3D Virtual Try-On System Using Personalized Avatars: Augmented Walking in the Real World

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***Abstract*— Despite the convenience offered by e-commerce websites for consumers to purchase clothes online, consumers still have difficulties imagining what they might look like. To address this problem, we propose a holographic 3D virtual try-on system that enables users a novel experience where they can view garments fitted onto their own personalized virtual body. The garment models are generated from the garment images from online shopping websites. Users can animate their dressed virtual body in a real-life scene in Augmented Reality. We have conducted a user study to compare our proposed system with an image-only shopping system and have validated the effectiveness of our system.**

Keywords-Virtual try-on; Virtual garment modeling; Augmented reality.

I. INTRODUCTION

With the continuous development of e-commerce technology, the number of consumers purchasing clothes online is increasing [1]. Consumers usually have the desire to try on garments in order to assess if they are suitable or not before purchasing. However, when shopping online, consumers have the problem of not being able to try them on. They might worry how well the clothes will fit on their own body. Furthermore, it is difficult for customers to imagine what they might look like with various postures (i.e., standing, walking, posing, etc.) or in different settings.

To address these problems, we propose a 3D virtual try-on system using personalized models (Figure 1). (a) We generate the virtual model of users based on their own body and face information. (b) We gather some garment information and realize the 3D garment visualization using Cloth-weaver [5]. (c) We customize the garment model for each user and match the garment model to their personalized virtual avatar. (d) We enable users to view their own personalized body model fitted with virtual garment. (e) These models can also be visualized in a real-life scene and together with animated motions. To understand the user's acceptability, we conducted a user study to evaluate the value and convenience of our system.

The main contributions of this paper can be summarized as follows:

- Virtual garment models generation based on online garment images;
- A method for users to view the virtual garment interactively and immersively in 360 degrees and enabling users to check the garment by augmenting the motion of a personalized user body in the real-world.

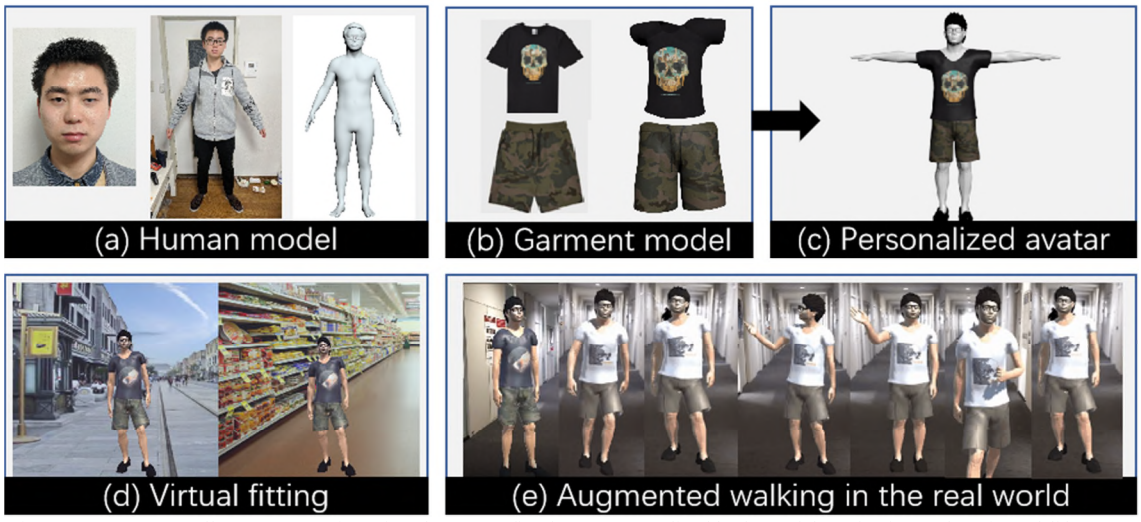

Figure 1. Our system allows users to view virtual garment fitted onto personalized body models and animate them in real-life scene.

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The rest of the paper is organized as follows. In Section 2, a brief review of previous research on 3D virtual try-on, garment modeling and virtual avatar is presented. In Section 3, we describe the system design, including human model personalization, garment model generation and 3D virtual try-on system. In Section 4, we present our evaluation result. In Section 5, we conclude our paper with a brief summary and discusses future work.

II. RELATED WORK

A. Virtual try-on

Earlier work on virtual try-on are mostly conducted in computer graphics [11][12][14]. Previous work focused on two types of virtual try-on: 2D overlay virtual try-on and 3D virtual try-on.

- **2D overlay virtual try-on**:
  Hilsmann et al. [15] retextured garment overlay for real-time visualization of garments in a virtual mirror environment. Yamada et al. [2] proposed a method of reshaping the garment image based on human body shapes to make fitting more realistic. However, like many other retexturing approaches, they operate only in 2D without using 3D information in any way, which lacked the ability for users to view their virtual self from arbitrary viewpoints.

- **3D virtual try-on**: 3D garment models perform precise garment simulation rather than just a 2D overlay. Protopsaltou et al. [20] created a virtual dressing room, where customers can view garments fitted onto their virtual body. Li et al. [21] proposed a multi-part 3D garment model reconstruction method to generate virtual garments for virtual fitting on virtual avatars.

Recently, virtual try-on combined with Augmented Reality (AR) or Virtual Reality (VR) technologies can give consumers a more realistic try-on experience. Consumers can get a better sense of what they look like when wearing the products. Several fashion firms utilized AR technology in the form of a mobile application, including Uniqlo and Gap [22]. Using VR technology, consumers can feel like they are physically in a virtual fitting room. Several fashion retailers have provided this kind of shopping experience, such as Alibaba and Dior [22].

B. Garment modeling

Unlike 2D images, 3D garment model performs precise garment simulation. Most garment modeling works focus on modeling 3D garment for a virtual character. Some garment-retargeting methods transform garment designs from one character to another. For example, Pons-Moll et al. introduced a system using multi-part 3D model of clothed bodies for clothing extraction and retargeting the clothing to new body shapes [16]. Pattern-based methods simulate the garment creation process in real life, while garment modeling tools, such as Marverlous Designer [25], offer garment modeling and editing in pattern design. Pattern-based methods require professional knowledge of garment design and are difficult for non-experts. To address the problem of digitizing garments, Zhou et al. created virtual garments from a single image [10]. Chen et al. captured real garment with a depth camera and built a coarse shape from its raw RGBD sequence using the RGB color information and depth information [17].

C. Virtual Avatar

Most virtual try-on systems provide virtual fitting experiences on a default virtual avatar, rather than one generated from user's own body [13]. The default virtual avatar can be modified by users based on the individual preferences and could be personalized if the consumers upload their facial image [23][24]. This type of virtual avatar does not reflect consumers' true body shape.

The absence of "true fit" may disappoint customers when shopping online. For our system, we propose to create virtual personalized models for each user, which can reflect their body shape and facial appearance, making their try-on experience more accurate, engaging, and increasing the customer's confidence when making purchasing decisions on garments online.

III. SYSTEM DESIGN

Our 3D virtual try-on system is composed of human model personalization, garment model generation and 3D virtual try-on.

1) *Human model personalization:* we personalize users virtual avatar using their face image and 360-degree body shape video. 2D face image is used for generating a face model of users, while 360-degree body shape video is used for generating the body model of the user. We then integrate the body model and face model into their personalized virtual avatar.
2) *Garment model generation:* in order to provide users a better visualization of online clothes, we generate 3D virtual garments based on 2D images of clothes. To realize 3D garment visualization, we map the garment texture to prepared garment model templates.
3) *3D virtual try-on:* we combine VR (Virtual Reality) and AR (Augmented Reality) technology to simulate try-on experience for users.
   - **VR fitting:** users can view their personalized avatar fitting different clothes in several virtual scenes.
   - **Augmented walking**: users can view their avatar doing daily life activity in their real environment.

Figure 2 gives an overview of our proposed system pipeline. Our system uses three elements as input: a single face image with a full-frontal face, a short video of the user's full body, and a 2D garment image from online shopping websites.

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- *Garment model generation:* (a) Mapping the 2D garment image into the 3D garment model templates and generating the 3D garment model based on online images.
- *Human model personalization*: (b) Generating the 3D human model based on the face image and recorded video.
- *3D virtual try-on:* (c) Matching the 3D garment model to the human model. (d) **VR fitting:** Users choose different clothes to try on. Users can change the pose and animation of the human model in different virtual scenes. **Augmented walking**: Users can animate personalized virtual body walking or do some natural activities in the real world.

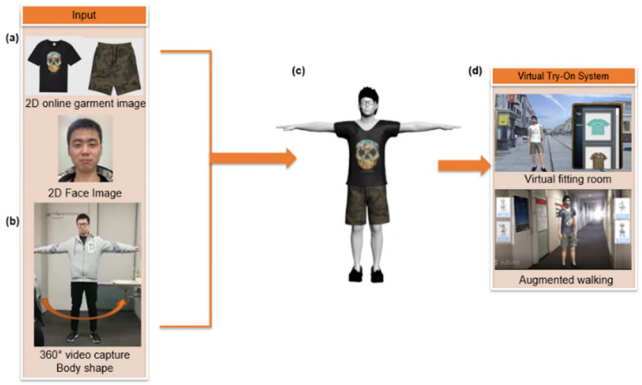

Figure 2. System Overview

A. Human Model Personalization

Due to the lack of "physical fitting" in online shopping experience, consumers may have a gap between actual and perceived body size, which may make it difficult to examine "true fit" on their own body and influence their purchase selection while shopping online. Therefore, virtual human body should have an appropriate 3D representation corresponding to the real user's human body shape and face features. This would give a better representation of the user and allows for a more accurate clothes fitting, as well as for virtual human body animation. We generate human body models based on Alldieck's work [4] and generate face models based on Deng's method [3]. Also, a hair model library is prepared, and the most similar hair model is matched to the face model we generated.

B. Garment Model Generation

In order to provide users with better garment product visualization, we allow users to view garments from various angles and directions when users are shopping online. Our approach uses garment image information from existing shopping websites (i.e., H&M [18], Zara [19]) to create a virtual garment library. Textures are extracted from the garment image and mapped onto the 3D garment model. The final 3D garment is shown in Figure 3. We mainly focus on these two parts: garment model templates used in our system and 3D modeling and texturing approaches.

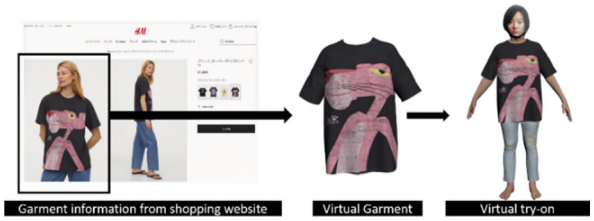

Figure 3. Generate 3D garment model based on the information from shopping website.

1) 3D Garment Model Templates

Garments are created using the traditional 2D pattern approach. We build several 3D templates of virtual garment models for the personalized human model using Cloth Weaver, which is a Blender template library. It allows us to simulate the methods of traditional garment designs. The 2D pattern is discretized into a triangular mesh. Next, we can design and modify the 2D pattern, and then use the reference line to automatically fit the flat pattern to the corresponding part of the body (Figure 4).

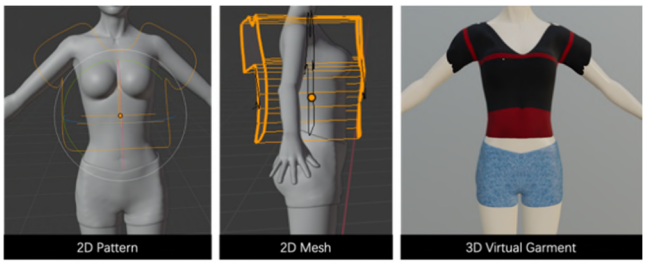

Figure 4. 2D patterns creation and positioning around generic body.

These are used as the basis for creating a variety of garment models (Figure 5). We simulated several types of clothing for female bodies and male bodies. For females, we prepare them with long sleeves, T-shirt, long pants, dress and skirt for fitting. For males, we prepare them with t-shirts, long sleeves and half pants for fitting.

Figure 5. Some 3D garment templates provided for users

2) Texture Mapping

We collected garment images from existing shopping websites (H&M, ZARA, etc.) and mapped these clothes images to generated 3D garment model templates (Figure 6). We segmented different parts of the garment from a single garment image. The segmented clothes can be divided into three main parts: left sleeves, right sleeves, and the front of clothes. The 3D mesh of a generated garment template can be extended into a 2D reference mesh in 3ds Max [26]. To map the Web garment image into a 3D virtual garment template, we

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map the different segmentation parts from the garments image to its corresponding parts on the garment template. In this way, we can generate 3D garment model with texture.

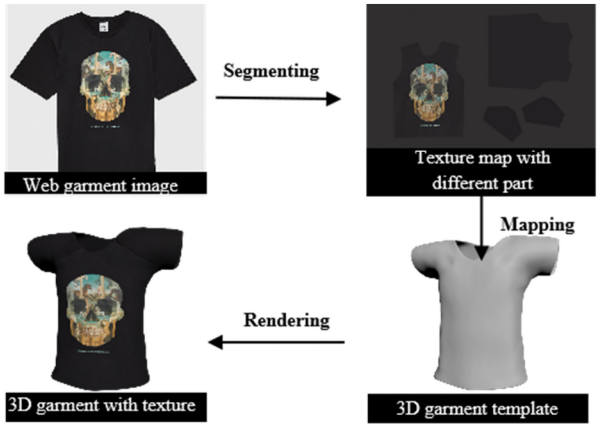

Figure 6. Mapping Web garment image to generated 3D garment templates

The garment can be customized in various ways to match the desired design. The most obvious change is the customization of appearance and color, which is achieved by modifying the texture of the cloth. Therefore, we collected garment images from online shopping websites as textures and created a garment model library for users (Figure 7).

Figure 7. Garment model library for female and male

C. 3D Virtual Try-on

We gather various garment information from online websites and enhance the online shopping experience for users. Our system was developed using Unity3D [27] on Windows10 and we deployed our system on Android smartphones. The 3D virtual try-on system consists of two parts: virtual fitting and augmented walking.

1) Virtual Fitting

Virtual reality relies on an entirely digital environment, which can provide an immersive and interactive shopping experience for users.

We prepared a variety of fitting scenes for users, such as on the street, in the office and at the supermarket. Users can view the virtual garment based on the different virtual scenes, giving them an idea of what they would look like for various occasions or purposes (Figure 8).

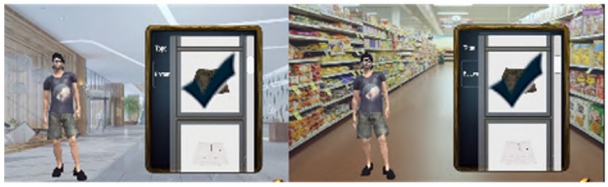

Figure 8. Fitting scenes.

2) Augmented walking

In our daily life, when users shop at the physical (offline) shops, they often check the attributes of clothes through various motions, such as twisting the body or raising the arm to help the user confirm the fit of the clothes. However, when shopping online, users cannot visualize the details of the garment. Compared to the offline try-on experience, the traditional online shopping purchasing environment lacks the capability for users to try-on garment on their own body and check whether the clothes fit on them in various postures. Therefore, we propose a dynamically interactive method that allows users to animate their dressed human body in 360 degrees and enables users view their virtual body walking in the real-life scene.

A. Overview of Augmented Walking

The implementation of the augmented walking framework aimed to animate the personalized avatar of users in the real world (see Figure 9 for its overview). Figure 9 shows the workflow of animating the personalized virtual avatar in the real world.

- *Personalized virtual avatar*: we integrate the virtual human model and clothes model in 3ds max and export the virtual avatar as .fbx file.
- *Skeleton Binding and Skinning*: we upload the personalized virtual avatar to Mixamo [7] which is a Web-based services for creating 3D human models' animation. We bind the skeleton to the virtual avatar and skin it using Mixamo.
- *Animate virtual avatar*: to attach the animation to personalized avatar, we use animator controller in Unity [28] to control the virtual avatar and perform various animation.
- *Augmented walking in real world*: we realize the augmented walking using Vuforia Augmented Reality SDK [6].

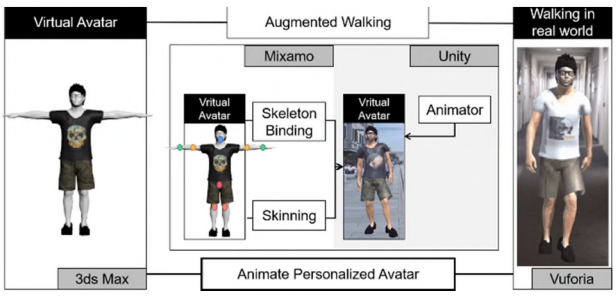

Figure 9. Implementation of augmented walking

B. Daily Life Animation

We fitted our generated human model with garment models and created walking and pose animations, as Figure 10 shows. Using Mixamo, the motions we generate are very lifelike actions, such as waving/shaking hands, walking, sitting, turning around, etc.

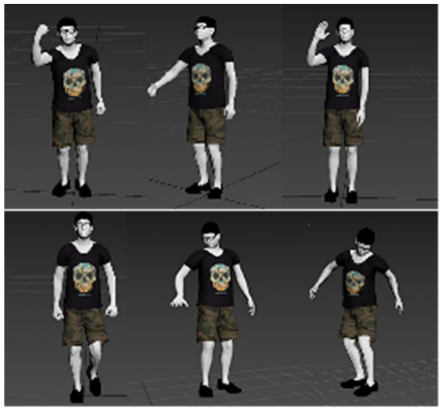

Figure 10. Postures of personalized human model

C. Augmented walking

Augmented walking enables users to view the dressed human model in a dynamic and interactive way from different perspectives (as Figure 11 shows). Therefore, users can have a better understanding of whether the garment is suitable or not while moving.

Figure 11. Views personalized model in different perspectives

Most of the previous work focused on fitting with a static body model [13][14]. So far, there is a lack of research exploring virtual try-on with motion. Therefore, we provide dynamic interaction with the virtual human model. To realize the augmented walking of the virtual human model in a real-life scene, we use Vuforia Augmented Reality SDK to detect the ground plane and place the user's virtual body into the real-life scene, in life size.

Our system enables users to view a life-size personalized virtual body with garment models and posing or walking augmented in the real-world so that they can get a sense of the real fit and get a sense of what they will look like wearing clothes with motion in a real-life scene. Figure 12 demonstrates different users animated with their virtual body with augmented walking or posing in the real-life scene.

Figure 12. Augmented walking in the real world

IV. EVALUATION

A. Evaluation Design

We have conducted an initial experiment to evaluate our system. The objective of our experiment is to assess whether our 3D virtual try-on system in augmented reality benefits users' experience when online shopping, thereby helping users make better purchasing decisions. To investigate users' attitude toward the traditional shopping experience and 3D virtual try-on with augmented walking experience, we conduct a user study with two conditions. The Experimental Conditions are indicated below.

- *Virtual try-on condition:* simulate the shopping experience with our 3D virtual try-on system.
- *Image only condition:* simulate typical online shopping experience with only images of garments online.

We hypothesized that the former condition would lead to a higher rating than the latter.

B. Participants

A total of 10 college students participated in both condition 1 (*Virtual try-on condition*) and condition 2 (*Image only condition*). College students aged 18-30 years are usually targeted by AR/VR applications, as they are more likely to try new technologies and they are proactive in online shopping for fashion products. Hence, we invited N=10 participants (7M, 3F) to complete our evaluation, with an average age of 22.5 years.

C. Procedure

For each participant, we personalized their human model based on their 2D face image and 360-degree body videos. Each participant simulated the shopping experience with two different conditions. The order of the conditions was randomized. After each task, participants were asked to rate their experience (from 1 "strongly disagree" to 7 "strongly agree") in our questionnaire, indicated on a 7-point Likert

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scale. At the end of the experiment, we interviewed participants to gather their preferences and open-ended feedback.

D. Measures

We measured enjoyment, convenience, and user behavior for the two conditions. We also measured whether augmented motion in the real-life scene enhances user's shopping experience. The questionnaire and measurement items are shown in Table 1.

TABLE I. QUSTIONNAIRE AND MEASRUEMENT ITEMS

Items	Statements
Enjoyment	**a.** Using the system, shopping experience was enjoyable for me.
Convenience	**b.** I can get a sense of how the outfit might look for the various occasions. **c.** I can get a sense of how I look wearing these clothes.
Augmented Walking	**d.** Seeing a model of me walking in the real-world enhanced my shopping experience. **e.** Having a model walking in a real environment helps me understand more about the appearance of the clothes.
User Behavior	**f.** I want to use this system when I buy some clothes online in the future.

E. Results

We separate the result into two sections: analysis of the rating from questionnaires and thematic analysis of the participants' comments.

We analyzed the result in terms of users' enjoyment, convenience, augmented walking and user behavior.

(1) **Enjoyment:** As Figure 13 shows, we found a significant main effect on participants shopping enjoyment. A repeated measures t-test revealed a statistically significant difference between the various conditions P<0.01. Participants' rated the enjoyment significantly higher in the virtual try-on condition.

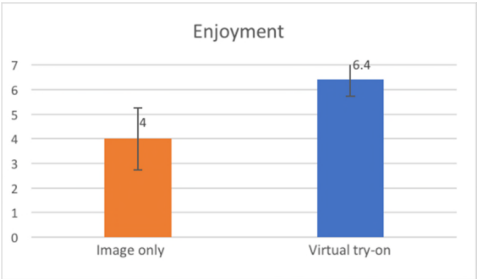

Figure 13. Participants rated their Experiences more enjoyable in the virtual try-on condition.

(2) **Convenience:** We analyzed the user convenience through the two questions below: A. *I can get a sense of how the outfit might look for the various occasions.* We found that participants rated the virtual try-on condition ($p < 0.01$) significantly higher than the other condition (Figure. 14). B. *I can get a sense of how I look wearing these clothes.* We also found that participants rated the virtual try-on condition ($p < 0.01$) significantly higher, meaning that it gave users a better feeling for how these clothes look like on their body (Figure 15).

Figure 14. Participants rated they feel easier to get a sense of how the outfit might look for the various occasions in the virtual try-on condition.

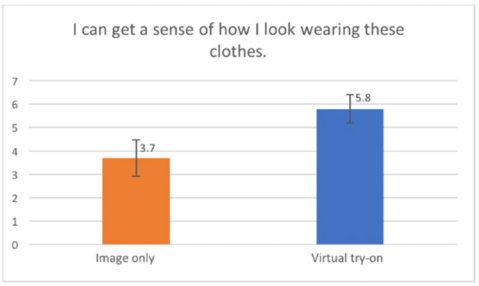

Figure 15. Participants rated that virtual try-on condition gave users a better feel for how these clothes look like on their body.

(3) **Augmented Walking:** To understand if the 3D virtual try-on system within the AR scene enhances the user's experience, we prepared two statements:

d. Seeing a model of me walking in the real-world enhanced my shopping experience. Figure 16 summarizes participants' opinions in the virtual try-on condition.

Figure 16. All participants agree that seeing own model in the real-world enhanced their shopping experience. 9 out of 10 participants strongly agree with it.

e. Having a model walking in a real environment helps me understand more about the appearance of the clothes. Figure 17 summarizes participants' opinions in the virtual try-on condition.

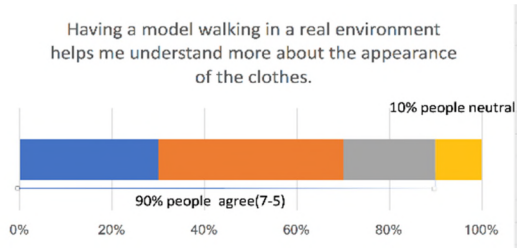

Figure 17. Most participants agree that the model walking in the real environment helps them understand more about the appearance of the clothes.

In conclusion, all the participants agreed that augmented walking may enhance their shopping experience. 9 out of 10 participants rated that the virtual model walking in the real environment helps them understand more about the appearance of the clothes. The main reasons given were, for example, the real environment is very realistic which helps them to view the appearance of the garment model. Moreover, for the participants, the virtual models walking in the real-life scene are very interesting and can improve their enjoyment of online shopping process. At the same time, augmented walking can also provide a better 3D visualization for users. The dynamic fitting display can show the shape of the clothes when they are in motion and increases the number of clothes attributes that can be observed.

(4) **User Behavior:** In summary, all participants preferred the virtual try-on condition, for both enjoyment and convenience. We also analyzed the user behavior about whether they want to use the virtual try-on system in the future or not. Results suggested that 9 out of 10 participants wanted to use this system in the future (Figure 18).

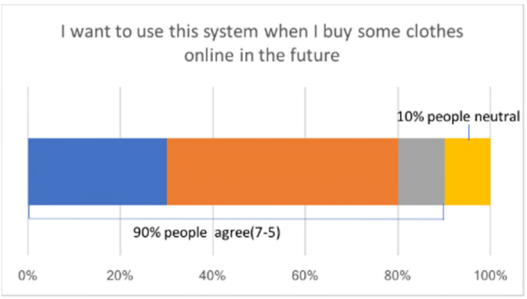

Figure 18. Most participants want to use this system when they buy some clothes online in future.

F. *Qualitative Results*

At the end of the experiment, open-ended feedback was sought from participants, and a thematic analysis was performed on participants' responses and their feeling of using our 3D virtual try-on system.

Most participants thought that the virtual avatar augmented walking in real world offers them a sense of wearing clothes on their own body, which can provide users with a better understanding of the detail of the clothes. Moreover, augmented walking allows users to visualize their personalized model in real world, increasing their shopping enjoyment. P6 mentioned that the augmented walking makes them feel like they are looking into a mirror. P7 said that augmented walking in the real world can help them observe more details of clothes.

Most participants thought that our system was interesting. Our system can enhance users' experience and narrow their selections when shopping online. For instance, P1 mentioned: "shopping online is difficult because the model's body shape is pretty, while actual people in real life don't have such a perfect body. This system shows how the clothes look like on my body in the real-world which makes me have confidence when buying clothes." Similar comments were received from P3 and P4.

Furthermore, the 3D virtual try-on system gives users outfit ideas and provides more clothing information to users. P3 thinks that 3D virtual system provides various virtual scenes to help users with selecting clothes, especially for special occasions. P6 mentioned that the 3D garment model allows him to see himself wearing clothes in 360 degrees and obtain additional clothing information than just looking in a mirror. P7 said the virtual model walking in the real world may help them to check how they look like in the real wearing conditions.

We also received comments about future improvement; P3 suggested that the material of clothes could be improved to look more like real fabric, and P9 thought that it would be better to use motion capture to simulate real movement of users' moving in the real world. The free comments from participants are summarized below in Table2.

TABLE II. CONCLUSION OF FREE COMMENT

Keyword	Conclusion and Comments
Augmented walking	**Judging of fitting:** Wearing clothes doing some activities in the real world provides users with better understanding of the detail of clothes, which allows to better judge of fitting. **Humanoid motion:** Using motion capture technology to capture user's movement may offer users a better sense of "real me".
Garment model	**Information visualization:** The 3D virtual try-on system gives users outfit ideas and provides more clothing information to users (muti-direction and muti-angle). **Realistic garment:** Garment material can be more like real fabric.
Shopping experience	The 3D virtual try-on system can narrow users' selections of clothes and increase their purchase confidence. Increases the enjoyment of shopping experience.

V. CONCLUSION AND FUTURE WORK

In this paper, we have presented a 3D virtual try-on system to facilitate consumers in getting a better sense of

how they would look when purchasing clothes online. To allow users to assess how well the displayed products match their actual body, we personalized users' own virtual avatar corresponding to real user's human body shape and face features. Based on online garment images, we generated 3D virtual garment to personalize the human body. Users can fit their 3D user models with a selection of virtual garments, and view the animated body in the real-life scene, as well as various virtual scenes, to get a better sense of the dynamic effects of the clothes. An initial evaluation reveals that the virtual try-on system was more enjoyable and more convenient than the typical experience of using images only. Augmented walking provides an interactive, dynamic virtual try-on experience for users, which provide users with better understanding of the detail of clothes. The virtual avatar wearing clothes in the real world can provide a better sense of "true fit", which helps users better judge of fitting. Furthermore, most of the participants would prefer using this system for online shopping in the future. They think that this system can increase their purchase confidence and solve the fit problem when shopping online.

However, our system still has certain limitations that can be improved. In the future, we plan to enhance our clothing animations and cloth simulation methods to provide users with a more realistic virtual try-on effect. Motion capture can also be used to better simulate user's walking motion, in order to provide a more realistic and more interactive fitting experience.

REFERENCES

[1] C. Garcia Martin and E. Oruklu, "Human friendly interface design for virtual fitting room applications on android based mobile devices, " Journal of Signal and Information Processing3, vol. 3, pp. 481-490, 2012. DOI:https://doi.org/10.4236/jsip.2012.34061

[2] H. Yamada et al., "Image-based virtual fitting system with garment image reshaping. In 2014 International Conference on Cyberworlds, " IEEE, pp. 47-54, 2014. DOI:https://doi.org/ 10.1109/CW.2014.15

[3] Y. Deng et al., "Accurate 3D Face Reconstruction with Weakly-Supervised Learning: From Single Image to Image Set, " In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops, 11pages, 2019. Retrieved from https://arxiv.org/abs/1903.08527

[4] T. Alldieck et al., "Video based reconstruction of 3d people models, " In 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition, pp. 8387-8397, 2018. DOI:https://doi.org/10.1109/CVPR.2018.00875

[5] Cloth-Weaver, https://clothweaver.com/. [retrieved: Oct, 2020]

[6] Vuforia Engine, https://developer.vuforia.com/. [retrieved: Oct, 2020]

[7] Maximo, https://www.mixamo.com/. [retrieved: Oct, 2020]

[8] L. Chen et al., "Encoder-decoder with atrous separable convolution for semantic image segmentation, " In computer vision (ECCV 2018), pp. 833-851, 2018. DOI:https://doi.org/10.1007/978-3-030-01234-2_49

[9] H. Tanaka and H. Saito, "Texture Overlay onto Flexible Object with PCA of Silhouettes and K-Means Method for Search into Database, "MVA, pp. 5-8, 2009.

[10] Z. Bin et al., "Garment modeling from a single image, " In Computer graphics forum, pp. 85-91, 2013. DOI: https://doi.org/10.1111/cgf.12215

[11] X. Han et al., "Viton: An image-based virtual try-on network, " In 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition, pp. 7543-7552, 2018. DOI:https://doi.org/10.1109/CVPR.2018.00787

[12] M. Sekine et al., "Virtual fitting by single-shot body shape estimation, " In Int. Conf. on 3D Body Scanning Technologies. Citeseer, pp. 406-413, 2014.

[13] Warehouse, https://www.warehouselondon.com/row/homepage. [retrieved: Jan, 2020]

[14] P. Decaudin et al., "Virtual garments: A fully geometric approach for clothing design," In Computer Graphics Forum, pp. 625-634, 2006. DOI:https://doi.org/10.1111/j.1467-8659.2006.00982.x

[15] A. Hilsmann and P. Eisert, "Tracking and Retexturing Cloth for Real-Time Virtual Clothing Applications, " In Proceedings of the 4th International Conference on Computer Vision/Computer Graphics CollaborationTechniques Springer-Verlag, Berlin, Heidelberg, pp. 94–105, 2009. DOI:https://doi.org/10.1007/978-3-642-01811-4_9

[16] G. