A Mixed-Reality Shop System Using Spatial Recognition to Provide Responsive Store Layout

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Abstract. Environment is very important for consumers shopping. In-store characteristics such as store layout, decoration, music and store employee are the key of consumers shopping experience. However, the current online shop system lacks environment information and in-store characteristics, which are very important for consumers shopping experience. In this paper, we designed a new mixed-reality (MR) shop system by mixing virtual in-store characteristics and real environment, which might be the possible direction for the future online shop system. Technically, we developed a new spatial understanding algorithm and layout mechanism to support responsive spatial layout. In our system, store designers only need to design once, and our system can make any place to the mixed reality shop. We have invited some participants to test the usability and efficiency of our system. We have obtained a positive feedback through the preliminary user study.

Keywords: Mixed-reality · E-commerce · Spatial recognition · Responsive layout

1 Introduction

The current online shop system lacks environment information and in-store characteristics. It is difficult to imagine whether the product is suitable in the real environment. Because of the lack of in-store characteristics. It is also difficult to express the brand characteristics [1].

Recently, with the development of mixed reality (MR) technology, it has become possible to use only head-mounted devices to scan the environment and bring a mixed reality experience. Evolving MR technology has brought new opportunity to the shopping system.

In this study, we proposed the concept of the MR shop system, which might be the possible direction of the future shopping system. The MR shop system consists of three main parts. Spatial recognition, responsive store layout, and store interaction (see Fig. 1). First, we scan the space through depth cameras and use a spatial understanding algorithm to understand the surfaces. Next, we have designed a layout algorithm which is based on the understood surfaces and layout preference of shop items, to generate the responsive MR store layout. Last, after building the designed shop, the user can use

J. Y. C. Chen and G. Fragomeni (Eds.): HCII 2020, LNCS 12190, pp. 18–36, 2020.
https://doi.org/10.1007/978-3-030-49695-1_2

gestures to move or rotate virtual products or use voice commands to communicate with the virtual store employee.

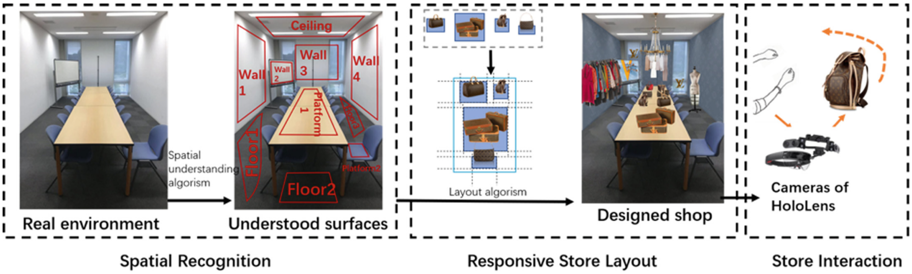
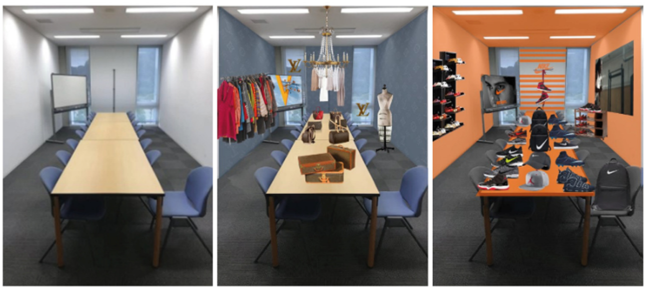


Fig. 1. The process of generating a mixed reality shop.

2 Goal and Approach

Our research tries to build a mixed-reality (MR) shop system which can recognize the space and mix virtual in-store characteristics and real environment, to provide: Immersive virtual preview and interaction in the real environment. It `also provides in-store characteristics`, such as store layout, decoration, music and virtual store employee.

As the Fig. 2 shows, after scanning the environment. The same room can be different MR shops. The Virtual products placed on the real table and chairs and the real walls and ceiling is decorated with virtual store characteristics. The user can use gestures to manipulate virtual products or use voice commands to communicate with the virtual store employee. This system can automatically make the real environment to be the MR shop and give users an immersive shop experience just like a physical shop.



(a) The real environment (b) MR Louis Vuitton shop (c) MR Chanel shop

Fig. 2. Different MR shop in the same environment.

If the user is in a different room, this system would automatically build another MR shop by using the same elements (see Fig. 3). This system is very convenient for shop designers. Designers only need to design the elements once, this system will automatically adapt these elements to all spaces. Although the elements are the same, each user has their own unique MR shop because they are in a different environment.

(a) The seminar room

(b) Another real environment

Fig. 3. The same MR shop in the different environment.

3 Mixed-Reality Shop System

To generate a MR shop, there are three steps: spatial recognition, responsive store layout, and store interaction.

3.1 Spatial Recognition

Spatial Detection. As the Fig. 4 shows, we use depth cameras to detect surfaces of the real world. By using the spatial understanding API of Mixed Reality Toolkit (MRTK) [2]. We can obtain the metadata of detected surfaces: Position, size, horizontal or vertical.

