

# Rethinking the Fashion Show: A Personal Daily Life Show Using Augmented Reality

Shihui Xu<sup>1</sup>, Yuhan Liu<sup>1</sup>, Yuzhao Liu<sup>1</sup>, Kelvin Cheng<sup>2</sup>, Soh Masuko<sup>2</sup>, and Jiro Tanaka<sup>1</sup>

<sup>1</sup> Waseda University, Kitakyushu, Japan

<sup>2</sup> Rakuten Institute of Technology, Rakuten, Inc., Tokyo, Japan

e-mail: shxu@toki.waseda.jp, liuyuhan-op@akane.waseda.jp, liuyuzhao131@akane.waseda.jp,  
kelvin.cheng@rakuten.com, so.masuko@rakuten.com, jiro@aoni.waseda.jp

**Abstract**—At present, most fashion shows are professional and exclusive in nature and are not easily accessible to the general public. Ordinary people are usually excluded from these events and have few chances to participate in fashion shows in their daily lives. In addition, setting up a fashion show can be frustrating because the garments for fashion shows are often specially designed and difficult to obtain for ordinary people. In this paper, we attempt to rethink the design of fashion shows and discuss how future fashion show could be redesigned. We proposed an Augmented Reality (AR) personal daily life show, which enables users to virtually attend a fashion show that is customized for themselves, and in their own environment. Personalized avatar is created for each user as a virtual fashion model in the fashion show. Furthermore, the avatar is enhanced with animations and can interact with physical objects in the real environment. We have conducted an evaluation and results show that such personal daily life show can improve user’s experience and narrow the gap between apparel show and user’s own life.

**Keywords**—*fashion show; Augmented Reality; personalized fashion.*

## I. INTRODUCTION

Fashion show is a crucial part of the fashion industry and is defined as a showcase, presenting fashion designers' new collections of clothes and accessories to audiences of consumers, buyers, journalists, influencers, etc. [1]-[3]. The purpose of the fashion show is not only to exhibit fashion designers' collections to the public, but also to include its practicality as a distribution channel [1][4]. Since the first modern fashion show at Ehrich Brothers, New York City in 1903, fashion shows have been adopted by upscale fashion brands as promotional events [3].

Although fashion shows have superiority in distribution channel and advertising, they have their limitations. Firstly, consumers cannot participate at fashion shows themselves. Clothing is an involved product category, it is difficult to evaluate, and needs to be seen in person and tried on because it is highly related to personal ego [5]. Considering the purpose of fashion show is to present clothing to consumers, it is crucial to include general consumers in fashion shows so that they could see the clothing by themselves. Second, there is a gap between the current fashion show and daily life of

the consumers. Current fashion shows prefer catwalks to showcase the apparels, which require specially built stages and are rarely seen in consumer’s daily life. In addition, apparels of fashion show are not widely applicable for general consumers. So that general consumers can hardly benefit from the current fashion show.

Recently, fashion show has incorporated technologies such as Augmented Reality (AR) and Mixed Reality (MR), attracting the attention of more audiences. For example, UK wireless company Three teamed up with designers to show off a fashion show augmented with 3D special effects through network and AR head-mounted display at 2019 London Fashion Week [6][7].

However, these technologies are applied in merely eye-catching strategies. The essential issue of how to effectively use these technologies to solve the problems of current fashion show to make fashion show a more extensive channel for general consumers has not been explored.

Thus, to bring consumers into a completely new area of fashion show, it is important to rethink the design of fashion show and related technologies for meeting consumers' demands. Therefore, two research questions are proposed. First, how might we redesign the future fashion show? Second, what is the role of AR technology to facilitate consumers' shopping in the future fashion show?

In this paper, we present a novel AR fashion apparels show system named personal daily life show to explore the above questions and to solve the existing problems of current fashion show. The novelties of the personal daily life show are:

1. Generation of life-sized personalized 3-dimensional human avatar of the user self.
2. 3D apparel modeling from 2D shopping website images.
3. Interaction of the personalized virtual avatar with the real physical environment.

The contributions of this work include:

1. The conceptual design and a proof-of-concept prototype implementation of personal daily life show.
2. Quantitative and qualitative evaluation of personal daily life show and how it is effective in narrowing the gap between fashion show and user’s own life.

The rest of this paper is organized as follows. Section II describes the related works on which our work is built. Section III describes the concept, design features and usage scenario of personal daily life show. Section IV goes into finer details with respect to the implementation of personal daily life show. Section V introduces the evaluation. Section VI gives the discussion of this work. The conclusions close the article.

## II. RELATED WORKS

We have examined related works in terms of the AR and MR technologies in fashion industry and virtual avatar in fashion show.

