Spatial Recognition Based Mixed-reality Shop System Providing Responsive Store Layout

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Abstract

The current online shop system lacks environment information and in-store characteristics, which are very important for consumers shopping experience. We try to build a mixed-reality (MR) shop system which could recognize the space, make the real environment become a part of the virtual shop, to provide: Immersive virtual preview and interaction in the real environment. In-store characteristics such as store layout, decoration, music and virtual store employee. We designed a new kind of online shop system by mixing virtual in-store characteristics and real environment, which may be the possible direction of the future online shop system. Technically, we developed a new spatial understanding algorithm and layout mechanism to support responsive spatial layout. By using our system, store designers only need to design once, and our system can make any place to be any shop.

Our system consists of three main parts. Spatial recognition, responsive store layout, and store interaction. First, we scan the space through depth cameras and use a spatial understanding algorithm to understand the surfaces. Next, we have 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 getting the designed shop, the user can use gestures to move or rotate virtual products or use voice commands to communicate with the virtual store employee. We use depth cameras to capture user's gestures and convert them into related manipulation of virtual products through the mixed reality toolkit. Microphones and speakers are used to capture the user's voice commands and provide feedback.

We have invited some participants to test the usability and efficiency of our system. We got a positive feedback through the preliminary user study.

Keywords: Mixed-reality, E-commerce, Spatial Recognition, Responsive Layout

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Chapter 1

Introduction

1.1 Introduction

Environment is very important for consumers shopping. In-store characteristics like 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. 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 investigated the current shop systems and compared their advantages and disadvantages. Then proposed the concept of a new shop system, MR shop system, which may be the possible direction of the future shopping system.

The Fig. 1.1 shows the process of generating a mixed reality shop. The MR shop system could scan the real environment, simplify the scan results into an understood surfaces that can be used, then make the real environment become a part of the virtual shop, so as to provide: Immersive virtual preview and interaction in the real environment and in-store characteristics such as store layout, decoration, music and virtual store employee.

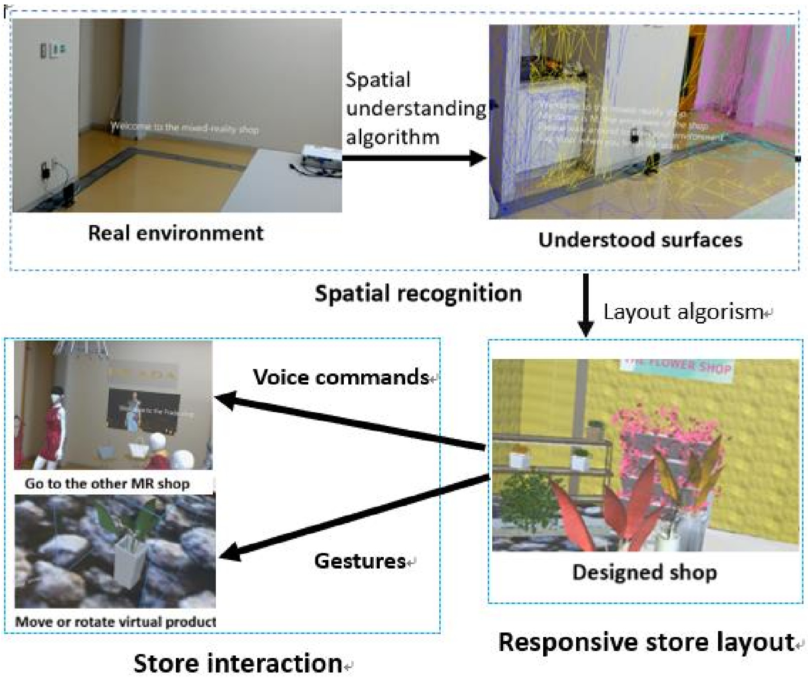


Fig. 1.1 The process of generating a mixed reality shop

1.2 Organization of the thesis

The rest of the thesis is organized as follows: Chapter 2 introduces the background of the thesis and also the comparison of the advantages and disadvantages of the current shop systems. Chapter 3 will tell the research goal and also the approach will be told briefly. Chapter 4 is the system design part, where the design concept and ideas will be introduced and the mechanism and algorithm design will also be told. Chapter 5 will be the system implementation part where the detailed environment and implementation will be talked. Chapter 6 will introduce the related work. Chapter 7 will be about the evaluation, we will talk about the usability and efficiency of our system. The last part, Chapter 8, will be the conclusion and future work part, where we will conclude the previous content and talk about future possibilities.

Chapter 2

Background

2.1 Current shop systems

Currently, there are four main shop systems: physical shop, online shop, augmented reality(AR) shop and virtual reality(VR) shop.

2.1.1 Physical shop

The physical shop has been developed for hundreds of years. Different physical shop has their own decorative elements and products layout, which makes them looks very unique.

The Fig. 2.1 shows two different physical shops. The Fig. 2.1(a) is a Chanel physical shop, the Fig. 2.1(b) is a Louis Vuitton physical shop, these two shops have their own brand personality because of the different in-store characteristics [2]. Because all the products are real, the user can view the products in detail, compare different products, and check if the product suits the current dress.

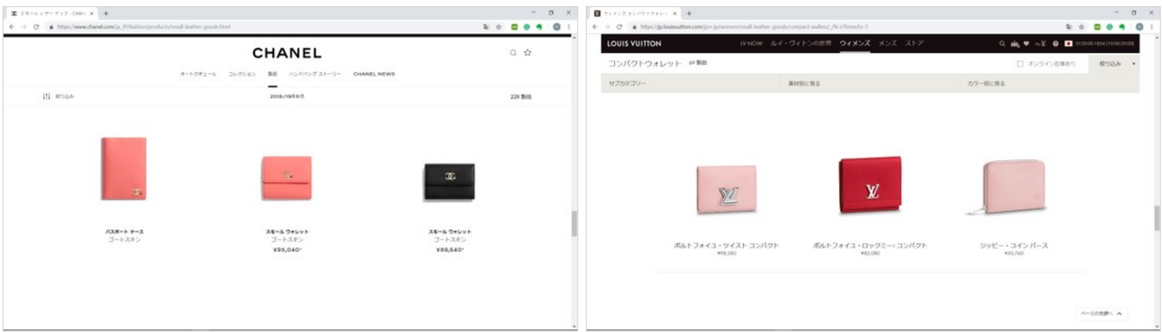
However, It is not convenient to go to a physical shop. It usually has a fixed business time and may be far away from home.

(a) The Chanel physical shop (b) The Louis Vuitton physical shop

Fig. 2.1 The current physical shop

2.1.2 Online shop

The current online shop is very convenient, we can buy products anywhere and anytime [3]. But it often has fixed products layout and lacks the decorative elements [4]. The left picture is the Chanel online shop, the right picture is the Louis Vuitton online shop, These two shops look very similar although they are different brands.



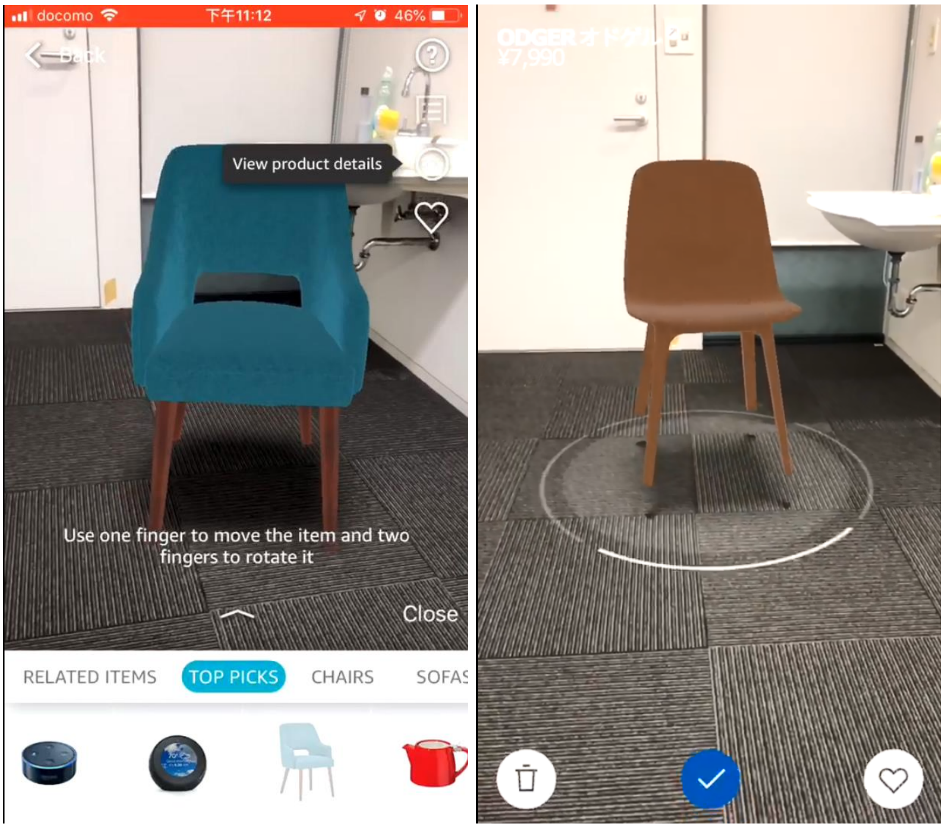
(a) The Chanel online shop (b) The Louis Vuitton online shop

Fig. 2.2 The current online shop

Online shops use 2D pictures to describe products. The user usually can't fully understand products just from the 2D images.

2.1.3 Augmented reality shop

AR shop becomes more and more popular now. There are two main types of AR shop systems [5]. The first type of AR shop system mainly focuses on how to preview products in the real world. Fig. 2.3 shows some AR shop systems. Their system structures are very similar: first detect a surface, next put the virtual objects on the detected surface. The main idea of these systems are adding AR feature to the online shop to preview products. By adding the AR feature, we can see if the products is suitable for the current environment. And we can move and rotate products to see details. For the first type of AR store, it still lacks the store layout elements that are important to the brand culture.[6]



(a) Amazon AR shop (b) IKEA AR shop

Fig. 2.3 The current in-home AR shop

The second type of AR shop Focuses on adding virtual things to the physical store. Zara has launched their AR shop app last year. When a user opens the ZARA AR app in a ZARA physical shop, some virtual models walking in the shop will be displayed. They use this way to enhance their brand personality. Rakuten also has a MR shopping system called MR shoppingu system [7]. When the user at a physical shop and picks up a product, the system will show the price, video, introduction of the product. This system adds additional product information by using AR. The main idea of these two systems are using AR to enhance physical shop. But these system cannot solve the convenience problem of physical shop.