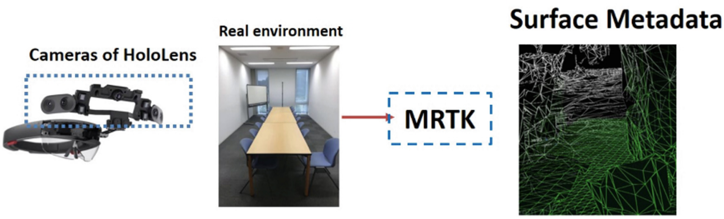


Fig. 4. The process of spatial detection

Spatial Metadata Processing. In a real store layout, different store elements tend to have different layout characteristics. For example, chandeliers are often placed on the ceiling, and merchandise is often placed on a table for easy viewing. Some advertisements may be posted on the wall to attract the attention of the user. Based on these placement preferences, we need to understand the specific meaning of each plane in the space. As the Fig. 5 shows, we designed an algorithm to understand detected surfaces. First, we remove all surfaces that are smaller than the smallest item of the store. Then understand the specific surface by judging the metadata.

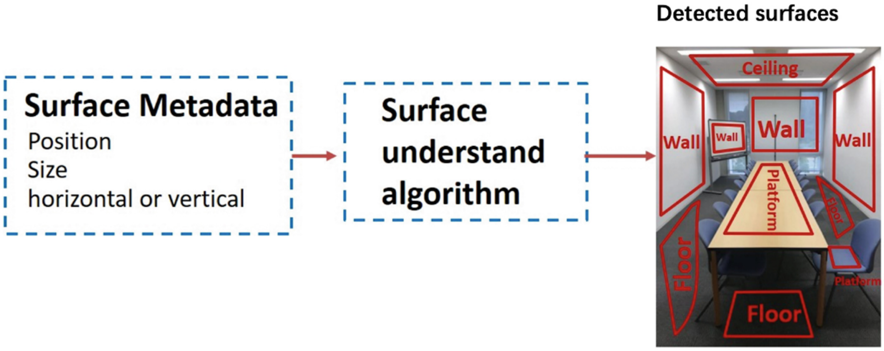


Fig. 5. The process of surface understanding

The specific spatial understanding mechanism is shown as Table 1.

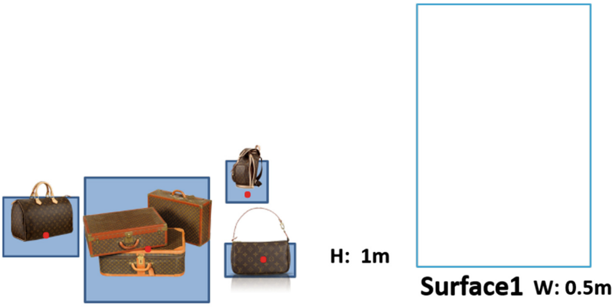
Table 1. The specific spatial understanding mechanism.

Type	Spatial understanding mechanism
Ceiling	The highest horizontal surfaces in space
Wall	Vertical surfaces
Platform	Horizontal surface in the middle of the ceiling floor
Floor	The lowest horizontal surfaces in space

Through this spatial understanding algorithm, we simplify complex, non-specific spatial metadata into concrete surfaces that can be understood by store designers and can be used for design, which is the basis for generating responsive stores.

3.2 Responsive Store Layout

After understanding the surfaces, we can generate the layout of the store. In order to get a regular store layout, we developed several layout mechanisms to correspond to store elements and the detected surfaces. These layout mechanisms depend on the placement characteristics of the store elements.



(a) Products (b) Target surface

Fig. 6 Products and target surface.

Independent Layout Mechanism. In this algorithm, shop items do not have an association. This algorithm has four steps. The example shown in Fig. 6 shows the specific steps of the algorithm:

1. Arrange the shop items into an ordered sequence. The order of this sequence will be used as the priority of the placement, and the item sorted first will be placed first when traversing (see Fig. 7).

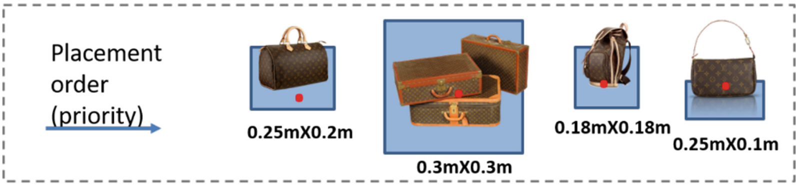


Fig. 7. Arrange the shop items into an ordered sequence.

2. Specify the direction of traversal for the target surface. In this example, Placement direction: row down. It means we'll traverse the surface along the row, and from top to bottom (see Fig. 8).

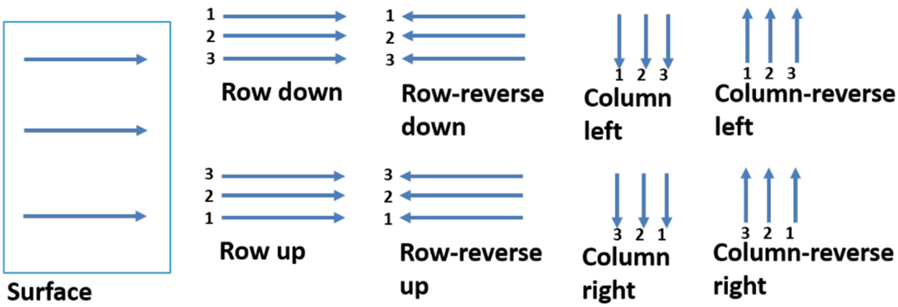


Fig. 8. The direction of traversal.

