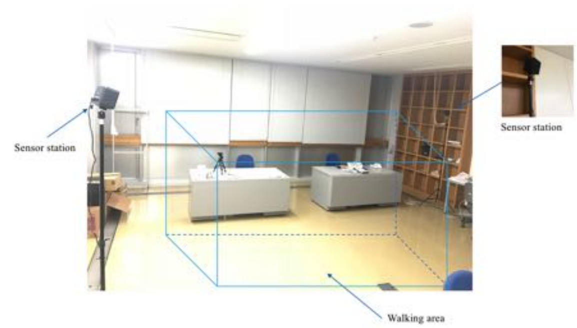

Figure 3. 3D space and walking area

In the room-scale VR shopping environment, there is also a virtual walking area, as shown in Figure 4. The virtual walking area is same with the area in real room. As the VR shopping store is larger than our real room, the user can change the virtual walking area when view the whole VR shopping store.

B. Gesture Set

In our research, we need to design a series of hand gestures specially for the room-scale VR shopping activities. The hand gestures must provide a natural and suitable interaction for the user and the system. According to the particular activities in room-scale VR shopping system, we design these 14 gestures in our system:

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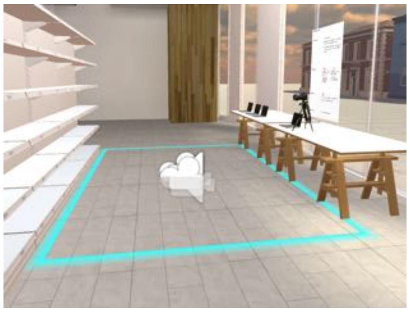

Figure 4. Walking area in VR environment

- (1) pointing, (2) holding, (3) OK gesture, (4) No gesture, (5) push/pull, (6) rotation, (7) drag, (8) waving, (9) click, (10) zoom in/out, (11) opening/closing, (12) grab, (13) two-fingers scroll/swipe, (14) changing area.

These gestures combine a new gesture set for room-scale VR shopping system.

C. Gesture Classification

We present a new gesture classification to classify the hand gestures based on their different characteristics. The gesture classification has three levels:

- Level 1: Core static hand postures are divided into the level 1. In level 1, gestures are just hand shape without hand motion. The classic example is pointing gesture.
- Level 2: Dynamic palm motions are divided into the level 2. In level 2, we just care about the palm movement. We don't care about the shapes of fingers. The classic examples are pull and push.
- Level 3: Combination hand gestures are divided into the level 3. Combination hand gestures combine the features of level 1 and level 2 gestures. In level 3, we care about the motion and shapes of fingers and the motion of palm.

In VR shopping environment, the hand gestures are divided into different levels. In the figures of level 2 and level 3, the red arrows mean the fingers movement trends.

The classification method will make the gesture set more structural. This classification method provides a structure that can also be used in other gesture sets in different VR systems. Based on the systematic structure, researchers can design suitable gestures for their VR systems.

1) Level 1 Gestures: In our system, we use level 1 gestures to give feedback to system. Level 1 gestures are static signals for shopping system. We do not need to care about the motion of fingers or hands. System just needs to detect the hand shapes. Figure 5 shows two level 1 gestures.

(a) OK gesture

(b) NO gesture

Figure 5. OK and NO gestures positive or negative feedback to system

2) Level 2 Gestures: Level 2 gestures are palm motions. After choosing a virtual object, the user can use level 2 gestures to control or interact with it. Figure 6 shows two level 2 gestures and Table I shows the functions of level 2 gestures.

(a) Push gesture

(b) Pull gesture

(c) Waving gesture

Figure 6. Level 2 gestures: push, pull and waving

TABLE I. FUNCTION OF GESTURES IN LEVEL 2

Level	*Gesture*	*Function*
2	Push/pull	Push or pull a virtual object with a hand.
2	Waving	Make virtual object return to the original position.