### A. AR/MR Technologies in Fashion

In fashion industry, the use of AR and MR technologies can be used to narrow the gap between online and brick-and-mortar shopping experience [8]. For example, Virtual try-on system provides virtual garments trial experience for consumers through AR and VR technologies, overcoming the lack of fitting experience of online shopping [9]. The apparel company Gap created an app called DressingRoom [10], which allows customers to virtually try on clothing on a dummy human model through a smartphone. Combining 3D modeling technologies, the London College of Fashion has created an app named Pictofit [11], adopting virtual avatar of the users and enabling users to browse clothes with their own avatar in AR environment. In contrast with DressingRoom, in Pictofit consumers can use their own avatar to try on clothing, undergoing mental simulation of the fitting with the garments during the process, leading vivid mental imagery and high purchase intention. However, both DressingRoom and Pictofit are limited to the virtual static human model, lacking dynamic view of clothing try-on. Users can only see the standing virtual model, with no interaction other than changing clothes.

The use of see-through type head-mounted displays (HMDs) with AR technology enables a more intuitive and immersive shopping experience compared to conventional e-commerce systems. With spatial computing, AR has the potential to provide a sensory and immersive virtual boutique shopping experience wherever the user is. For example, H&Moschino and Warpin [12] created a virtual fashion shop using MR head-mounted display, where users were able to watch 3D videos and sounds surrounding different garments. Portal is an AR fashion show application launched by MESON [13], making it possible to watch a brand's new seasonal items fitted with hundreds of 3D virtual human models in real-world through smartphone, tablet or AR glasses. But Portal adopts professional models instead of consumers themselves, causing a low correlation with consumers. In addition, the models in Portal is static and clothes could not be changed.

### B. Avatar in Fashion Show

Previous research has investigated the design and development of avatar in AR and VR system. Avatars have been widely used in most virtual worlds and games. An avatar represents a user self and it allows the user to

experience the virtual world by manipulating the avatar [14][15].

In this paper, we mainly focus on how people perceive their avatars in fashion show related system. For instance, Stephen Gray proposed a VR fashion show in which users can have a virtual model of the same shape as their own bodies [16]. The avatar can be fitted with virtual clothing and walk catwalks in a virtual environment. However, the avatar can only reflect the body shape of the user, without the face features of the user. Besides, the interactivity is limited. Users can only watch the performance of their avatar. Recently, virtual avatars have appeared in real-world fashion show using projection an AR technology. Central Saint Martins and Three launched a fashion show where a 3D life-size avatar of a famous model could walk in AR on the runway at 2020 London Fashion Week [17]. The audiences can watch the catwalks of virtual avatar by smartphone. In this system, the avatar is embedded with the motion capture animations of model self. But it is generated by professional and expensive setup, so that there is only one avatar and one dress available.

## III. PERSONAL DAILY LIFE SHOW

This section describes the concept and design of personal daily life show and the scenario of its usage.

### A. Concept

One of our major design decisions was to not design for a runway catwalk fashion show. Instead, we focus on closing the gap between fashion show and the general consumers, bringing the fashion show into users' life and displaying the lifestyle of users. While we agreed that the runway catwalk fashion show has great commercial value for fashion industry, we decide to design a fashion show from which consumers can directly benefit. In our concept, we focused on making the fashion show available for users anywhere in their life, which means users can experience a fashion show in their real environment.

Another major design decision was to let the user participate in the show instead of just being an audience. In order to allow users to see their own performances while participating in the show, we adopted users' personalized avatar as the show model. We think it is important to allow users to engage with the show, which could increase the engagement and enjoyment of users.

Based on above decisions, we defined the personal daily life show enabling general consumers to watch the fashion apparels on their own life-sized personalized avatar, which is overlaid on user's real environment and can interact with the real environment using AR technology. Furthermore, instead of having models only walking and posing, as in current fashion shows, our personalized avatar can perform human-like daily activities, such as walking around in the real-world, and interacting with real-world objects. A main consideration for the design of personal daily life show was to depict the scene of user's daily life, increasing the self-relevance of users during the show experience and facilitating consumers to imagine themselves fitted with fashion apparels in their own life.

### B. Design

Based on the concept proposed above, we designed a proof-of-concept prototype of personal daily life show for further investigation. Figure 1 shows the pipeline of the personal daily life show.

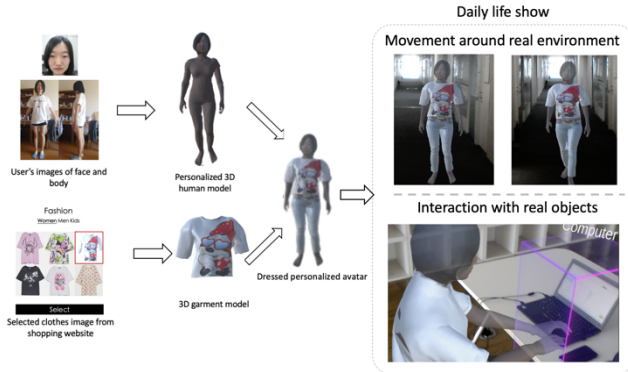


Figure 1. Pipeline of personal daily life show

The novelties and features of personal daily life show include the following items.