2.1.4 Virtual reality shop

The Fig. 2.5 shows the current VR shop, because all the elements of the current virtual reality(VR) shop are virtual, we can create a shop with decorative elements and flexible products layout, just like the physical shop [8].

But The VR shop doesn't have a connection with the real world [9]. We need to make a walking area in the real world, so the user's movement is limited [10].

Chapter 3

Research Goal and Approach

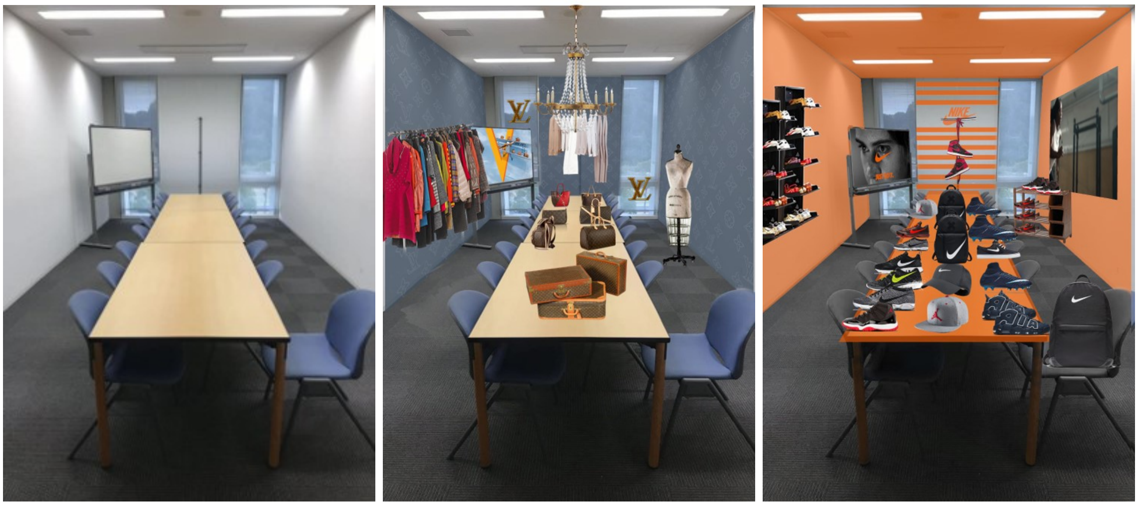
3.1 Goal

Our research tries to build a mixed-reality(MR) shop system which could recognize the space, to make the real environment become a part of the virtual shop, so as to provide:

1. Immersive virtual preview and interaction in the real environment;
2. In-store characteristics such as store layout, decoration, music and virtual store employee.

3.2 Approach

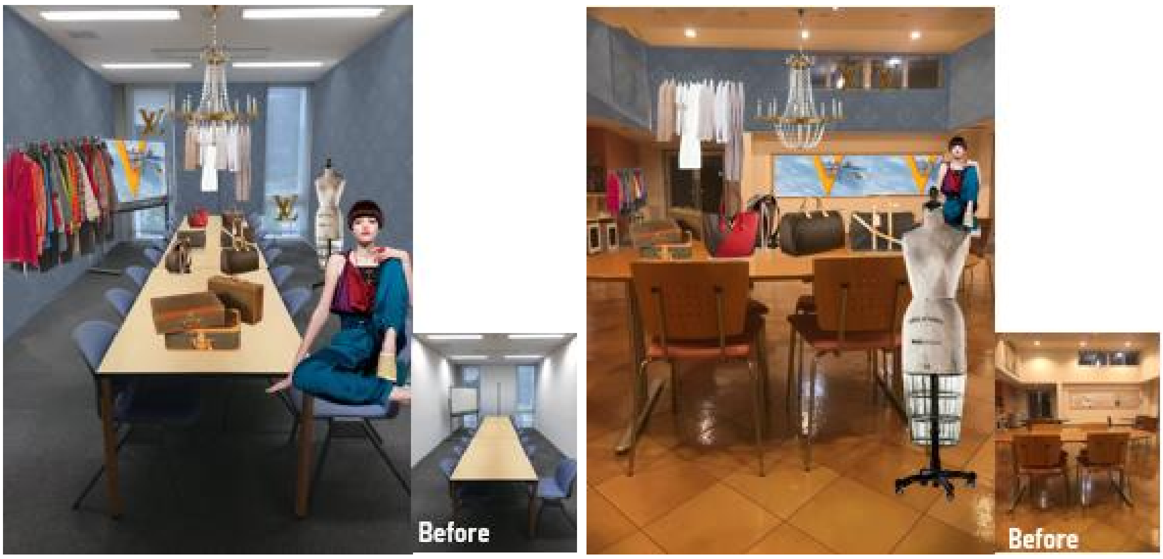
Like the image shows, by using our system, after scanning the environment. The seminar room can be a Louis Vuitton MR shop, or be a Nike MR shop. The Virtual products placed on the real table and chairs, the real walls or ceiling is decorated with the virtual store characteristics. The user can use gestures to manipulate virtual products or use voice commands to communicate with the virtual store employee. This system can automatically make everywhere be ever 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. 3.1 The different MR Shop in the same environment

If there is another environment, this system would automatically build another MR shop by using the same elements. Just like the figure shows. So this system is very convenient for shop designers. Designers only need to design the elements once, and the 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. 3.2 The same MR Shop in the different environment

Chapter 4

System Design

4.1 System Overview

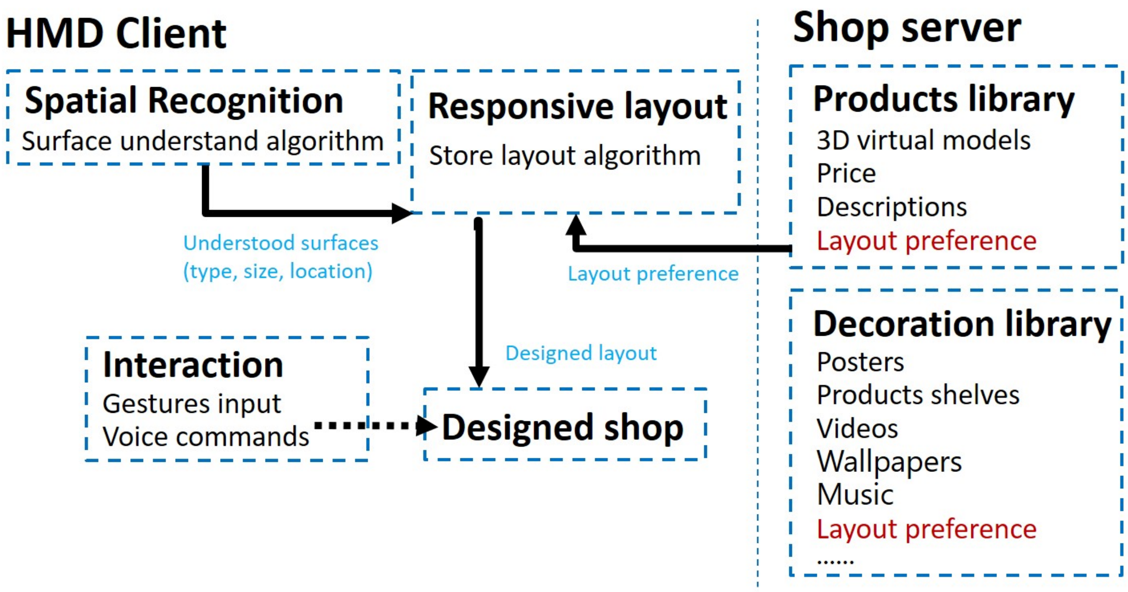


Fig. 4.1 System overview

The Fig. 4.1 shows the overview of our system. First, we understand the space by recognizing the surfaces. Then generate the store layout base on the understood surfaces and the store items layout preference which is stored in the shop server. After getting the designed shop, the user can use gestures to manipulate virtual products. Or use voice commands to communicate with the virtual store employee.

4.2 Spatial Recognition

4.2.1 Spatial Detection

As the Fig. 4.2 shows, We use depth cameras to detect surfaces of the real world. By using the spatial understanding API of Mixed Reality Toolkit(MRTK). We can get the metadata of detected surfaces: Position, size, horizontal or vertical.

These unclassified data are complex and cannot be utilized.

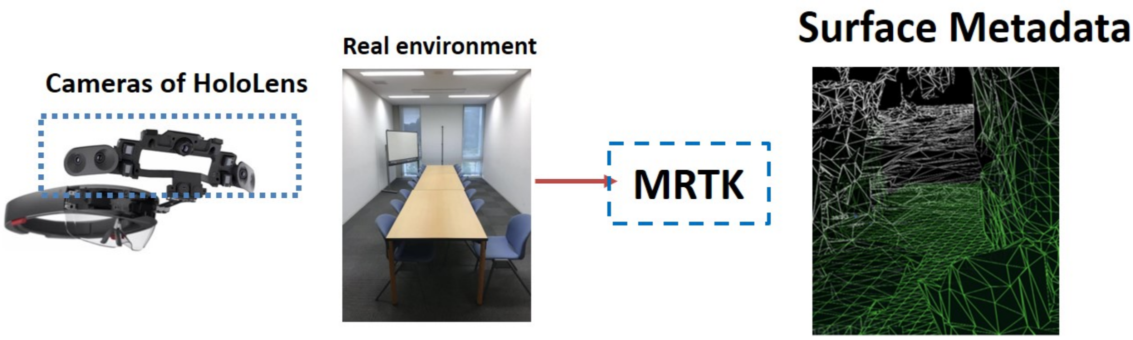


Fig. 4.2 The process of spatial detection

4.2.2 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 this placement habit, to generate a layout, we first need to understand the specific meaning of each plane in the space. As the Fig. 4.3 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.