3) Level 3 Gestures: Gestures in level 3 are hand gestures that combine finger shapes and hand motions. These gestures are complex and combine the features of level 1 and level 2 gestures.

Designing a suitable and convenient gesture set for user determines whether the user could have an immersive VR shopping experience. Level 1 and level 2 gestures are simple and a little weak. Thus, level 3 gesture set is the focus of our research.

In level 3, we need to recognize the hand shapes and detect the motions of the fingers and hands at the same time.

The gestures have different usage. Thus, we need to introduce a classification for level 3 gestures. There is the classification:

- The core gesture: pointing gesture
- Gestures for interacting with virtual object: (1) grab gesture, (2) hold gesture, (3) drag gesture, (4) rotation gesture, (5) zoom in/out gesture;
- Gestutes for interacting with menu: (1) click gesture, (2) scroll/swipe gesture, (3) opening/closing gesture;
- Gesture for interacting with space: change area gesture

In the gesture set, pointing gesture is the most important gesture, because we need to choose a target object or button with the pointing gesture before any interaction, as shown in Figure 7 and Table II.

TABLE II. FUNCTION OF POINTING GESTURE

Level	*Gesture*	*Function*
3	Pointing	Point a virtual object with index finger.

Some gestures are mainly used to interact with virtual objects in the VR shopping store, such as moving a virtual

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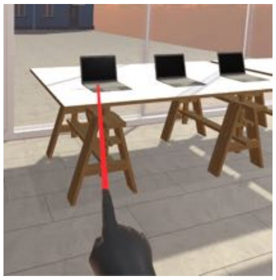
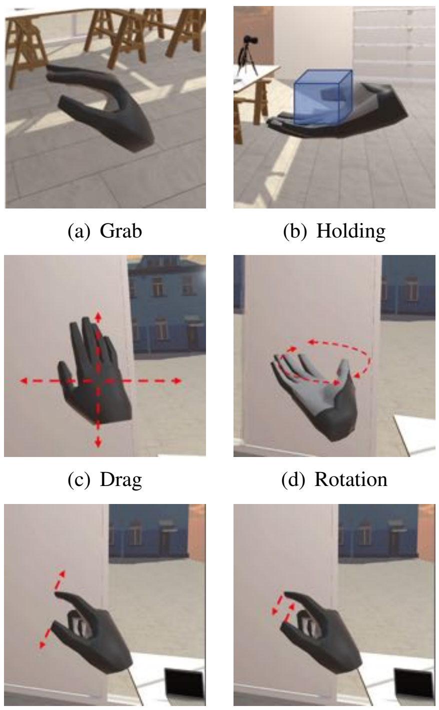


Figure 7. Pointing gesture

object. We design these gestures to achieve it: grab gesture, hold gesture, drag gesture, rotation gesture, and zoom in/out gesture, as shown in Figure 8 and Table III.



(a) Grab (b) Holding (c) Drag (d) Rotation (e) Zoom in (f) Zoom out

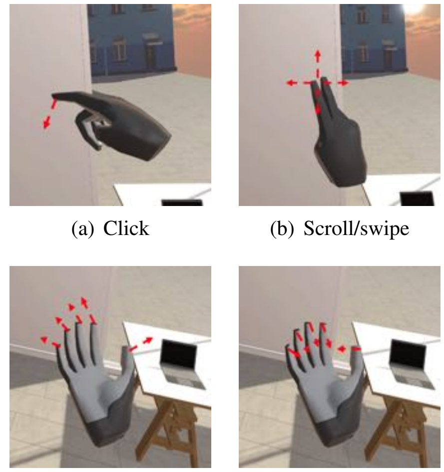
Figure 8. Gestures for interacting with objects

TABLE III. FUNCTIONS OF GESTURES FOR INTERACTING WITH OBJECT

Level	*Gesture*	*Function*
3	Grab	Make object move close to hand and grab it with hand.
3	Holding	Hold a virtual object on one hand.
3	Drag	Move virtual object freely with a hand.
3	Rotation	Rotate a virtual object when viewing it with a hand.
3	Zoom in/out	Make a virtual object show a larger or smaller size using relative motion of thumb and index finger.