1) *Adopting users' personalized avatar as models in the show.*

In order to create a fashion show with the user, while enabling the user to watch the show at the same time, we propose to make a life-sized personalized avatar for each user and adopt the user's personalized avatar as the model of the fashion show. Thereby, users can watch the fashion apparels exhibited on their own personalized avatar and get the imagery of trying on the apparels on themselves. The personalized avatar is customized according to photos of user's body and facial appearance.

2) *Providing virtual 3D apparel models based on 2D apparel images from shopping website.*

The apparels of fashion show are usually difficult to obtain and purchase. To solve this problem, we provide users with 3D virtual apparels so that they could virtually fit the apparels on their personalized avatar. In addition, the 3D virtual apparels are generated according to the 2D apparels images from online shopping websites. In this way, users can easily purchase the apparels that appears in the fashion show. Besides, if they are satisfied with the apparel, they can purchase it using online shopping.

3) *Enabling user's personalized avatar to interact with real environment using AR technology.*

To close the gap between fashion show and user's daily life, we made use of AR technology to visualize and superimpose the personalized avatar in user's real environment. And users can make the user's personalized avatar interact with the real environment, such as walking and doing daily activities like a real person. By doing so, we intend to simulate the daily life of the user, giving user a fashion show experience that is associated with their own life and providing the user further information about how they will look like in their daily life.

### C. Scenario

We propose a usage scenario illustrating how the personal daily life show can benefit the general consumers when online apparels shopping. And at the same time, users can also browse the clothes of online shopping website in a more intuitive and engaged way by the personal daily life show system.

When the user uses the system for the first time, before the user starts shopping on the apparels website, she can upload the images of her face and body to create a personalized avatar which reflects the face appearance and body shape of the user.

The user can then browse the shopping website of apparels to select the clothes she wants to view. Our system will generate the 3D model of the clothes selected by the user. Next, our system will provide a personalized avatar of herself fitted with the 3D clothes model to the user.

By wearing a see-through type AR head-mounted display (HMD) with a depth camera, users can launch the show where they are. Once the show is launched, the real-world environment of the user will be mapped by the HMD using the built-in depth camera. After that user can see the life-sized personalized avatar of herself superimposed onto the real environment through the HMD.

The user can interact with the system to make the personalized avatar interact with the real environment, similar to what a real person would do in their daily activities.

## IV. IMPLEMENTATION

In this section, the implementation details of the personal daily life show will be described. The implementation contains the hardware, development environment, pre-processing and daily life show.

### A. Hardware

The prototype system was built with a see-through type AR HMD, Microsoft HoloLens, with a 2GB CPU embedded [18]. HoloLens features four "environment understanding" sensors, a depth camera with a 120 \* 120-degree angle of view, which is used for computing the real-world meshes in our system.

### B. Development Environment

The software was developed using the Unity 3D game engine (2017.4). And a cross-platform toolkit for building Mixed Reality experiences for Virtual Reality (VR) and Augmented Reality (AR), MRTK, was used for building the application. This framework allowed us to rapidly prototype the personal daily life show system that supports spatial awareness and various interaction cues.

### C. Pre-processing

After the pre-processing, a dressed personalized avatar with motions embedded will be available, which can be used in the fashion show as an apparel model.

1) *Generation of personalized avatar*

Figure 2 shows the process of the personalized avatar generation.

Our approach to generate the personalized avatar is to model the user's face and body separately and combine the two parts together. For the face modeling, our approach only uses a single frontal image of the user's face. By making use of existing face modeling technology, Avatar SDK [19], the photorealistic face model can be generated.

With body modeling, a front image and a side image of the user's body are required to build a body model of the user. By uploading the body images to 3DLOOK [20], the body model of the user can be generated.

The face model and body model are combined by replacing the head part of generated body model with the face model. This is done in a 3D modeling software.

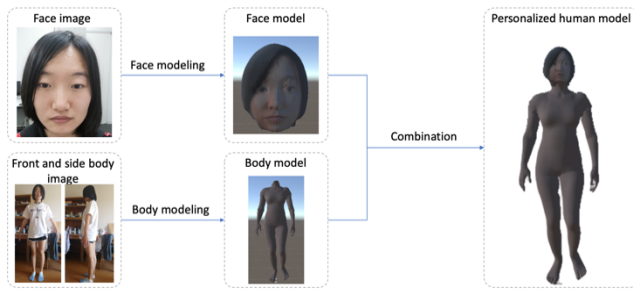


Figure 2. Generation of personalized avatar

2) Generation of 3D apparel model

Methods used to generate garment models from images are widely used in virtual try-on systems. Our aim is to handle the clothe images from online apparel shopping websites. However, it is difficult to process all the images on such large collections. Therefore, we focused on dealing with simple clothes images that have a unique or similar background color.