The specific spatial understanding mechanism is:

1. Ceiling: The highest horizontal surfaces in space.

2. Wall: Vertical highest.

3. Platform: Horizontal surface in the middle of the ceiling floor

4. Floor: the lowest horizontal surfaces in space.

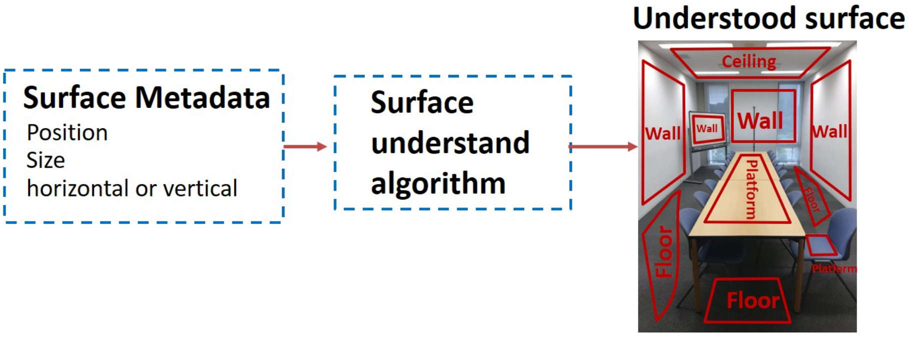


Fig. 4.3 The process of surface understanding

Through this spatial understanding algorithm, we simplify complex, non-specific spatial metadata into a concrete plane that can be understood by store designers and can be used for design, which is the basis for generating responsive stores. We will understand that good planes are stored in four arrays in a flat size. They are "ceiling", "wall", "platform" and "floor". The size of these four arrays describes the characteristics of a space.

4.3 Responsive Store Layout

After understanding the surfaces, we can generate the layout of the store. The process of generating a store layout is the process of placing store elements on the plane being understood [11, 12]. The difficult part is how to get the regular responsive store layout [13]. In fact, this is a dynamic programming problem with complex constraints [14, 15]. However, Head mounted display usually do not have a powerful calculation capability. At the first stage, I tried to generate the store layout by a very huge dynamic programming algorithm, However, using this algorithm, In head-mounted devices, we can't get a real-time results because of the complex calculation process. So we should simplify the complex dynamic programming problem into a simpler algorithm, so as to provide the user with a real-time, automatic responsive store layout. In order to get a regular store layout, we developed several layout mechanisms to correspond to store elements and the planes that are understood. These layout mechanisms depend on the placement characteristics of the store elements.

4.3.1 Surface Segmentation Layout Mechanism

As the Fig. 4.4 shows, In this mechanism, every understood surface is divided into nine blocks by the position. Each block is divided into four edges and one center. We defined a matching layout preference attributes for each store item.

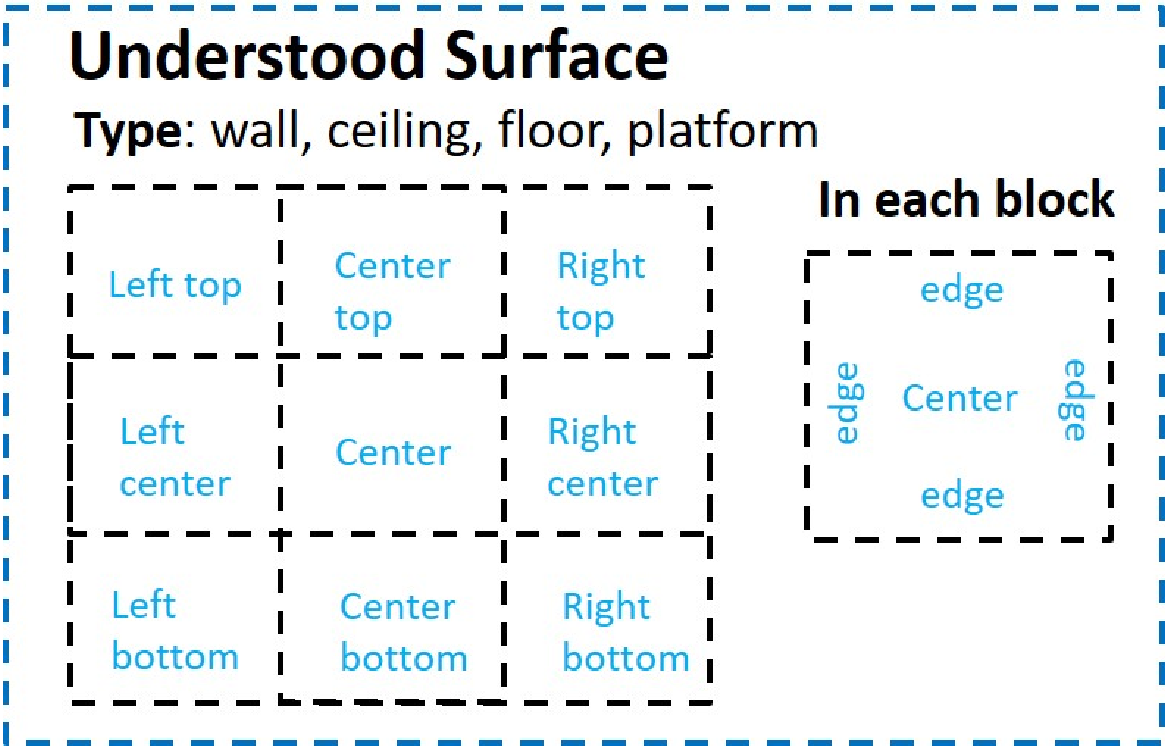


Fig. 4.4 Surface segmentation

The center point of shop items should be placed on the:

1. Wall/ceiling/floor/platform;

2. Existing biggest / smallest surface;

3. Left top/ Center top/······ of the surface;

4. Center/ edge of the block.

We also have an attribute called placement priority (order), which has the value 1(Lowest) — 10(Highest): It determines the order of the placement. If multiple items have the same layout preference, they should be given different placement priority, in our system, the higher priority one will be placed first.

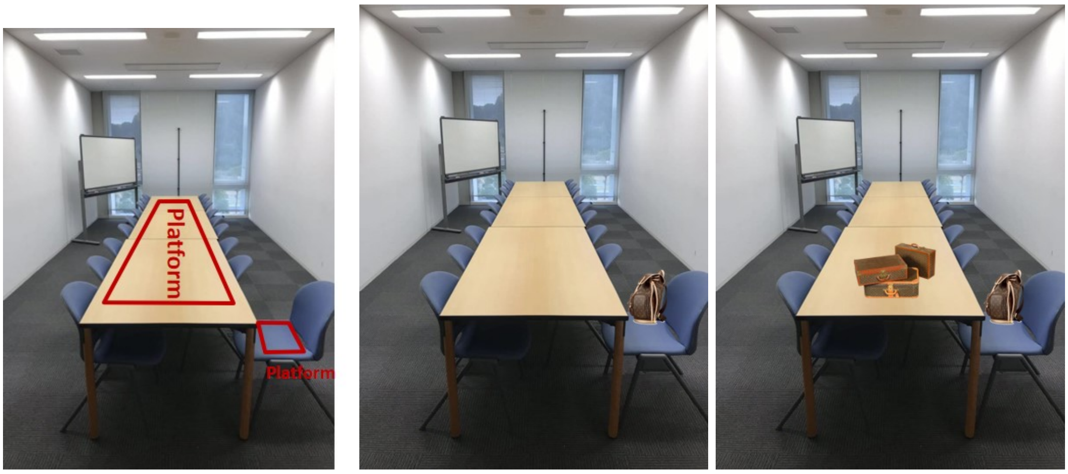
We will generate the store layout of each surface based on the size of the surface and the size and layout preference of the store items.

For example, As the Fig. 4.5 shows, there are two virtual products. The first one should be placed on the biggest platform, center bottom, center. The second one should be placed on smallest platform, center top, top edge.

(a) product1 (b) product2

Fig. 4.5 Surface Segmentation Layout Mechanism example items

Fig. 4.6 shows the process of surface segmentation layout mechanism. Because product2 has a higher priority, it will be placed first. It is designated to be placed on the smallest platform, which means it will be placed on the chair. As the Fig. 4.6(b) shown, it will be placed on the center top of the chair, and top edge of the block. Next, product1 will be placed. It is designated to be placed on the biggest platform, which means it will be placed on the table. As the Fig. 4.6(c) shown, it will be placed on the center bottom of the chair, and center of the block.



(a) The understood platforms (b) Placement of the product2 (c) Placement of the product1

Fig. 4.6 The process of Surface Segmentation Layout Mechanism

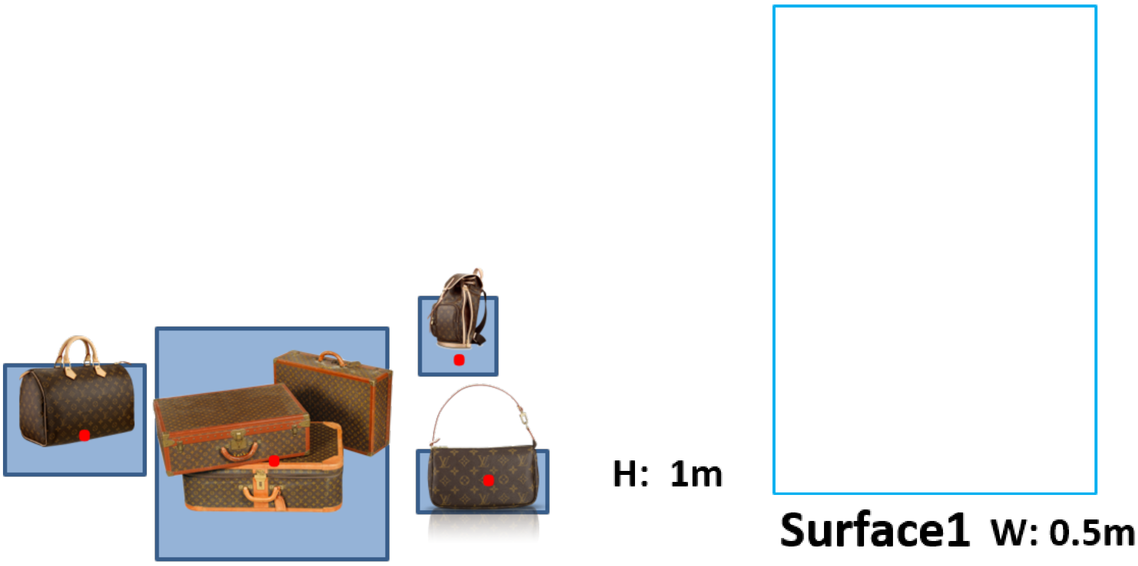
Surface Segmentation Layout Mechanism has some disadvantages:

1. Just divide surface into 9 blocks is limited;
2. If there are a lot of products, it will take long time to set their layout preferences one by one;
3. If there is not enough space, some lower priority items which may interest users may not be placed;
4. There is no association between shop item.