In some cases, we need to interact with menu to achieve shopping activities. We design these gestures: click gesture, scroll/swipe gesture, opening/closing gesture, as shown in Figure 9 and Table IV.

In room-scale VR shopping system, the user can walk in the real walking area in his own room. However, the room-scale walking area is always smaller than the VR shopping store. Thus, we need to design a gesture for the user to change area in the room-scale VR shopping store. Figure 10 and Table V show the changing area gesture. When performing the changing area gesture, the user needs to extend his index finger and thumb finger. In the system, when the user wants to change area in the VR shopping store, he can point at a position on the virtual floor with the special hand gesture and use thumb to click the index finger to tell system that he wants to move there.



(a) Click (b) Scroll/swipe (c) Opening (d) Closing

Figure 9. Gestures for interacting with menu

TABLE IV. FUNCTIONS OF THE GESTURES FOR INTERACTING WITH MENU

Level	*Gesture*	*Function*
3	Click gesture	Click the buttons with index finger.
3	Scroll/swipe	Using two fingers gestures to control menus in user interface.
3	Opening	Open five fingers to open the dashboard.
3	Closing	Close five fingers to close the dashboard.

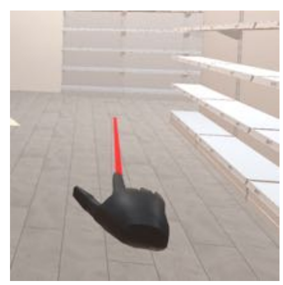


Figure 10. Gesture for changing area in VR environment

TABLE V. FUNCTION OF THE GESTURE FOR CHANGING AREA

Level	*Gesture*	*Function*
3	Changing area	Use index finger to point a new position on the floor and make the thumb click the index finger, then the view in VR will move to the new position.

IV. GESTURE RECOGNITION

In our system, we use Leap Motion as the depth sensor to track the users' hands. Leap Motion can track the joints, fingertips and palm center of user's hands. Meantime, Leap Motion can record the positions of these important points of user's hands in every frame.

With the original position data, we can use machine learning method to recognize the hand shapes. Then combining the hand shapes and motions, we will achieve recognizing the gestures that we design for the room-scale VR shopping system.

A. Hand Shape Recognition

At first, we need to confirm how many hand shapes that we need to recognize. In some cases, several hand gestures have the same hand shape. For example, drag gesture, holding gesture and rotation gesture have the same hand shape. Their differences are the motions of palm. As we have introduced all the 14 gestures we design in Section III, we summary the following hand shapes that we will recognize, as shown in Figure 11.

Besides, the system also needs to recognize whether the user's hands just move naturally without interaction intention. So, we need to recognize the natural hand shape. Therefor, there are 9 hand shapes that we need to realize.

Here is the relationship between 14 hand gestures and 9 hand shapes:

1) OK hand shape (including 1 gestures): OK gesture.
2) Pointing hand shape (including 3 gestures): pointing gesture, NO gesture, click gesture.
3) Extending hand shape(including 5 gestures): pull/push gesture, wave gesture, holding gesture, drag gesture, rotation gestures gesture.
4) Grab hand shape (including 1 gestures): grab gesture.
5) Zoom hand shape (including 1 gestures): zoom in/out gesture.
6) Scroll/swipe hand shape (including 1 gestures): scroll/swipe gesture.
7) Opening/closing hand shape (including 1 gestures): opening/closing gesture.
8) Changing area hand shape (including 1 gestures): changing area gesture
9) Natural hand shape: the hand shape when the user move hands without interaction intention

Then we apply Support Vector Machine (SVM) method in our system to realize these nine hand shapes. So, we need the multi-label classification method in our system. We use open source software, libsvm-3.22 in our system [15]. There are four steps for multi-label classification:

- data collection
- data normalization and scale
- model training
- predicting

1) Data Collection: In a hand, we will capture the end-points of bones and palm center as "key points" to describe the hand structure [16]. As shown in Figure 12, we will track all the position data of the key points in every frame in VR environment.