Our approach to generate garment model is to create 3D garment templates for each personalized avatar and map the 2D garment images to the garment templates, which are created from online apparel websites. The 3D garment templates are created for each personalized avatar using Cloth Weaver. The 2D garment images are then mapped onto the generated 3D garment model templates in 3ds Max. In doing so, 3D garment models can be created that matches online shopping website images.

3) Fitting apparel model to personalized avatar

With the generated 3D garment model, we fitted the garment model to user's personalized avatar by adjust the size and position of the 3D garment model within 3ds Max, which result in a dressed personalized avatar.

4) Attaching motions to personalized avatar

By embedding motions to the personalized avatar of users, they can be animated to mimic how we would normal move about in our daily activities. In order to embed motions to the personalized avatar, the personalized 3D avatar is rigged as a humanoid. We then select motion capture animations that mimics human actions, and attach them to the rigged personalized avatar.

a) Motion capture animations

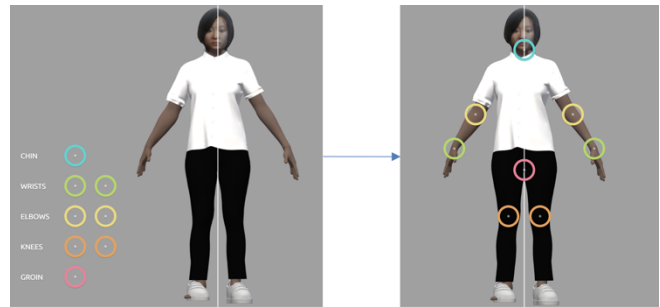
Motion capture animations are the animation clips which record the movement of people or objects, widely used in games and movies. To make the personalized avatar act naturally and closer to real life, we chose to prepare motion capture animations that can reflect human's daily activities, such as sitting, walking, and standing.

The motion capture animations used in our system were sourced from Mixamo [21].

b) Rigging of Personalized Avatar

Rigging is the process of creating a skeleton for a 3D model so it can animate. Before the motion capture animations can be used, the personalized avatar need to be rigged.

The rigging process can be done in a 3D modeling software like 3ds Max or Maya, but it is time consuming using this method. Auto-rig software is currently available, which enables users to rig a 3D character by assigning several joints. We used the auto-rig function of Mixamo to rig the personalized avatar in our system, as the Figure 3 shows. By aligning several joints (i.e., chin, two elbows, two wrists, two knees and groin) to the 3D personalized avatar, Mixamo will help do the rigging process automatically. We can also choose different levels of skeleton details to optimize the performance of our personalized avatar.



Upload the model to Mixamo

Assign joint points

Figure 3. Rigging of the personalized avatar

c) Attaching the motion capture animation to rigged personalized avatar.

After rigging, we attached the prepared motion capture animation to the personalized avatar via Unity Animator Controller, which allows humanoid models to utilize multiple kinds of motion capture animations. Figure 4 shows a few examples of personalized avatar with various kinds of motions.

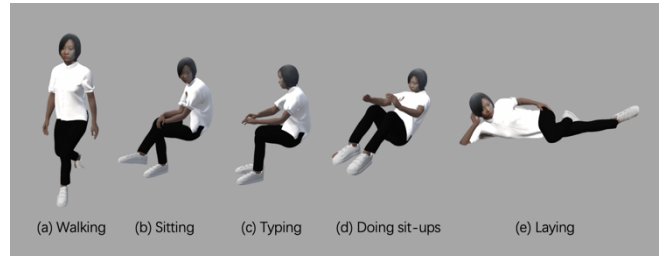


Figure 4. Personalized avatar with motions

### D. Daily Life Show

The implementation of daily life show includes the avatar’s movement around the real environment and avatar’s interaction with real objects.

#### 1) Movement around the real environment

In this section, the implementation of the avatar’s movement around the real environment is explained. As shown in Figure 5, the implementation of avatar’s movement includes specifying the destination, calculation of distance between avatar and destination, and avatar’s response to the environment (walking or standing).

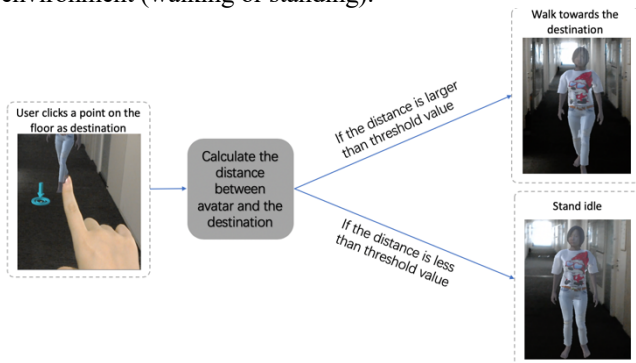


Figure 5. Avatar’s movement around the real environment

#### a) Specifying the destination

The movement of avatar is triggered by user’s specifying a destination on the floor by performing an “air-tap”. “Air-tap” is a built-in gesture provided by HoloLens, which refers to straightening the index finger and then tapping down. The users can gaze on the floor and make an “air tap” gesture towards the floor. A virtual arrow will then appear as the indicator of destination of the movement.