Therefore, we need a new layout algorithm to solve these problems.

4.3.2 Independent Layout Mechanism

In this algorithm, shop items still do not have an association. So I named it independent layout. This algorithm has four steps. I will use the specific example shown in Fig. 4.7: how to put these four items on surface1 to introduce the specific steps of the algorithm.



(a) Products (b) Target surface

Fig. 4.7 Products and target surface

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.

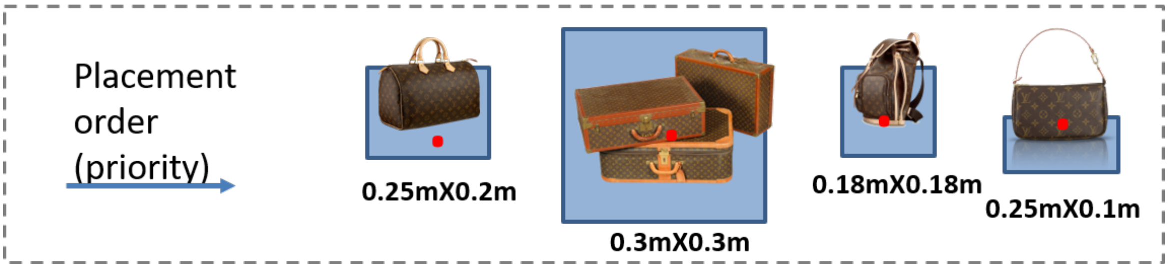


Fig. 4.8 Arrange the shop items into an ordered sequence

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.

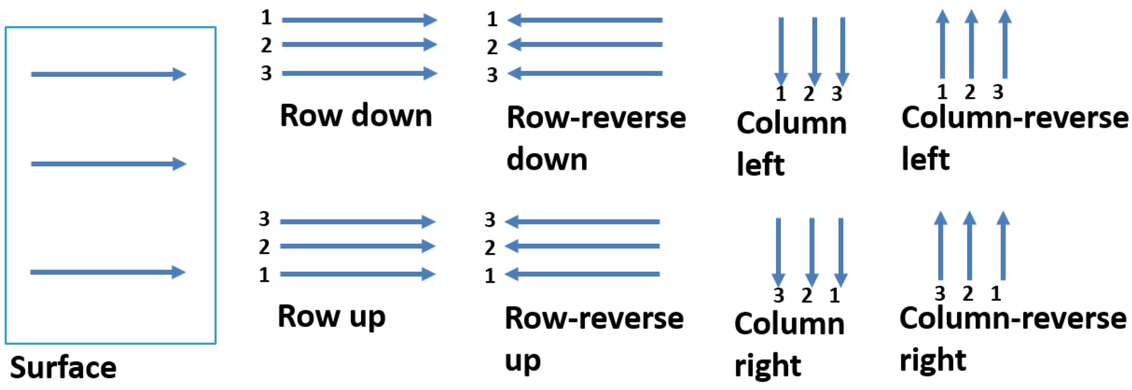


Fig. 4.9 The direction of traversal

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.

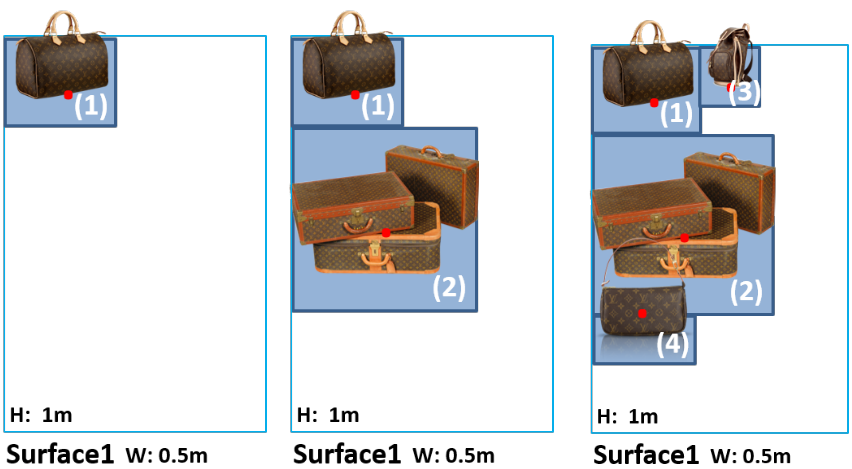


Fig. 4.10 The layout sequence of the Independent Layout Algorithm

4. Let the items have the same spacing between rows and columns.

4-1 Make the same spacings between each row. (H – Hrow1 – Hrow2 – Hrow3) / 4

4-2 Make the same spacings in each row.

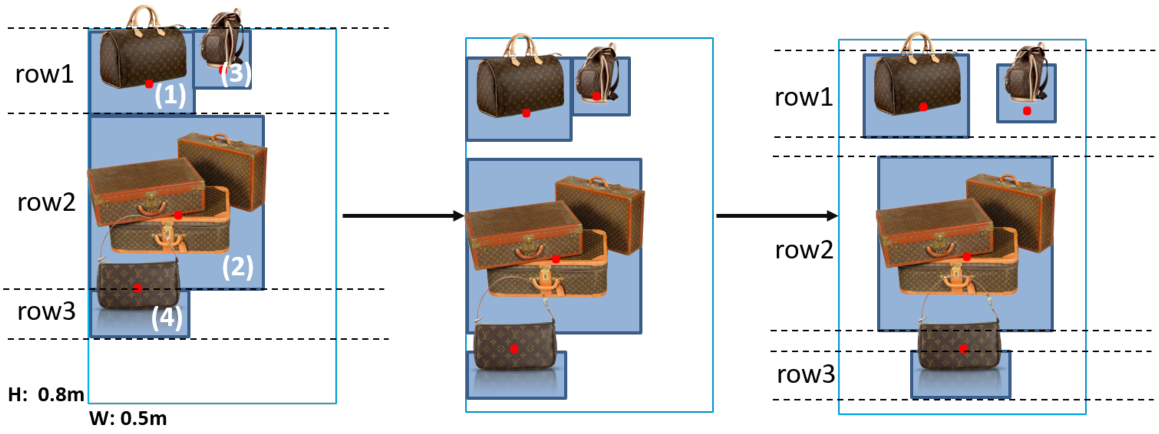


Fig. 4.11 Make the same spacing between rows and columns

In some cases, if there is not enough space, lower priority items may not be placed. As shown in Fig. 4.12, 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.

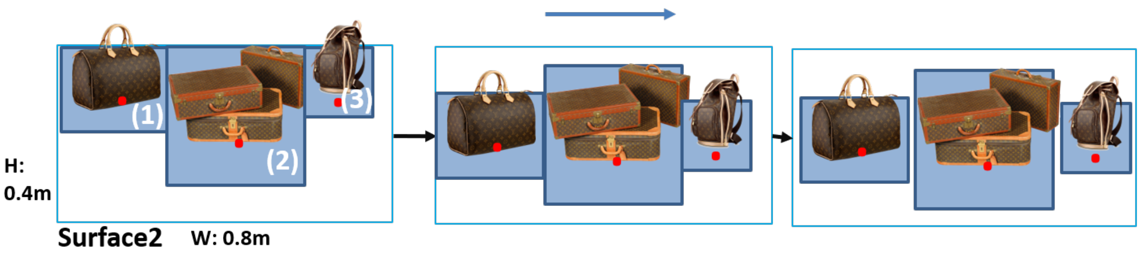


Fig. 4.12 The process of placing products on the surface2

However, Users may also be interested in items that are not placed.

I Designed a float indicator to indicate there are hidden items available for display. Added a new voice command: “Show other items” to show available items that are not displayed. As shown in Fig. 4.13, 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.

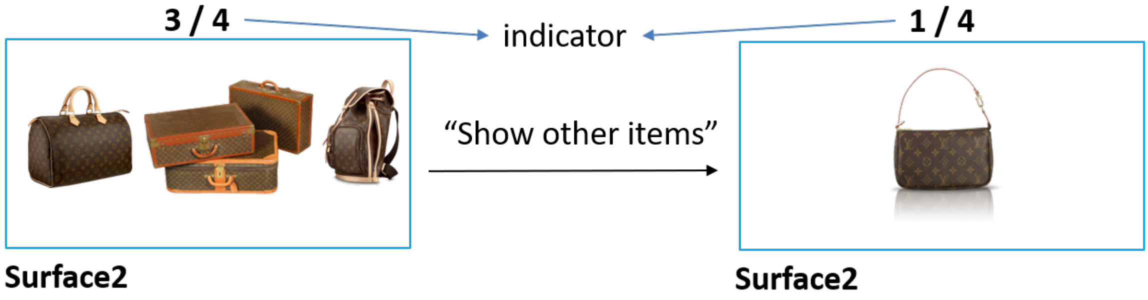


Fig. 4.13 Products indicator

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.

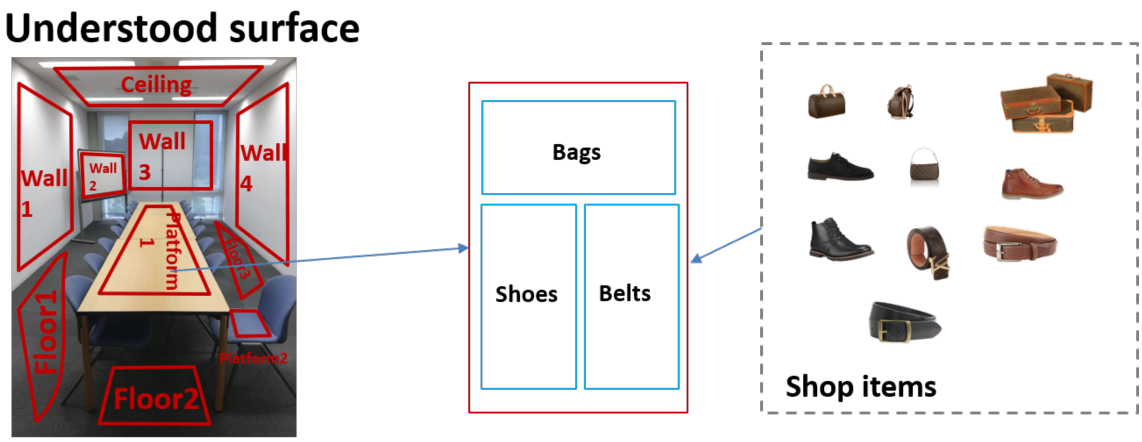


Fig. 4.14 Group layout example

4.3.3 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). This kinds of association is very important for shop layout.