2) Data Normalization and Scale: We calculate other key point positions relative to palm center. Data normalization follows these steps:

- Move positions to make palm center on the origin coordinate.
- Rotate the points to make palm parallel to the x-z axis plane.
- Rotate the points around the y coordinate axis to make the palm point the –z axis.
- Scale the data to [-1, 1].

(a) OK hand shape

(b) Pointing hand shape

(c) Extending hand shape

(d) Grab hand shape

(e) Zoom hand shape

(f) Scroll/swipe

(g) Opening/closing

(h) Changing area

(i) Natural hand shape

Figure 11. The nine hand shapes

Figure 12. Key Points: two blue points represent the palm center and the wrist joint; red points represent the endpoints of bones in hand

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3) Model Training: There are three steps to train the data and get a classifier model:

- Capture 50 groups coordinates of the key points for every hand shape.
- Normalize and scale the data and get 9 groups training sets.
- Through training sets, get the multi-label classifier.

4) Predicting: After getting the classifier, we will use it in VR shopping system to recognize the nine hand shapes. When the user viewing the room-scale VR shopping store, the user moves his hands freely. Depth sensor tracks the hands and gets a group of original data set in every frame. Then, with the classifier, we will get the predicting result. The predicting result will tell the system which hand shape that the user is performing. If the hand shape is natural hand shape, system will not give feedback; if getting other hand shapes, system will respond to the user's interaction intention.

B. Motion Detection

After knowing the hand shape, the system needs motion detection because gestures are defined by both hand shape and motion together.

Once getting the hand shape, the system begins motion detection. The system will calculate the hand data in every frame. For different hand shapes predicting result, system detects hand center or different fingertips to realize gestures.

Based on the hand shapes from label 1 to label 9, there are nine situations when recognize motions.

- **Situation 1**: for OK hand shape, OK gesture is the level 1 gesture and the system does not need to recognize the motion.
- **Situation 2**: for pointing hand shape, if the system finds that two hands are in pointing hand shape, system needs to detect the positions of two index fingertips. If the two index fingertips are close, it shows that the user is performing NO gesture. If only one hand is in pointing hand shape, the system needs to detect the direction and motion of index finger, because we need to use pointing gesture to choose a target or click a button.
- **Situation 3**: for extending hand shape, it is a little complexed. (a) if system detects that the palm center orients to face and moving toward to face, it is pull gesture; (b) if system detects that the palm center orients forward and moving forward, it is push gesture; (c) if system detects that the palm center orients left and moving to left, it is waving; (d) if system detects that the palm center orients to sky, it is holding gesture; (e) if system detects that the palm center orients forward and moving on a vertical plane, it is drag gesture; (f) if system detects that the palm center orients to sky and rotating around the palm center, it is rotation gesture.
- **Situation 4**: for grab hand shape, the system detects the motion of palm center and the target object follows the motion of palm center.
- **Situation 5**: for zoom hand shape, the system detects the motion of index and thumb fingertips. If the fingertips move away from each other, it is zoom in gesture; if the fingertips move closely to each other, it is zoom out gesture. The movement distance will be used to change the size of the target object.
- **Situation 6**: for scroll/swipe hand shape, the system detects the motion of index finger. The movement distance will be used to control menu.
- **Situation 7**: for opening/closing hand shape, the system detects the motion of index, middle and thumb fingertips. If their motions are moving closely to each other, it is closing gesture; if their motion is moving away from each other, it is opening gesture.
- **Situation 8**: for changing area hand shape, system detects the direction of index finger and the motion of thumb fingertip. If index finger points to a position on the floor and thumb fingertip clicks the index finger, it is changing area gesture and the user will move to the target position.
- **Situation 9**: for natural hand shape, system does not need to detect any motion. Because in this situation, the user moves his hands freely in 3D space and does not want to interact with system.