The first and second steps are all the attributes that the store designer needs to configure. Next, we will start the layout. The principle of layout: Try to ensure that high-priority products can be placed.

3. For each shop item, this algorism traverses the surface from the first line (alone the direction). If there is enough space for the placement, place it, if not, go to the next line (see Fig. 9).

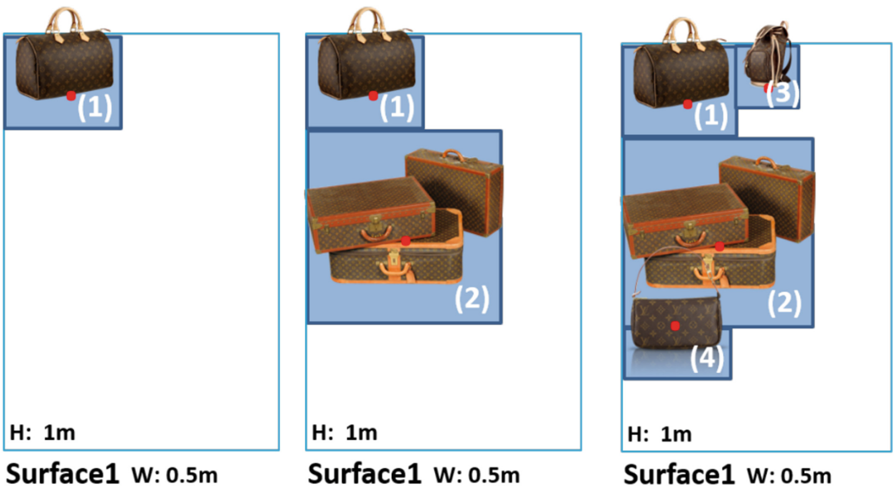


Fig. 9. The layout sequence of the independent layout algorithm

4. Let the items have the same spacing between rows and columns (see Fig. 10).
   - Make the same spacings between each row. (H – Hrow1 – Hrow2 – Hrow3)/4.
   - Make the same spacings in each row.

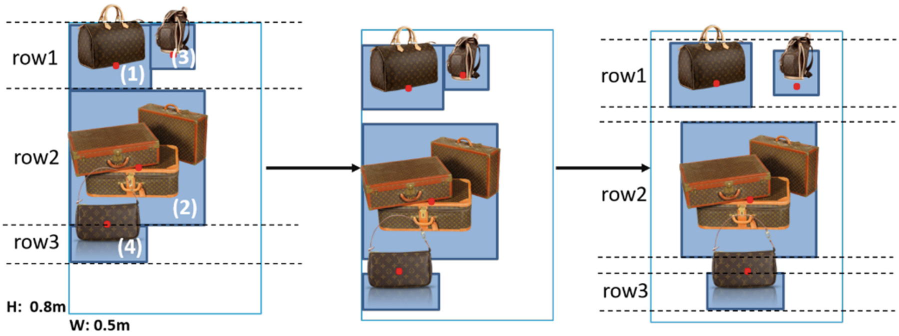


Fig. 10. Make the same spacing between rows and columns.

In some cases, if there is not enough space, lower priority items may not be placed. As shown in Fig. 11, if we say that the four items are placed on the smaller flat surface2, the fourth item will not be placed because there is not enough space after the first three items are placed.

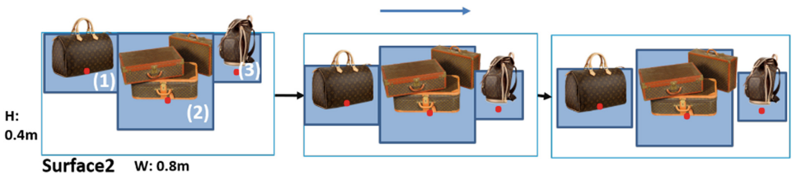


Fig. 11. The process of placing products on the surface2.

However, Users may also be interested in items that are not placed. We Designed a float indicator to indicate there are hidden items available for display. We Added a new voice command "show other items" to show available items that are not displayed. As shown in Fig. 12, in the initial case, we placed three items. Since there are four items that can actually be placed, we will display an indicator "3/4" to indicate the current placement status. When the user gazes the indicator and says, "show more", the items that are not displayed will be displayed, and the status of the indicate will also change. When the user says "show more" again, we will return to the state of the initial display of three items.

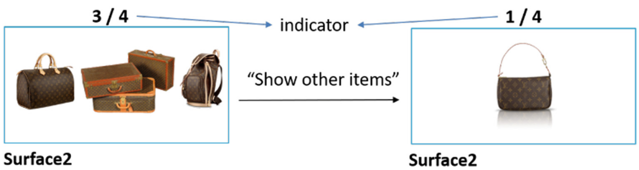


Fig. 12. Products indicator.

Independent layout has some limitation. The placement of shop items usually has an association. For example. Sometimes we may want to put some shop items to the platform on this structure. In this case, we cannot implement such layout just using the independent layout mechanism. So, it is very important to have a group layout mechanism to solve this problem.