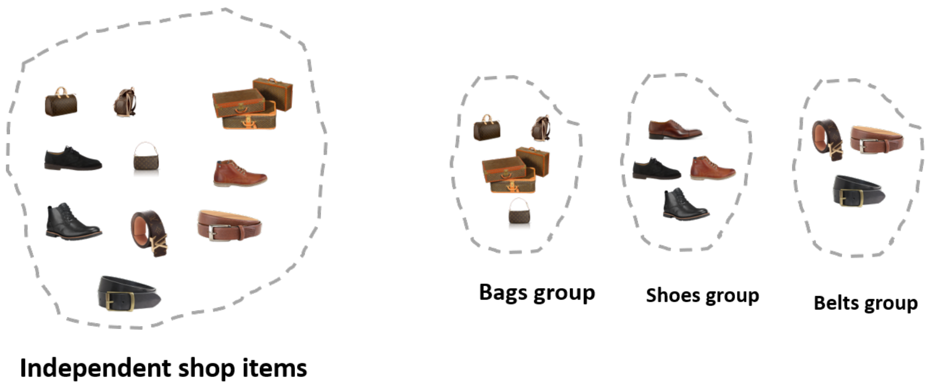


Fig. 4.15 Products association

Moreover, we may place multiple groups on one surface. The placement of different groups may also have a structure. For example, as the Fig. 4.1.6 shows, I want to put the bags group at the top of surface, and put shoes group at this block. Like the image shows, we can implement such a layout structure by defining the size of each group. Then use the independent layout algorithm to get this layout structure.

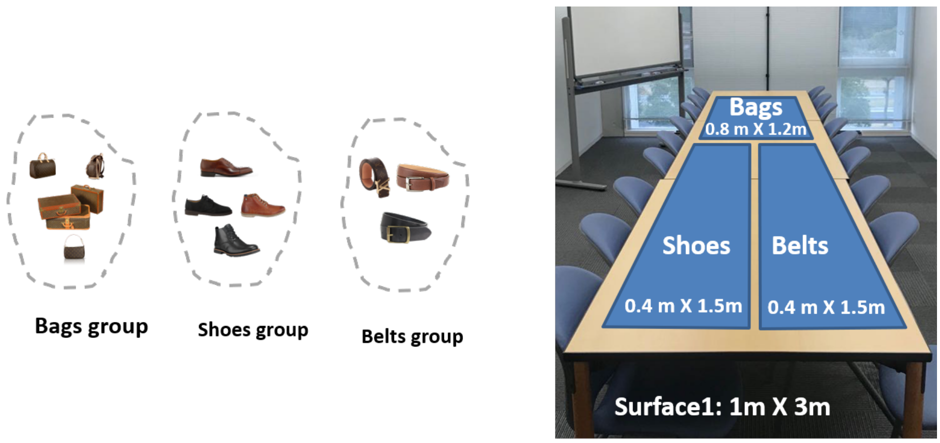


Fig. 4.16 Layout structure

However, different surface in the different environment may have different size. So we cannot define the fixed size of each group. as the Fig 4.1.7 shows, because the surface1 and the surface2 have different sizes. The groups' sizes of surface 1 cannot be used to generate the layout of surface2.

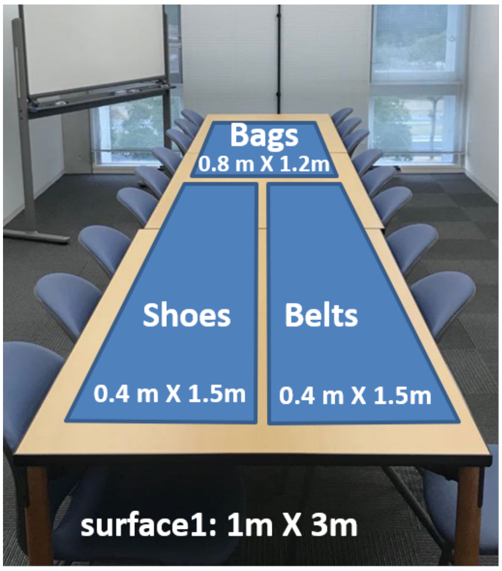


Fig. 4.17 Different surfaces cannot use a same group size

So How to make the same structure on different size surfaces? It also means How to describe the structure?. Before that, I would like to introduce a concept: 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. The calculation method is

For example, there is a flex block which has flex size : forty percent width and fifty percent height. When it is place on surface one. Its real size will be 0.4m width and 0.5m height, while it is place on surface2, Its real size is 0.4m width and 0.35m height.

Flex size can be used to describe the proportion of a plane to another fixed plane. By defining Flex size, we can describe the size relationship between planes without knowing the specific plane size.

My solution to describe the structure of groups layout is to use the flex size. In different environment, calculate the real size of each group base on the real surfaces. For example, I

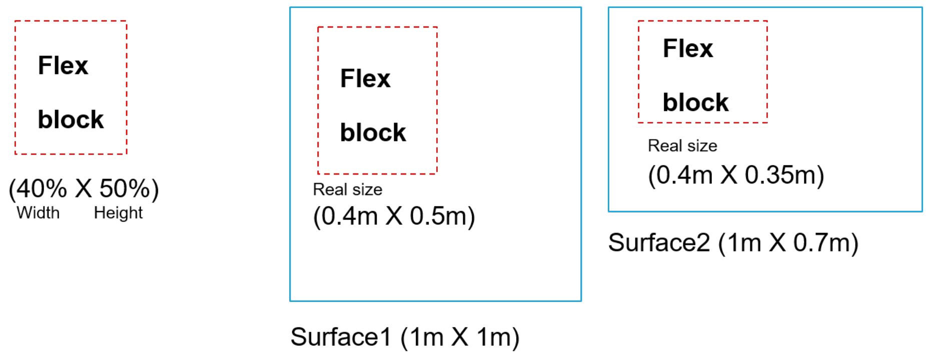


Fig. 4.18 Flex size and real size

Table 4.1 The real size of group

Group	Percentage size		Real size in surface1		Real size in surface2	
	Width	Height	Width(m)	Height(m)	Width(m)	Height(m)
Bags group	80%	80%	0.8	1.2	0.8	0.8
SHoes group	40%	50%	0.4	1.5	0.4	1.5
Belts group	40%	50%	0.4	1.0	0.4	1.0

define a group layout structure like the Fig. 4.19 shows. The actual size of this structure on different planes is shown in Table 4.1.

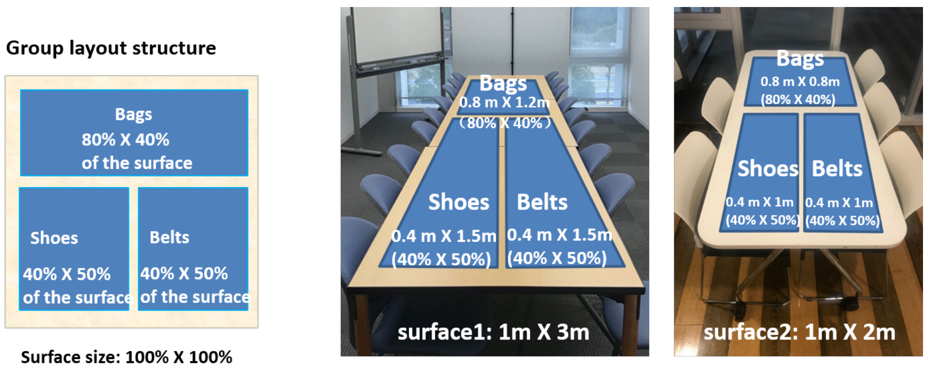


Fig. 4.19 Same layout structure in different surfaces

It's not enough, A fixed structure may not be suitable for all surfaces. For example, like the Fig. 4.20 shows, because the width of surface3 is very small. So if we use this layout structure, we may not have enough width to place any items.

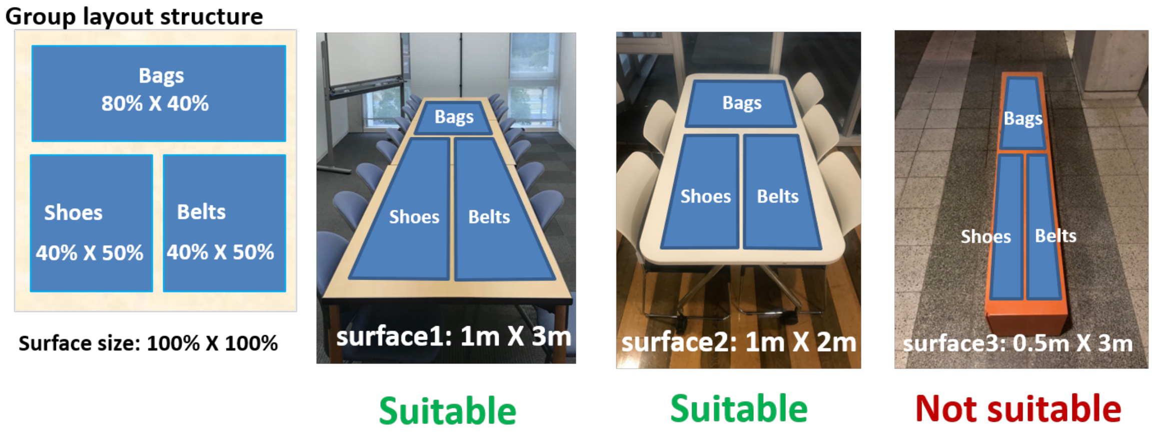


Fig. 4.20 A fixed structure may not be suitable for all surfaces

How to solve this problem. My solution is to allow store designers to give multiple sets of structures and specify their size range. In different surfaces, We'll use the related structure to generate the layout.

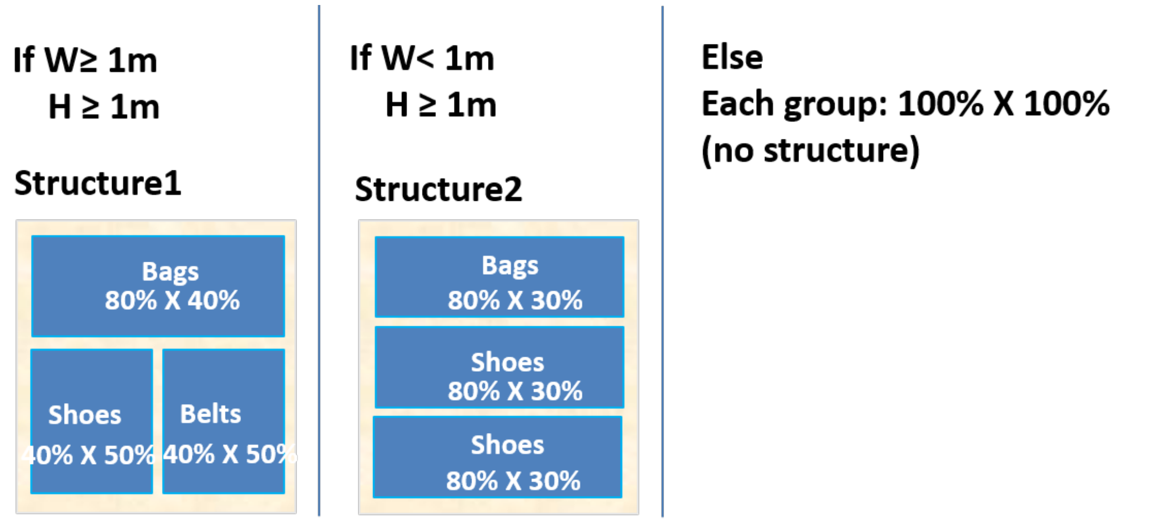


Fig. 4.21 Multiple sets of structures

Store designers can give multiple sets of structures and specify their size range. In different surfaces, We'll use the related structure to generate the layout. For example. If I put these three groups on the surface 1, we'll use the structure1 while we put them to surface 2, use structure2.

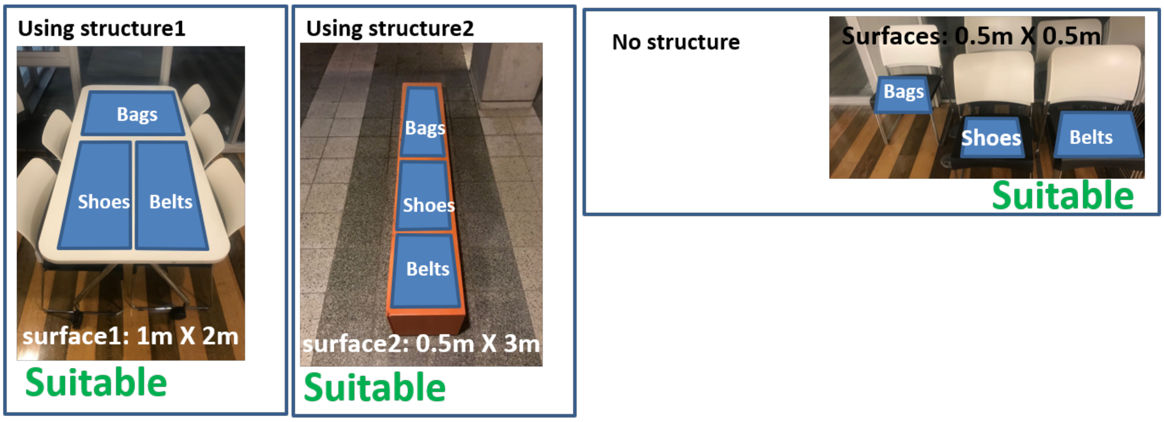


Fig. 4.22 Different layout structures in different surfaces

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

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.

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.

   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.

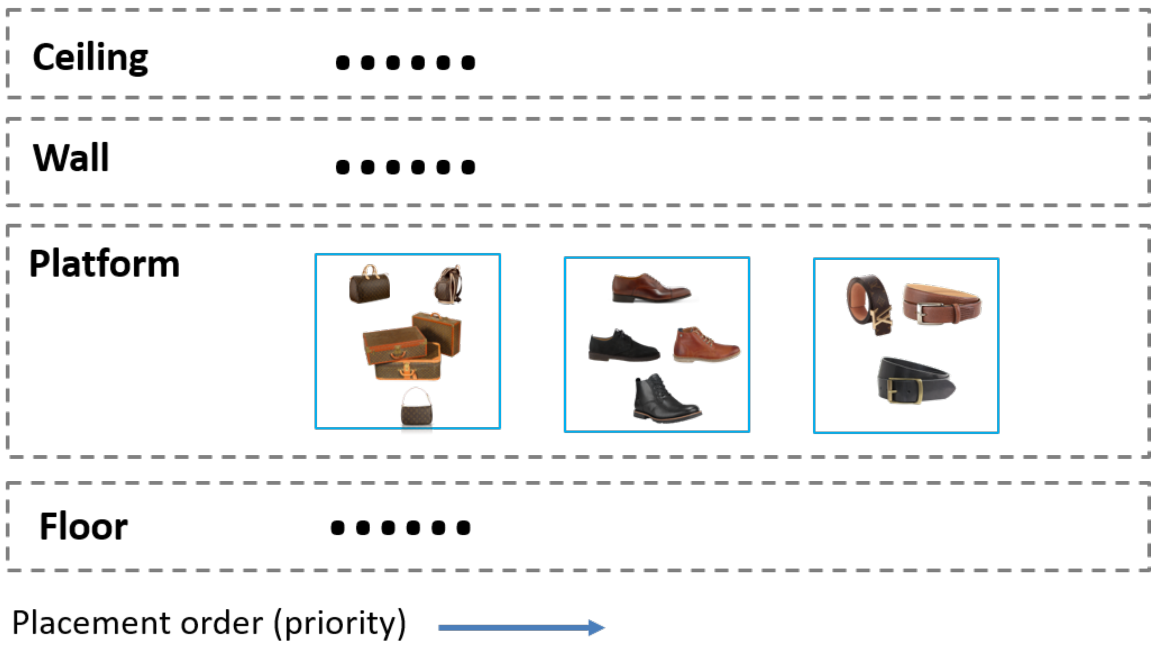


Fig. 4.23 Arrange shop items groups into an ordered sequence

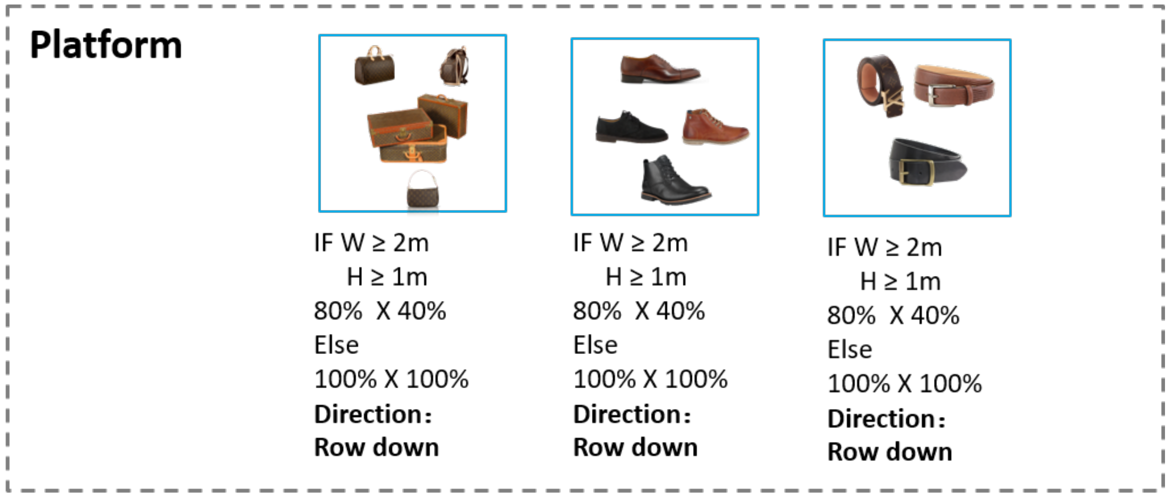


Fig. 4.24 Describe multiple sets of layout structures

4.4 Interaction With Mixed Reality Shop

In order to give users a more immersive shopping experience after getting a design based on the current space, we simulated several interactions that often occur in real stores. Designed an interactive system for mixed reality stores.

4.4.1 Spatial Sound

Many studies have shown that in the store system, sound feedback may affect the consumer's shopping experience.[16]. Background music is an important symbol of brand culture, and different background music highlights different shopping environments[17]. 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.

4.4.2 Virtual Store Employee

In the physical store, interaction with the clerk 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.[18, 19]. After getting the designed shop. The user can use voice commands to communicate with the virtual store employee [20].

1. I want to visit the Prada shop.

2. Introduce this product.

3. What's the price of the product? I'll take it.

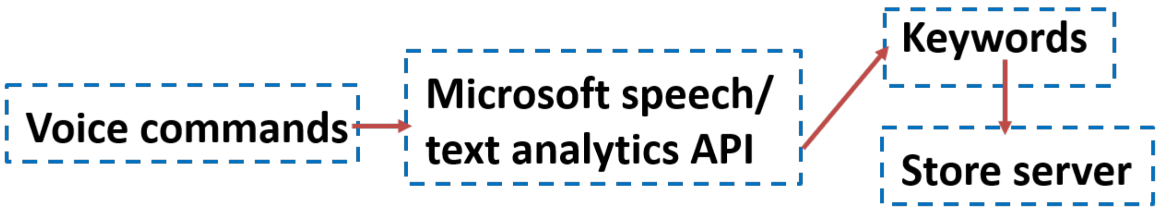


Fig. 4.25 Voice command conversion process

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.

4.4.3 Virtual Product Manipulation

The user can also use two-hand manipulation gesture to move or rotate virtual 3d objects. We use cameras of Hololens to detect the users gestures, then use the mixed-reality toolkit to achieve rotate and move operations [21].

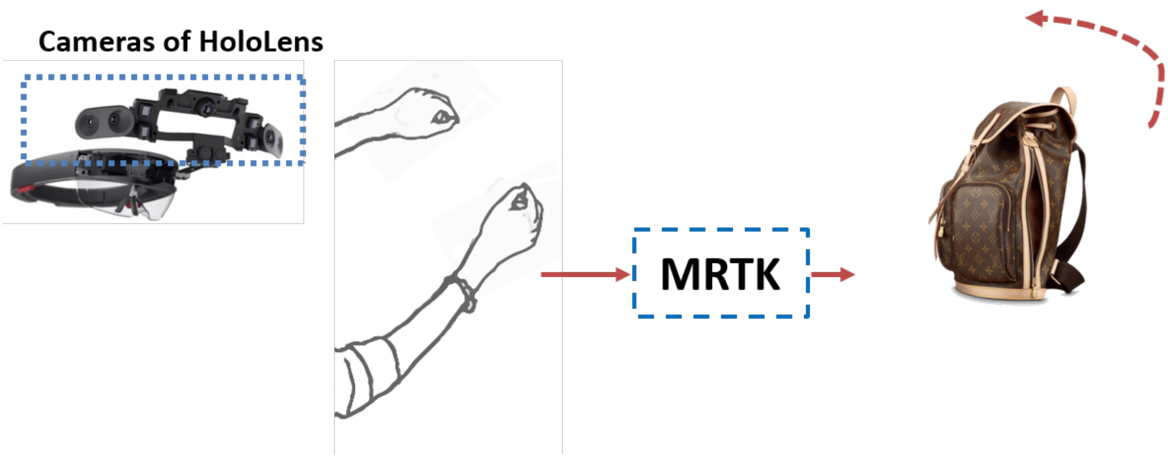


Fig. 4.26 Two-hand manipulation gesture

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.

Chapter 5

System Implementation

5.1 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.

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

Fig. 5.1 See-through type head-mounted display

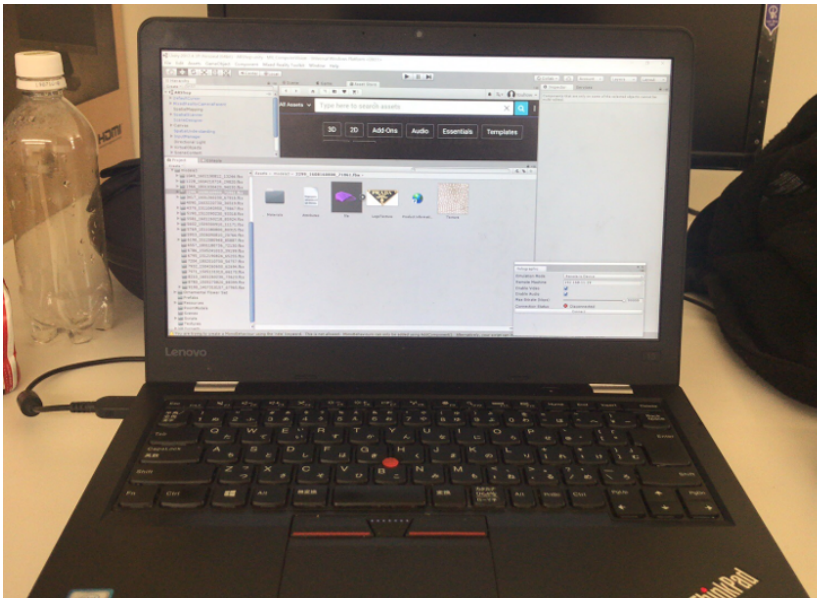


Fig. 5.2 Laptop as the shop server

5.2 Development Environment

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).

To make a 3D environment and build it to Hololens, I use Unity 2017, and Visual studio 2017.

5.3 Graphical User Interface For Shop Designer

As the Fig. 5.3 showss, 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, 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.

5.4 Store Database

To store the shop items and the placement layout preference, we design a database contains several entities, including surface, understood surface, decoration, product, group, shop etc. In this section, we will describe the details of entities and the relationship between them.

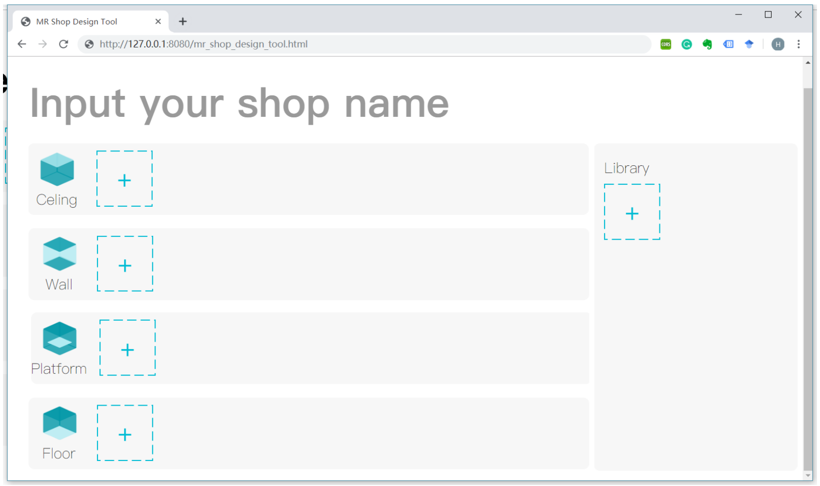


Fig. 5.3 Graphical user interface for shop designer

5.4.1 Entities

1) surface The surface entity refers to the Raw data obtained by the depth camera. Table 5.1 shows that this entity stores the information including surface's ID, the x-axis, y-axis, and z-axis coordinates of the four points in the surface range can be determined.

2) Understood_surface The Understood_surface entity is the surface data after filtering and grouping by the surface understanding algorithm. Table **??** shows that this entity stores

Name	Type	Description
ID	LONG	The unique ID of the surface.
Size	DOUBLE	The area of the surface rectangle.
LeftTop_point_x	DOUBLE	The x-axis data at left top point.
LeftTop_point_y	DOUBLE	The y-axis data at left top point.
LeftTop_point_z	DOUBLE	The x-axis data at left top point.
RightTop_point_x	DOUBLE	The x-axis data at right top point.
RightTop_point_y	DOUBLE	The y-axis data at right top point.
RightTop_point_z	DOUBLE	The z-axis data at right top point.
RightBottom_point_x	DOUBLE	The x-axis data at right bottom point.
RightBottom_point_y	DOUBLE	The y-axis data at right bottom point.
RightBottom_point_z	DOUBLE	The z-axis data at right bottom point.
LeftBottom_point_x	DOUBLE	The x-axis data at left bottom point.
LeftBottom_point_y	DOUBLE	The y-axis data at left bottom point.
LeftBottom_point_z	DOUBLE	The z-axis data at left bottom point.

Table 5.1 Surface table

Name	Type	Description
ID	LONG	The unique ID of the Understood surface.
Type	VARCHAR	The type of the understood surface, including ceiling, wall, platform and floor.
Size	DOUBLE	The area of the surface rectangle.
LeftTop_point_x	DOUBLE	The x-axis data at left top point.
LeftTop_point_y	DOUBLE	The y-axis data at left top point.
LeftTop_point_z	DOUBLE	The x-axis data at left top point.
RightTop_point_x	DOUBLE	The x-axis data at right top point.
RightTop_point_y	DOUBLE	The y-axis data at right top point.
RightTop_point_z	DOUBLE	The z-axis data at right top point.
RightBottom_point_x	DOUBLE	The x-axis data at right bottom point.
RightBottom_point_y	DOUBLE	The y-axis data at right bottom point.
RightBottom_point_z	DOUBLE	The z-axis data at right bottom point.
LeftBottom_point_x	DOUBLE	The x-axis data at left bottom point.
LeftBottom_point_y	DOUBLE	The y-axis data at left bottom point.
LeftBottom_point_z	DOUBLE	The z-axis data at left bottom point.

Table 5.2 Understood surface table

understood surface's ID, type, the x-axis, y-axis, and z-axis coordinates of the four points in the surface range can be determined.

3) Decoration The Decoration item of mixed realiy shop. Table 5.3 shows this entity decoration's ID, Name, sID, 3D model and size.

4) Product The Product entity is the Product item of mixed reality shop. Table 5.4 shows that this entity stores Product's ID, sID, name, type, price value and the introduction of the product.

Name	Type	Description
ID	LONG	The unique ID of the decoration.
Name	VARCHAR	The filename of the decoration.
sID	LONG	The ID of the shop which the decoration is belonged to.
3D model	BLOB	The byte array of the decoration's 3D model.

Table 5.3 Decoration table

Name	Type	Description
ID	LONG	The unique ID of the product.
Name	VARCHAR	The name of the product.
Type	VARCHAR	The type of the product.
Price	DOUBLE	The price of the product.
Introduction	DOUBLE	The start time of the activity.
sID	LONG	The ID of the shop which the product is belonged to.

Table 5.4 Product Product

Name	Type	Description
pID	LONG	The unique ID of the shop item.
mID	LONG	The unique ID of the item's 3D model.

Table 5.5 Item_model table

5) Item_model The Item_model stores the relationship between shop items (includes decoration and product) and its 3D model. Table 5.5 shows that each column stores the item's unique ID and contained 3D model's unique ID.

6) Group The group entity stores group's ID and layout preference information, as shown in Table 5.6.

7) Shop The shop entity stores shop's account information, as shown in Table **??**.

8) Layout preference The layout preference entity refers to the layout preference of a mixed reality shop. Table 5.7 shows that each column stores the group's unique ID.

5.4.2 Relationship

//todo

Name	Type	Description
ID	LONG	The unique ID of the group.
Name	VARCHAR	Group's name.
Preference	VARCHAR	Group's layput preference.

Table 5.6 Group table

Name	Type	Description
sID	LONG	The ID of the shop.
gID	LONG	The ID of the group which the shop liked.
isChecked	BOOLEAN	Whether the feedback is checked.

Table 5.7 Preference table

5.5 Voice Command

In order to provide users with a more natural approach [22]. 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 [4, 5]. 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.

//todo

5.6 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.

Name	Type	Description
sID	LONG	The ID of the shop.
is	BOOLEAN	Whether the shop relationship between these two shops.

Table 5.8 Shop table

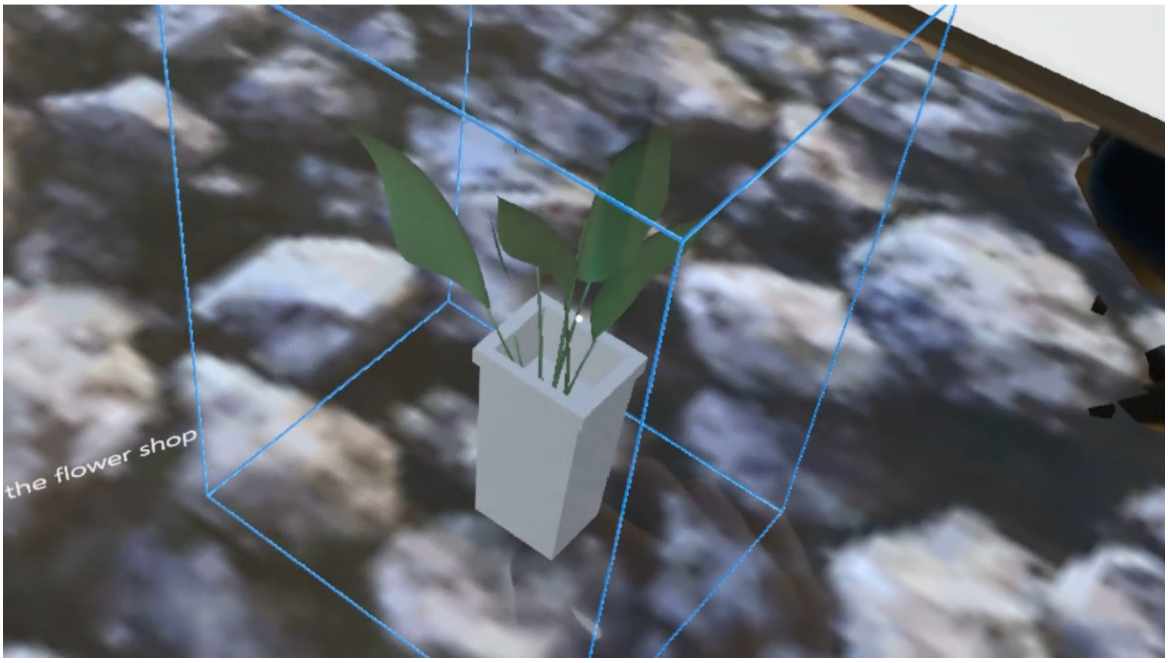


Fig. 5.4 Two-hand manipulation

Chapter 6

Related Work

6.1 Related Works on Online and In-store Shopping

In this study, we compared the advantages and disadvantages of online shopping and in-store shopping and combine these advantages in the mixed-reality shopping system. For physical stores, many studies have shown the importance of in-store characteristics for users to shop.

6.1.1 In-store Characteristics

Most studies have shown that consumers often look for hedonic properties in a store environment and are keen on shopping experiences [23, 24]. Personality such as gender, shopping enjoyment also motivates consumers to choose in-store purchases [25, 26]. Consumers like the shopping experience and don't think it's a chore [27, 28]. They see it as an entertainment process and enjoy pleasure and enjoyment [29]. This is especially true for in-store shoppers [26]. The in-store experience is seen as an information gathering exercise, and sensory stimulation is seen as an important part of the search process. Entertainment is another key factor driving in-store purchases. In-store shoppers who participate in window shopping do not necessarily need pre-planned shopping intentions. Attractive retail displays also motivate consumers to browse and stimulate purchases [30].

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 [31]. Consumers expect social interaction with other consumers, friends or family members in the store. Social networking enhances creative shopping by facing live visualizations of new or unknown products. Personalized one-to-one customer service also has a positive attitude towards retail stores [32]. Warm greetings from customer service representatives, personalized attention, promotional offers and product knowledge from salespeople increase consumer loyalty to the store [33].

6.1.2 Online shopping

Unlike offline stores, shopping convenience is a major factor driving online shopping. The entire process is completed from the home or workplace, so the user can save the shopping time. Rich product details, reviews and delivery facilities are another aspect of online shopping convenience [34]. Other benefits include ease of tracking and lightening salespeople or crowded shopping environments. Convenience is one of the main factors that motivate consumers to shop online. Online protection time and psychological resources are more than physical stores. A wider range of product choices, faster checkout and delivery facilities provide a convenient shopping experience. Reduced search costs due to information availability and price comparisons are convenient factors [35].

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.

6.2 Related Works on Responsive layout

6.2.1 Placer and Packer Algorithms

a 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 [36].

Placer is the most simplistic geometry manager and is used typically in specialized applications. Slave widgets are placed by the manager precisely where specified by the place Command options; there are no special algorithms applied to the layout. It is simplistic because it does very little work, putting the onus on the application to manage the layout. The placer should be used only in situations where the gridder or packer cannot perform the required layout. The placer does provide a relative placement option, which gives a "rubber sheet" effect to the slave widgets. Slave windows managed by the placer do not affect other slave geometries as is the case in other geometry managers, nor is size information propagated to the master. Placement is controlled by an exact location (-x, -y) and by an exact size (-width, -height) and is a position within the master window, or relative placement may be used where the location (-relx, -rely) and size (-rolwidth, -relheight) are specified as floating-point numbers relative to the master. The placer is simple, but it's not powerful enough, each slave placed individually relative to its master [37].

Packer is also one of Tk's geometry management mechanism. The Geometry Manager is used to specify the location of multiple widgets relative to the container that contains each widget-a common master. Unlike the somewhat unwieldy placer, the packer is a qualitative relationship specifier-above, to the left of, filling, etc. It receives-and makes all the exact placement coordinate determinations.

The size of any master widget is determined by the size of the internal "slave widget". The packer is used to control where the slave widget is placed in the master widget ahead of the pack. To achieve the layout you want, you can pack the widget into a frame and pack that frame into another frame. Furthermore, once packing is performed, the arrangement will be adjusted dynamically according to the subsequent configuration changes. The packer is more powerful than the placer. it arranges groups of slaves together (packing list). Packs slaves around edges of master's cavity [37].

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.

6.2.2 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 1024×768 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 [38] is an attempt to solve this problem. It's core concept is "flexible layout".

Flexible grids are created by using percentage (a relative unit) instead of pixel (an absolute unit) [39]. Media queries make it possible to apply different cascading style sheets (CSS) depending on the media type and the maximum width of the device screen. With cascading style sheets, one can control images and other fixed-width elements so that they stay contained in their container blocks (see table 4.1). 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.

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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.

Chapter 7

Preliminary Evaluation

In this section, we introduce our preliminary user research and results analysis. 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. We will also discuss the received feedback from a questionnaire.

7.1 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.

7.2 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 as shown in Figure 7.1. 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.

7.3 Result

Question 1, 2 and 3 are used to test the ease of use and usability of the system. m. They mainly concern whether it's easy to use the controller to interact with 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 gestures 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 shows 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

QUESTIONNAIRE

Name: Age: Gender: Date:

QUESTIONS

The questions are based on 5-point scale.

Answer the following questions by circling the most appropriate answer

1. **The system is easy to use.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

2. **The interaction with virtual store employee is useful or interesting.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

3. **The gestures interaction is useful or interesting.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

4. **I can easily find products of interest in the mixed-reality shop.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

5. **I can easily understand the details of the products in the mixed-reality shop.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

6. **I can feel the brand characteristics in the mixed-reality shop.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

7. **The system can provide a good shopping experience.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   How could the system be improved?

Fig. 7.1 Questionnaire

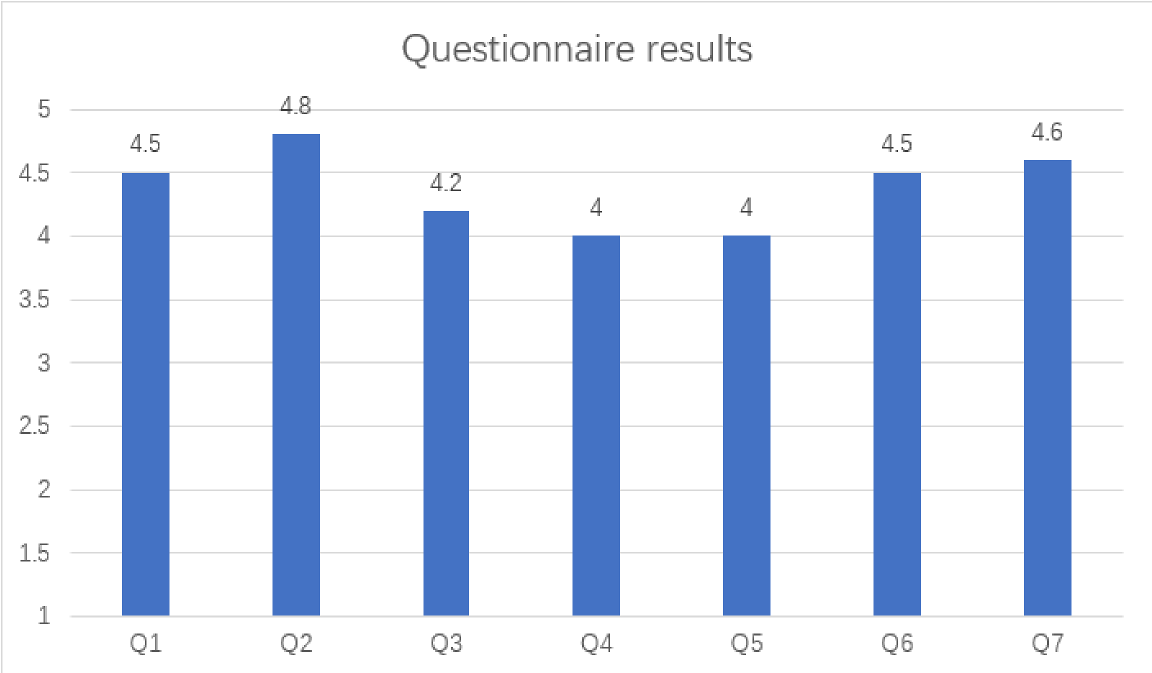

Fig. 7.2 Questionnaire results

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.

Chapter 8

Conclusion and Future Work

8.1 Conclusion

In terms of design, 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 understood planes. 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 mechanism, 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.

In order to test the usability and efficiency of our proposed system, we have included some participates in our evaluation. The feedback is positive.

8.2 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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