V. Preliminary Evaluation

We apply the gesture set in our VR environment to build the interaction system. We design a typical shopping activity as an example: viewing and buying a laptop.

Firstly, the user can move to the desk with the change area gesture where the laptops are placed in the room-scale VR shopping environment, as shown in Figure 13. In this situation, the desk is a little far away from the user and is out of the original walking area of the user. Then, the user walks near to the desk. He selects one of the laptops with the pointing gesture. Once being selected, the laptop will show a bounce animation, as shown in Figure 14(a). The user can make the laptop move to his hand with the hold gesture, as shown in Figure 14(b). The user can also grab the model. After that, the user can view the details of the laptop with the zoom in/out gesture, as shown in Figure 14(c). Besides, he can also call out the menu to check more information with the open/close gesture and the scroll/swipe gesture, as shown in Figure 14(d) and Figure 14(e). Finally, he can perform the OK gesture to tell the system that he decides to buy it, as shown in Figure 14(f).

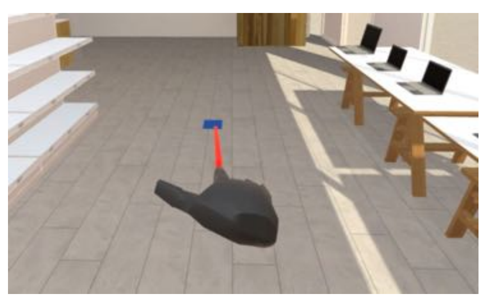

Figure 13. Using change area gesture

We invited 5 students to use our room-scale VR shopping system. The range of their ages is from 19 to 27. They repeated the shopping activity that we designed and performed the nine hand shapes for 50 times respectively. We collected data and found the errors of hand shape classification with SVM method.

Table VI shows the errors of classification of every hand shapes for every user. There are nine hand shapes. So, every

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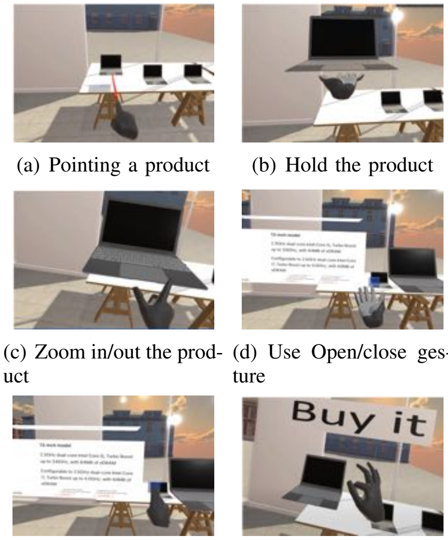

(a) Pointing a product (b) Hold the product

(c) Zoom in/out the product (d) Use Open/close gesture

(e) Use scroll/swipe gesture (f) Use OK gesture

Figure 14. The gestures used in shopping activities

user performs the hand shapes for 450 times in all in our evaluation. Then, we can get the accuracy rate when a user is performing hand shapes in our system, as shown in Table VII.

TABLE VI. ERRORS OF CLASSIFICATION OF NINE HAND SHAPES FOR EVERY USER

Hand Shape	*User 1*	*User 2*	*User 3*	*User 4*	*User 5*
OK	1	0	0	2	1
Pointing	0	0	1	2	1
Extending	3	2	4	5	4
Grab	1	2	2	3	3
Zoom	0	1	1	3	1
Scroll/swipe	1	1	1	2	1
Opening/closing	0	0	1	1	0
Changing area	1	1	1	4	2
Natural	4	3	4	5	4