Group Layout Mechanism. In the independent layout, the placement of the shop items is independent. However, in the real shop, items usually have associations (bags group, shoes group, belts group). These kinds of association are very important for shop layout.

Moreover, we may place multiple groups on one surface. The placement of different groups may also have a structure (see Fig. 13), but different surface in the different environment may have different size, we cannot define the fixed size of each group to describe the layout structure.

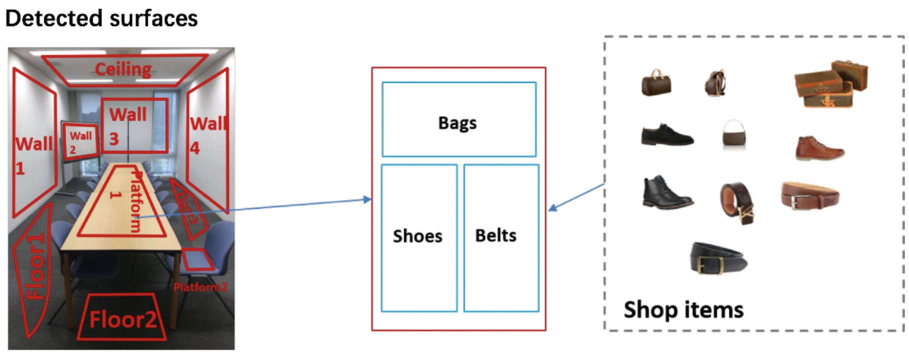


Fig. 13. Group layout example.

In order to describe the same structure on the different surfaces. We introduced a new concept of size: flex size. Flex size is described by a percentage that less than 100%. Its real size depends on the surface on which it is placed.

For example, there is a flex block which has flex size: 40% width and 50% height. When it is place on surface1, its real size will be 0.4 m width and 0.5 m height, while it is place on surface2, its real size is 0.4 m width and 0.35 m height (see Fig. 14). By defining flex size, we can describe the proportion structure between different surfaces, and calculate the real size of each group base on the real surfaces, in this way, we keep the same layout preference in different environment (see Fig. 15).

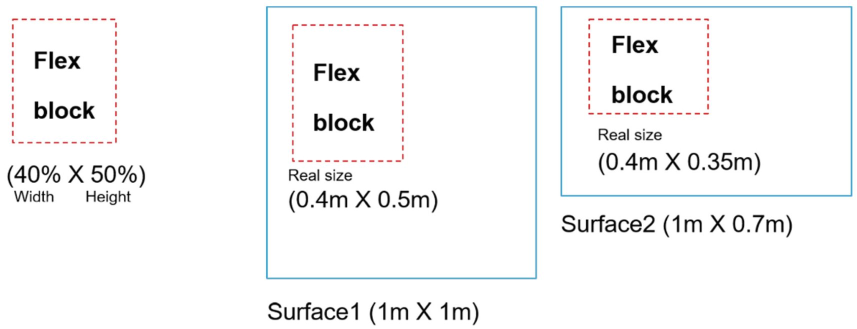


Fig. 14. The flex size and the real size

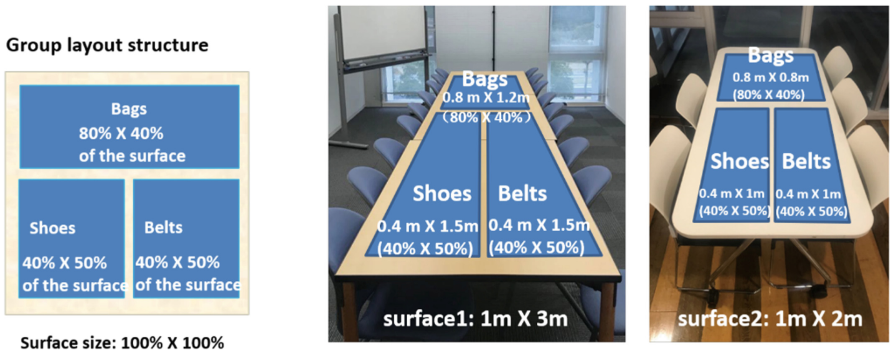


Fig. 15. Same layout structure in different surfaces.

It's not enough, A fixed structure may not be suitable for all surfaces. For example, as the Fig. 16 shows, because the width of surface3 is very small. If we use the same layout structure as surface1 and surface2, we may not have enough width to place any items.

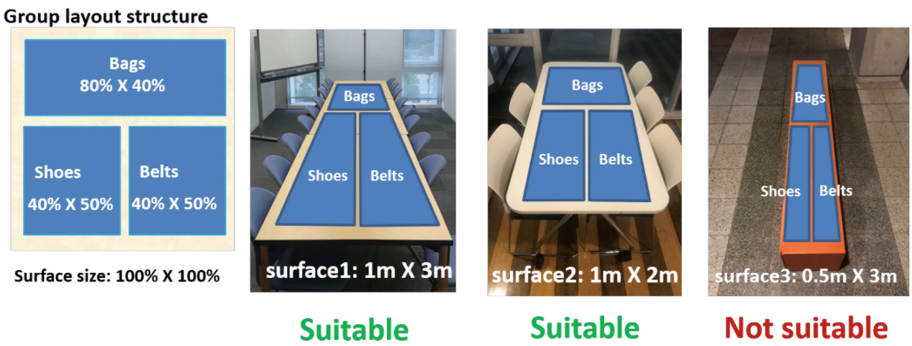


Fig. 16. A fixed structure may not be suitable for all surfaces.

In order to solve this problem. We allow store designers to give multiple sets of structures and specify their size range (see Fig. 17). In different surfaces, this system uses the related structure to generate the layout. For example. If we put these three groups on the surface 1, we'll use the structure1 while we put them to surface 3, use structure2.

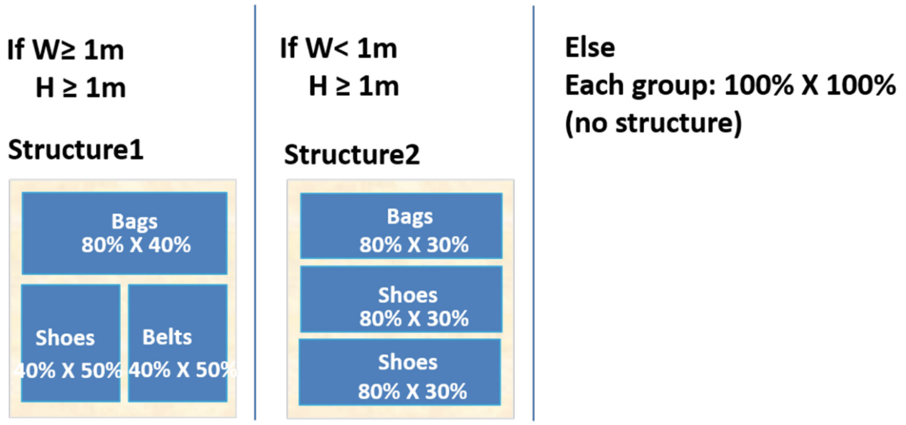


Fig. 17. Multiple sets of structures.

If there is no specified range, we'll give each group 100% × 100%. It means has no structure. And One group will take one whole surface. Like the Fig. 18 shows. In this way, we can get suitable group layout in any environment.

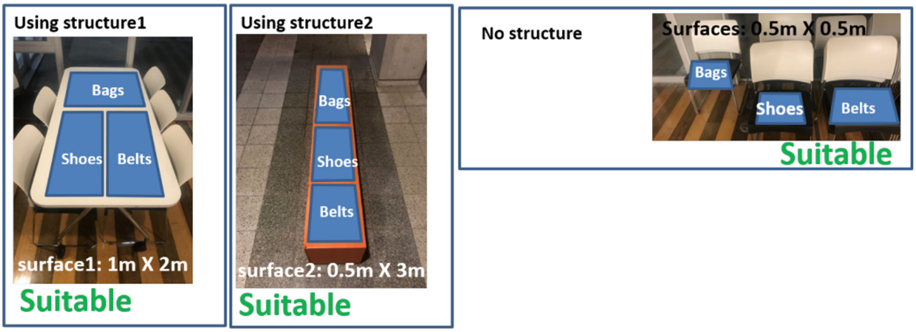


Fig. 18. Different layout structures in different surfaces.

Here is the summary of the layout mechanism.

1. Arrange shop items groups of each kind of surfaces (ceiling, wall, platform, floor) into an ordered sequence. We will traverse from ceiling to floor. In each kind of surface, from largest surface to smallest surface (see Fig. 19).

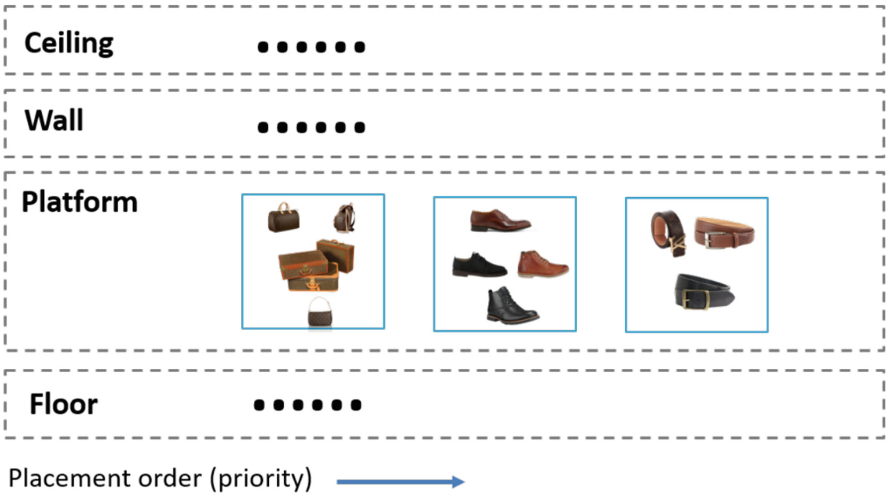


Fig. 19. Arrange shop items groups into an ordered sequence.

2. Describe multiple sets of layout structures (set the percentage size of each group) and set a traversal direction of each group. When generating the layout within each group. We will use this traversal direction (see Fig. 20).