#### b) Calculation of distance between avatar and destination

We calculate the distance between the avatar’s current position and the destination at every frame. The calculation is done by updating the position information of the avatar.

#### c) Response of avatar

If the distance between avatar and destination is larger than the pre-determined threshold value, which means the avatar need to move, we set the motion of the avatar to be “walking” motion. This is one of the animations that is already embedded in the avatar in pre-processing, and which sets the avatar in motion towards the destination. In this case, the avatar appears as walking towards the destination.

If the distance between avatar and destination is less than the threshold value, the position of avatar will not be changed. However, the avatar will perform the standing motion, which is also embedded in avatar in pre-processing.

#### 2) Interaction with real objects

The implementation of avatar’s interaction with real objects is illustrated in Figure 6. It consists of specifying real object for interaction, object detection in AR, and avatar’s interaction with real object.

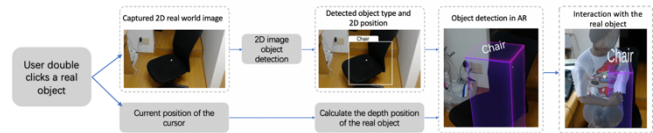


Figure 6. Avatar’s interaction with real objects

#### a) Specifying real object for interaction

Users can specify which real object to interact by “double taps” to trigger the personalized avatar’s interaction with real objects. “Double taps” means performing the “air-tap” gesture twice. The users can make the virtual user interact with real object by gazing at the real objects and performing the “double taps” gesture towards the real object. When the “double taps” gesture is recognized by HoloLens, it captures a screenshot of current view of real world and record the current position of the cursor for next step’s object detection in AR. However, the limitation of “double taps” is that sometimes it will be misidentified as “air-tap” gesture because of the limited recognition speed of HoloLens.

#### b) Object detection in the AR environment.

In this step, we recognize the type of real object to interact with and compute the 3D position of the real object in the AR environment. To recognize the objects in the AR environment, we first recognize the objects’ type by using 2D images object detection model, then calculate the 3D position of real object in AR environment.

Before object detection in runtime, we first train the model used to recognize the objects in 2D images. As a proof of concept, we chose several everyday objects, i.e., chair, bed, sports mat, computer. For each real object, we captured 50 images from multiple perspective as the database to train model. The images were uploaded to Azure Custom Vision and trained on webservice. After training, we can publish the model and can access it through APIs.

At runtime, after user performs double clicks, the captured 2D images of real-world view will be sent to the server for 2D object detection processing using Azure Custom Vision APIs. From this, we can get the type of object and its 2D position in the image. With the recorded 3D cursor position combined with detected 2D position from captured image, we could calculate the 3D position of the real object in AR with depth information through Camera.ViewportPointToRay API. After getting the type and position of the real object in AR, our system could draw a cube with a type label in the AR environment to demonstrate object detection results for the users. For example, Figure 6 shows an example where a chair is detected, in which case a cube with a “chair” label is drawn at the position of the chair.

#### c) Avatar’s interaction with real object.

Knowing the 3D position and type of the real object, the avatar is then able to interact with the real object.

The type of real object that is recognized determines the type of motion that the avatar should perform. Different kinds of real object correspond to different kinds of motion. For instance, chair type objects will trigger the personalized

avatar to do a sitting motion, whereas bed type objects will trigger the personalized avatar to perform a laying down motion. The position of the personalized avatar is determined by the distance between the real object and the current position of the personalized avatar. If this distance is less than a threshold value, the personalized avatar’s position will be unchanged. If the distance is more than the threshold value, we set the position of the personalized avatar to the same position as the real object.

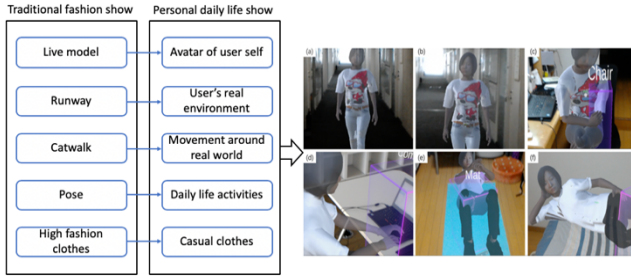


Figure 7. Personal daily life show. (a) Walking in real environment. (b) Standing in real environment. (c) Sitting on a chair. (d) Typing on a computer. (e) Doing sit-ups on a sports mat. (f) Laying on a bed.

With the movement and interaction of avatar, the users can conduct a fashion show in their real environment. Figure 7 shows a system image of personal daily life show. Compared with traditional fashion show, the personal daily life show uses an avatar of the user self rather than a live fashion model. In addition, instead of walking on the catwalks and making poses on the runway, the avatar can move and perform daily activities within user’s physical environment.

V. EVALUATION

To assess our system, we conducted a user study in terms of quantitative and qualitative aspects. As previous work has already verified that the personalized avatar has positive effect on user’s evaluation towards shopping experience, we will not re-evaluate personalized avatar redundantly. Instead, we are interested in evaluating the impact of interactivity of virtual avatar in AR fashion show system.

A. Experimental Design

The experiment follows a one-factorial design. In this case, our independent variable is the interactivity level of personalized avatar of user: static, in-situ animated and real-world-interactive. The conditions are:

1. Static personalized avatar: users can watch a static standing personalized avatar of themselves.
2. In-situ animated personalized avatar: the personalized avatar can make different animations on the same spot in front of the user, such as walking, sitting, typing, doing sit-ups. User can change the animation of personalized avatar.
3. Real-world-interactive personalized avatar: the personalized avatar can move around the real environment and make interaction with real objects, such as sitting on a chair, typing on a computer, doing sit-ups on a sports mat and so on.

B. Experiment Environment and Set-up

We set up our experiment in an office room with accommodation appliances, including tables, chairs, computers and a sports mat. The area of the room is about 50 square meters.

The device used in the experiment is see-through type head-mounted display HoloLens.

C. Participants

Twelve female students from a graduate school were recruited in the experiment. We focused on women participants because previous work [22] had examined women represent the largest apparel segment. All the participants had knowledge about fashion and had purchasing experience online, and 10 out of 12 had AR experience and learnt about human-computer interaction.

D. Task and Procedure

Before the experiment began, to reduce the impact caused by the unfamiliarity of device and hand gestures, each participant was required to be trained to use HoloLens and learn the basic gestures used in HoloLens. After training, each participant was informed about the experiment contents by a short video with explanations.

The experiment was a within-subject design. Each participant was asked to experience the fashion show of the personalized avatar using all three conditions. During each condition, each participant had 10 minutes to browse 20 apparel items. The clothes types were T-shirt, shirt, oversize T-shirt, skirt, tight skirt and pants. Participants were able to browse the next item by clicking on the personalized avatar.

TABLE I. QUESTIONNAIRE FOR QANTITATIVE EVALUATION

No.	Question	
	Aspect	Description
1	Likeness of avatar	I feel the avatar looks like me.
2	Affection to avatar	I like the avatar.
3	Interest	I think the show is interesting.
4	Engagement	I feel engaged in the show.
5	Future application	I would like to use the system in the future.
6	Assistance	I think the system is helpful for viewing apparels.
7	Relevance to real life	I feel the show is close to my life.

To minimize the effect of learning and transfer across treatments, we randomly assigned the test order and apparel items of the 3 conditions for each participant.

During the experiment, participants were asked to report their thoughts and feelings through think-aloud protocol.

After completing all three conditions, each participant was asked to complete a questionnaire to evaluate the three conditions in terms of likeness of the personalized avatar, affection to the personalized avatar, interest, engagement, future application, assistance and relevance to users’ real life

using 7-point Likert scale. The questions are described in Table 1.

Afterwards, participants were interviewed about our system. The whole experiment was captured by voice recording and dictation notes.

**E. Results**

From the experiment, we were able to collect two kinds of data, quantitative data from the questionnaires and qualitative data from the transcriptions of think-aloud sessions and interviews.

We conducted quantitative analysis for the former data and qualitative analysis for the latter data, which are described in detail below.

*1) Result 1: Quantitative Analysis*

In quantitative analysis, we aimed to examine if there was a significant difference between users' evaluation of

TABLE II. RESULTS OF ANOVA

Aspect	ANOVA	
	F-value	p-value
Likeness of avatar	0.084	0.919
Affection to avatar	4.333	0.021*
Interest	10.164	<0.001***
Engagement	16.148	<0.001***
Future application	6.547	0.004**
Assistance	5.481	0.009**
Relevance to real life	8.589	0.001**

each condition and the way in which these differences could be explained. As each participant tested all three conditions (within-subjects design), we analyzed the quantitative data using a one-way repeated measures ANOVA, comparing the effect of each condition on the user experience of the interface. We also conducted a Tukey's HSD test as a post-hoc test for pairwise comparisons.

The one-way ANOVA with repeated measures revealed significant effects of conditions on users' ratings on user experience except for the likeness of avatar. TABLE II shows the results of ANOVA. Based on the results, we further conducted Tukey's HSD test to investigate pairwise comparisons between each condition. The results are visualized in Figure 8. We categorized the results in terms of the main issues below.

*a) There is no significant influence of interactivity on the perceived likeness of the avatar, but the users tend to adore the real-world-interactive avatar (Q1, Q2).*

We tested interactivity level's influence on users' ratings of personalized avatar. From the comparisons, even though participants evaluated that the perceived likeness of the personalized avatar was not related to the interactivity level, we observed that the participants tended to prefer real-world- interactive personalized avatar to the other two

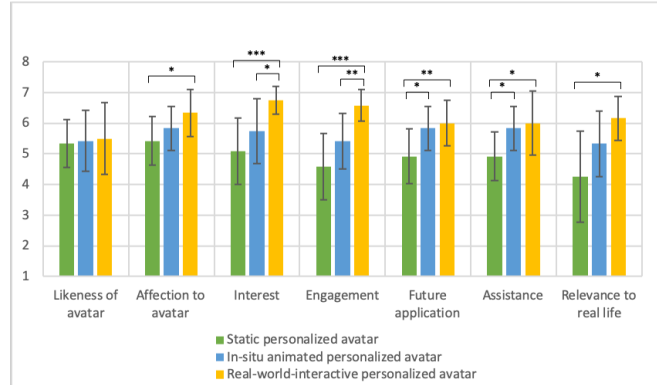


Figure 8. Visualization of quantitative analysis. (\*\*p<0.01, \*\*\*p<0.001, \*p<0.05)

conditions (static personalized avatar and in-situ animated personalized avatar). The received scores of real-world-interactive avatars were significantly higher than static avatar (p = 0.016). The results showed that there was a trend that participants adored the personalized avatar with high interactivity level, especially the real-world-interactive avatar.

*b) Real-world-interaction positively affected participants' interest and engagement (Q3, Q4).*

One of the most interesting results of the analysis was that the user experience of the apparels show could be significantly improved by real-world-interactive personalized avatar, while only adding daily life motions to the personalized avatar was not obviously effective. We evaluated user experience from participants' interest and engagement, with significant differences found in both items. From a post-hoc test, we noticed the condition with real-world-interaction was distinct from the other two conditions. In the case of interest, the real-world-interactive condition showed significantly higher scores than static condition (p < 0.001) and in-situ animated condition (p = 0.029). In the case of engagement, participants felt more engaged in condition with real-world-interactive personalized avatar than static personalized avatar (p < 0.001) and in-situ animated avatar (p = 0.006). Besides, the post-hoc test suggested that participants did not perceive differences between static and in-situ animated conditions in terms of interest (p = 0.188) and engagement (p = 0.062).

*c) Showing apparels using avatar with daily life motions is more helpful and more likely to be chosen for future use (Q5, Q6).*

We also evaluated the effectiveness in terms of assistance and future application. The comparisons revealed that participants inclined to the conditions with motions, whether in-situ animated or real-world-interactive. From the assistance aspect, participants evaluated the condition with static personalized avatar as least helpful, compared with condition with real-world-interactive avatar (p = 0.011) and condition with in-situ animated avatar (p = 0.036). And from the aspect of future application, the post-hoc test showed that participants were more pleased to choose

condition with real-world-interactive avatar ( $p = 0.005$ ) and condition with in-situ animated avatar ( $p = 0.020$ ) for future purchase of apparels than condition with static avatar. There was no significant preference between in-situ animated condition and real-world-interactive condition ( $p = 0.864$ ), and both are likely to be adopted by the participants in the future.

*d) Daily life motions can bring the feelings of participants' own life (Q7).*

We identified that the conditions with real-world-interactions received higher scores in the relevance of participants' own life. The comparisons showed that participants felt the fashion show was significantly closer to their own daily life when the personalized avatars were enabled to interact with the real environment, compared with the static avatar ( $p = 0.001$ ). Even though there is no significant difference between the condition with in-situ animated avatar and the condition with statically standing avatar, the received average score of the former condition was higher than the latter condition. This trend could also imply the daily life motions have a positive influence on user's perception about the relevance of the show and their own life, especially when the daily life motions are companied with interactions with the real-world.

*2) Result 2: Qualitative Analysis*

The qualitative data from the think-aloud sessions and interviews were transcribed and analyzed. In the qualitative analysis, we aimed to investigate the users' thoughts in more depth and discover the hidden characteristics beyond the quantitative analysis. The collated qualitative data is shown in TABLE III.

*a) Avatar's interaction with real environment is important, especially the movement around the real environment.*

As seen in the quantitative analysis, we also verified the importance of enabling avatar to interact with the real world in the qualitative analysis. Participants said that the personalized avatars' interactions with real environment provided imagery of their own daily activities. For example, P8 said, "Looking my avatar walking around the room makes feel like walking by myself." P2 also mentioned, "My avatar is typing on my computer, just like that I usually do in my office." Making the avatar move around freely in the real environment is crucial because it could facilitate users to view avatar's performance from different perspectives without having to move. P7 said, "I could imagine myself walking back and forth when instructing my avatar to walk. But I do not need to actually move at all." P11 also said, "With the movement of avatar, I can observe the apparels from different degrees of view while just standing still at a point."

*b) Users enjoy engaging with the show, rather than just watching the show as audience.*

TABLE III. QUALITATIVE RESULTS

Keyword	Description
Avatar's interaction	"Looking my avatar walking around the room makes feel like walking by myself." "My avatar is typing on my computer, just like that I usually do in my office." "I could imagine myself walking back and forth when instructing my avatar to walk. But I do not need to actually move at all." "With the movement of avatar, I can observe the apparels from different degrees of view while just standing still at a point."
Engagement with the show	"I feel the time is too long when I can just look at a static model." "I want to leave this session (static avatar) and go to next one." "I feel enjoyable when I can interact with the show, and this kind of experience is like playing a game."
Interface	"The 'click' is easy to use." "Using gestures is very interesting." "I want my avatar to do sports, but she just walks away." "I feel hard to let the avatar sit on the chair. It did not respond. Is there something wrong?"

From the think-aloud process, we observed that participants were eager to interact with the show. Insufficient interactions may make users feel bored during the show. For example, P12 said, "I feel the time is too long when I can just look at a static model." P11 also said, "I want to leave this session (static avatar) and go to next one." We also found that adding user interaction to the show could bring hedonic value. Participants tended to seek fun during the interactive experience. P9 reported, "I feel enjoyable when I can interact with the show, and this kind of experience is like playing a game."

*c) The interruptive interaction interface may hinder the performance of the real-world-interactive avatar.*

Despite verifying the real-world-interactive avatar in the apparels show, participants' evaluations to the interaction were heavily influenced by the interaction interface. For example, participants were confused with the two kinds of hand gestures, leading to undesired effects. During the experiment, P3 said, "I want my avatar to do sports, but she just walks away." The reason was that P3 used the wrong gesture. And in some cases, the time to wait for the avatar to respond could be longer than expected due to network delay. For instance, P4 said, "I feel hard to let the avatar sit on the chair. It did not respond. Is there something wrong?" Because of the above reasons, some participants felt difficult to make the avatar interact with the real environment, so that they could hardly perceive the hedonic value and practical value of the real-world-interaction.

VI. DISCUSSION

In this section, we summarize our findings of the study and discusses its implications for future fashion show design in general. We also report the plans of our future work as well as the limitations of current study.



*A. Avatar for apparels exhibition should be embedded with motions, and interaction with real world is preferable.*

As we have seen in both the quantitative and qualitative results, users prefer their personalized avatar animated. Avatars that are embedded with motions attract more affection from users, which may indirectly increase the fondness of using the whole system. Especially where motions of the avatar are related to the real environment, users show an obvious preference for the avatar. Furthermore, the real-world-interaction can close the gap between virtual apparels and users' own real life.

Therefore, when designing avatar for apparels exhibition, it is important to consider including real-world-interaction and animated avatar. When it is hard to enable the avatar to interact with real environment, having only in-situ animation is also effective to a certain degree.

*B. Let users interact with the show while avoiding complicated interactions*

From our analysis, we discovered that users are eager to participate in the show, such as interacting with the avatar and the environment. Users may feel tedious if there is no way to interact. Enabling users to participate more with the show, for instance manipulating and controlling the avatar, would improve the show experience.

However, complicated interaction should be avoided in order to prevent users getting confused. When users are stuck by the complex interaction interfaces, they tend to give up, they would usually lack confidence to try again. Despite adding interactions is crucial, the interface should be designed very carefully. Simple and user-friendly interaction interfaces are necessary. Complicated interaction interfaces will hinder the benefit of interaction.

*C. Limitations and Future Work*

As a proof-of-concept, we designed only a limited set of real-world-interaction, which cannot represent all the daily activities in users' daily life.

As future work, we will continue to include more real-world-interactions and investigate the interaction interface in the AR fashion apparel show to coordinate the interaction among users, virtual avatars and real environment. We are also interested in making the avatars aware of the real environment and react to it based on the user's behaviors.

VII. CONCLUSION

In this paper, we proposed a novel fashion show system, personal daily life show, using AR technology. It has three key features: (1) Adopting users' personalized avatar as the fashion show model (2) Providing virtual 3D apparel models based on 2D apparel images from online shopping website (3) Enabling user's personalized avatar to animate and interact with the real-world environment using AR technology.

We conducted an evaluation using both quantitative and qualitative analysis to verify our system. The results showed that the real-world-interaction of personal daily life show can

significantly improve the experience of the show and narrow the gap between user's real life and the show.

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