TABLE VII. THE ACCURACY RATE OF HAND SHAPE RECOGNITION OF 5 USERS

User	*Amount*	*Accuracy*	*Accuracy Rate*
1	450	439	97.56%
2	450	440	97.78%
3	450	435	95.56%
4	450	423	94.00%
5	450	433	96.22%

In Table VI, we can see the relative high error rates of the extending hand shape and the natural hand shape. That is because these two hand shapes are similar when the user performs them in our VR environment. For example, some users often extend their fingers when they perform nature hand shape. Some users sometimes bend their fingers a bit when they use extending hand shape to hold the models. In this situation, system cannot detect which hand shape that they want to perform.

VI. RELATED WORK

With the perfection of VR technology, many researchers and companies try to apply VR technology in e-commerce field and want to find a way to generate economic value. Alibaba is a famous IT company and is known for its great on-line shopping services. Alibaba presented a VR shopping application, called Buy+, running on the smart phone [17]. The Buy+ tried to combine the convenience of on-line shopping and the facticity of physical store shopping. With the simple and cheap VR devices and smart phone, people in China could view an overseas virtual shopping mall and pay for orders on-line.

Some companies use VR technology to create virtual store. IKEA is a famous furniture company. It presented a room-scale VR kitchen to show its beautiful design [7]. In the room-scale VR kitchen, the user could use HTC Vive to view the equal proportion VR kitchen, even could interact with the VR environment like opening the virtual range hood. Comparing with physical furniture stores, the VR environment could provide more functions and interactions. The user could view the kitchen freely in his own room without warring about the crowd in the physical IKEA mall. In the VR kitchen, the user also could change the color of furniture freely, which is impossible in the physical IKEA mall.

A VR technology company, inVRsion, presented a VR supermarket system based on room-scale VR [8]. Their retail space, products and shopping experience VR solutions provide an immersive shopping environment. In the VR shopping environment, businessman could analyze shopper behavior through eye-tracking for extremely powerful market research insights. The system could help sellers to test their category projects, new packaging and communication in the stores before implementation. The users could search their target products more easily than physical supermarket. This system tries to provide a method for people to view a big virtual supermarket in his own room.

In our previous work, we extended 2D multi-touch interaction to 3D space and introduced a universal multi-touch gestures for 3D space [16]. We called these midair gestures in 3D as 3D multi-touch-like gestures.

The previous related works prove the broad application prospect of room-scale VR shopping and gestures. Our work about designing gesture set for room-scale VR can be used in these systems to provide better VR shopping experience.

VII. CONCLUSION

In this research, we built a room-scale VR shopping system and proposed a new hand gesture set for the room-scale VR shopping system. We used the gesture set to replace the controllers of VR device to improve the limitation of controllers in VR shopping activities. Researching on the gesture set, we introduced a new gesture classification. We designed three levels for classification method. The gestures in level 1 were static hand shapes, the gestures in level 2 were movement of palm and the gestures in level 3 combined the features of gestures in level 1 and level 2. The gestures in level 1 and level 2 were simple and were not enough for room-scale VR shopping activities. Therefor, we focused our research on the level 3 gestures.

For the gestures in level 3, we introduced four categories to classify them: core gesture, gestures for interaction with virtual object, gestures for interaction with menu and gesture for interaction with space. The classifications helped us to understand the gesture set in room-scale VR shopping system. Also, the gesture set and 3-level classification method could be transplanted to other VR or AR systems conveniently.

In order to achieve the complex gestures recognition, we applied SVM method in our VR shopping system. In the

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end, the user could walk around in his room to view the VR shopping store and interact with the system with his natural hand gestures.

In the future work, we will research on two aspects: realizing "natural" hand gesture set and improving the accuracy of hand shape recognition. The gestures we have designed in this paper do not fully reflect the natural hand shapes. Also some hand shapes are very similar and they lowers the accuracy of hand shape recognition. Therefore, we would like to further refine our current gesture set and make our hand gesture more natural and more accurate.

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