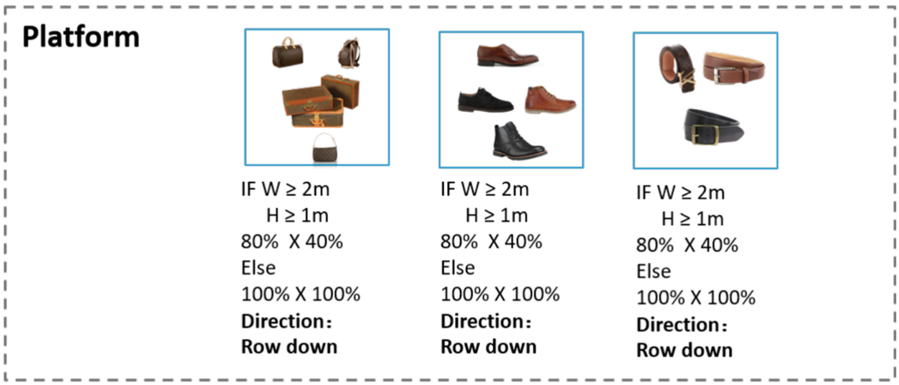


Fig. 20. Describe multiple sets of layout structures.

The first and second steps are all the attributes that the store designer needs to configure. Next, we will start the layout.

3. In the real environment, choose the related structure base on the real size of current surface.
4. Calculate the real size of each group using the structure. Then use independent layout algorism to generate the layout of each group.

After these four steps, we generated an MR shop. And the user can interact with it.

3.3 Spatial Sound

Many studies have shown that in the store system, sound feedback may affect the consumer's shopping experience [3]. Background music is an important symbol of brand culture, and different background music highlights different shopping environments [4]. We offer store designers two different modes of music interaction. One is the global mode, which allows users to hear the same sound anywhere in the virtual store. The other is space sound. Spatial sounds allow store designers to place a certain type of sound on a particular store element, which provides new interaction possibilities for the elements of the store item. For example, a store designer can place a dynamic show video near a particular item. Or specify a sound command that is sent when a particular item is in use. In this way, users can get a more immersive shopping experience.

3.4 Virtual Store Employee

In the physical store, interaction with the store employee is very important. When a user is interested in a product, it is often necessary to ask the store employee for details. The employee's description of the design source of products often enhances the user's trust and delivers a brand culture [5, 6]. In our system, after getting the designed shop. The user can use voice commands to communicate with the virtual store employee, and there are three kinds of voice commands:

1. I want to visit the Prada shop.
2. Introduce this product.
3. What's the price of the product? I'll take it.

After getting the voice commands, we use Microsoft speech to text and text analytics API to get the keywords of the voice command and get the related information from the store server.

3.5 Virtual Product Manipulation

The user can also use two-hand manipulation gesture to move or rotate virtual 3D objects (see Fig. 21). We use cameras of HoloLens to detect the user's gestures, then use the mixed-reality toolkit to achieve rotate and move operations [7].

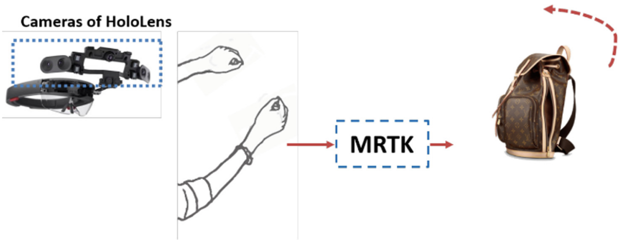


Fig. 21. Two-hand manipulation gesture.

In this chapter, we introduced the system design of our system:

1. We use spatial recognition technology to build a mixed-reality shop system which provides immersive virtual preview and interaction in the real environment.
2. We propose a layout mechanism to automatically mix virtual in-store characteristics with the real environment to provide a responsive mixed-reality store layout.

4 Implementation

4.1 Hardware

We divided this system into two parts: HMD client and server. To achieve the system, we need:

1. Depth sensors to detect the environment to recognize the space.
2. Microphones and speakers to capture the user's voice commands and provide feedback.
3. Head-mounted display to show the MR shop.
4. A computer as a server to store the shop elements.

We choose Microsoft HoloLens. It is a see-through type head-mounted display with built-in depth camera set and microphone. It blends cutting-edge optics and depth sensors to deliver 3D holograms pinned to the real world around the user. Built-in microphones and speakers are used to capture the user's voice and provide audio feedback. When the user makes a voice command, we use the HoloLens dictation system to convert the user's voice commands into text. Then proceed to the next operation based on the text instructions.

In order to store shop elements and store layout preferences, we use a laptop as a store server. Laptops and head-mounted displays are in the same network environment to increase access speed.

The other technical supports are:

1. Mixed-Reality Toolkit (MRTK), it Supports environment data analysis and gestures input functionality of my system.
2. Microsoft speech-to-text API, it converts the user's voice commands into text.

3. Microsoft text analytics API, it extracts keywords from user commands that have been converted to text. For example, when the user says, "I want to go to the Prada store" or "Take me to the Prada store", we will extract the keyword "Prada store" and perform the same operation (generating the Prada mixed reality store).

4.2 Graphical User Interface for Shop Designer

As the Fig. 22 shows, we provide the store designer with a user interface for the web server. The store designer only needs to upload the elements of the store, specifying the attributes of the store elements, such as size and placement preferences. We will store the store elements in the store server and generate a mixed reality store using the corresponding store elements and placement preferences when the user accesses with voice commands.

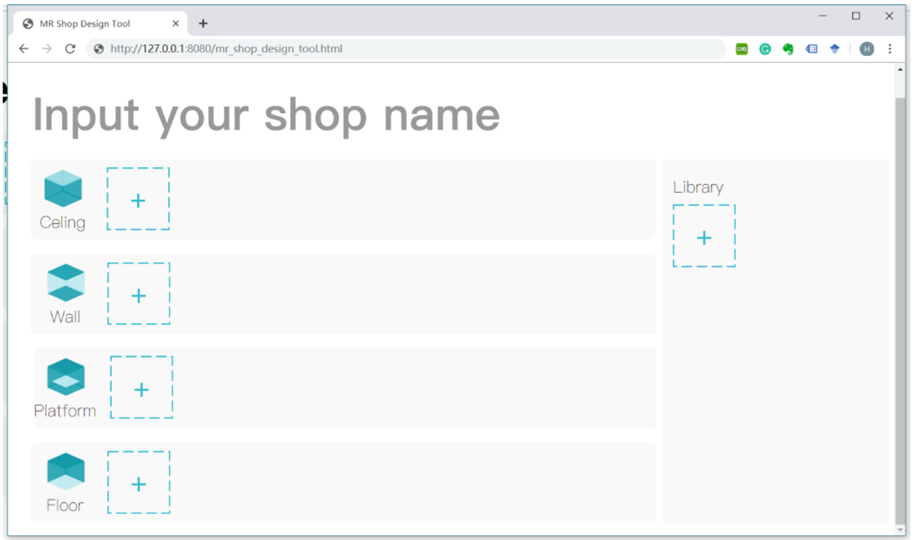


Fig. 22. Graphical user interface for shop designer.

4.3 Voice Command

In order to provide users with a more natural approach [8]. to interact with our assistant system, we designed our system to allow voice input. With the help of existing speech recognition techniques, the system can extract the user's command and keywords, and it can provide responses in real-time response [9, 10]. Users can say a sentence including the mixed reality shop that they desire, our system will generate the related mixed reality shop in the real time.

4.4 Two-Hands Manipulation

We built a shop server to store the 3D models of shop items and the layout preference designed by the shop designer. Each product in our system has its own 3D virtual object. So that when the products result is returned, the 3D virtual objects can also be shown. We pre-processed the virtual models to make sure that they can be operated successfully. Using MRTK, bounding box around the virtual objects is used to help users judge the size of the objects. By adding two-hand manipulation scripts in MRTK, users can use their hands to drag and rotate the virtual objects.

5 Related Works

5.1 Related Works on In-Store Shopping

For physical stores, many studies have shown the importance of in-store characteristics and the communication with clerks for users to shop. Most studies have shown that consumers often look for hedonic properties in a store environment and are keen on shopping experiences [11, 12]. Consumers like the shopping experience and don't think it's a chore [13, 14]. They see it as an entertainment process and enjoy pleasure and enjoyment [15]. Attractive retail displays motivate consumers to browse and stimulate purchases [16].

Physical stores enable consumers to touch, feel and smell products, giving them the opportunity to validate their products. Store environment tips such as design, layout, lighting, music, cleanliness, perfume and salesperson professional influence shopping behavior [17]. Consumers expect social interaction with clerks in the store. Personalized one-to-one customer service also has a positive attitude towards retail stores [18]. Warm greetings from customer service representatives, personalized attention, promotional offers and product knowledge from salespeople increase consumer loyalty to the store [19].

Based on these studies. In our proposed system, we offer store designers two shop elements, "decoration" and "product" to ensure that store designers can provide these in-store elements that are important to the user's shopping experience in a mixed reality store to preserve the benefits of in-store shopping. We also provide the "virtual employee" function to provide communication functions similar to physical stores, which not only meets the social needs of users in shopping, but also further strengthens the brand characteristics. By Comparing consumer's shopping channel choice motivations, we added the most important in-store factors that are lacking in the online shop to the mixed-reality shop system, and also provided speech input and voice feedback (virtual store employee interaction) to give users a natural shopping experience.

5.2 Related Works on Responsive Layout

Placer and Packer Algorithms. In the geometry management system of tcl/tk. The packer arranges widgets around the edges of an area. The placer provides simple fixed and "rubber sheet" placement of widgets [20].

In a real store system, we also have the need to separate objects from a single plane to a specific plane, so I introduced an independent layout method in the store layout algorithm which is similar with the "placer". But in fact, commodity groups with a certain pattern are more common in stores, so I also introduced a group layout method which is similar with the "packer" to allow individual items to be packaged into groups, thus providing a more realistic layout unit.

Responsive Web Layout. A web browser is a dynamic medium, it allows a user to re-size the browser window itself, and users can also change the size of the font as well. And when this happens, web pages created with pixel-perfect web design principles often break. If a web page was optimized for a 1024 $\times$ 768-pixel screen size, that web page will look quite wrong in a smaller or bigger screen. As the number of mobile devices that have a variety of screen sizes grows, pixel-perfect web design has become problematic. Responsive web design [21] is an attempt to solve this problem. Its core concept is "flexible layout".

Responsive web design makes a web page adjust itself in response to the screen size of a device. This means that there is no longer one fixed layout in which the elements of a web page are permanently placed. Instead, as the size of the screen changes, the layout of a web page adjusts itself and rearranges the elements of the page.

In my mixed reality store system, in order to create a corresponding virtual store with the same material in different environments, I designed a traversal-based responsive layout algorithm. It dynamically generates the corresponding layout on different planes based on the product placement priority. Unlike tcl/tk and web responsive layouts, real environments have fixed and non-expandable sizes. Therefore, I also designed a layout indicator to extend the size of the store, which in turn expands the capacity of the real environment.

6 Preliminary Evaluation

We asked participants to accomplish their shopping tasks in our mixed-reality shop system. The main purpose of this study was to test whether our system can provide brand characteristics in the mixed-reality shop to give users a good shopping experience and whether the interaction of our system is easy to use.

6.1 Participants

We invited 10 participants (2 females and 8 males), ranging from 22 to 25 years of age. All participants have basic computer skills. Two of them had experience with head-mounted displays.

6.2 Method

All participants are given a brief introduction of the system. Before each study, we introduced the basic operations of Microsoft HoloLens to the participants. After the participants became familiar with the device, we asked them to visit two mixed-reality shops (one is the Prada shop, another is a flower shop), and try to find the products that they are interested.

After that, the participants will be asked to fill in a questionnaire. The questionnaire has following 7 questions and these questions use the 5-point Likert scale.

1. The system is easy to use.
2. The interaction with virtual store employee is useful or interesting.
3. The gestures interaction is useful or interesting.
4. I can easily find products of interest in the mixed-reality shop.
5. I can easily understand the details of the products in the mixed-reality shop
6. I can feel the brand characteristics in the mixed-reality shop.
7. The system can provide a good shopping experience.

6.3 Results

Question 1, 2 and 3 are used to test the ease of use and usability of the system. The average score of question 1 is 4.5. The results prove that the system is easy to operate. Question 2 is used to test the usability of the store employee interaction, the average score of question 2 is 4.8, the results shows that participants agree that voice interaction with virtual clerk is useful. Question 3 is used to test the usability of the gesture's interaction, the average score is 4.2. All the results show that even though users are not familiar with the operation of the head-mounted display, our voice and gestures-based system is still easy to use.

Questions 4, 5, 6 and 7 are used to determine whether our system can give users a good shopping experience. The average score of question 4, 5, 6, 7 is 4, 4, 4.5 and 4.6. The results show that participants agree that using our system can easily find products of interest, feel the brand characteristics and get a good shopping experience. One participant thought that using our system can better understand products information than traditional mobile shopping systems. Traditional mobile shopping systems typically use limited 2D images and captions to describe the specifics of the product, and users may not be able to get more specific information from these descriptions. Our system allows users to understand the product more fully by visually displaying a rotatable virtual 3D product with descriptive information.

In general, all participants rated our system higher than the traditional system. This may signify that our system is designed to be reasonable and practical. It demonstrates that our system can build a new way of shopping, allowing users to intuitively get high-quality recommended products based on the current scene and make quick shopping decisions.

Overall, we got a positive feedback through the preliminary user study.

7 Conclusion and Future Work

7.1 Conclusion

Our research compared current shop systems' advantages and disadvantages, then proposed the concept of a new shop system, mixed reality shop, which may be the possible direction of the future shopping system.

Technically, we developed a spatial understanding algorithm that divides the complex environment metadata into detected surfaces. This algorithm simplifies the information in space then reduce the amount of calculations. we also designed several matching layout mechanisms to generate the store layout. Under these mechanisms, we can generate the responsive store layout just through simple calculations.

For shop designers, we provide a simple layout interface, and store designers can easily complete the design of a mixed-real store by simply uploading store elements, grouping them, and specifying their order. When consumers use a mixed reality store on the client side, we will use a comprehensive layout algorithm to automatically generate the corresponding store based on the current environment. We also designed a virtual voice employee system and a simple gesture interaction system to allow consumers to interact with the mixed reality store.

We received feedback from the users by conducting a user study. Overall, we received positive feedback.

7.2 Future Work

Although we have proposed a prototype of mixed reality shop system, there are still some limitations and future possibilities to improve its efficiency. In this system, for the designer's design interface, it is still a 2D web interface. However, for the final mixed reality store, it is displayed in a real 3D environment. Therefore, there is a process of conversion between design and real layout, and store designers may not be able to imagine the final 3D store just through the 2D layout page. We hope this can be solved by a 3D design interface (for example, a store designer designs a store directly in a real environment). Also, we are thinking of the possibility of involving machine learning ability In the store's layout algorithm, because the store layout is subjective and difficult to measure with data, it may be related to the store style, related to the characteristics of the real environment, and related to the commodity elements. Through machine learning methods, we can not only be limited to a layout algorithm, but also consider the most possible layout factors to provide a better store layout.

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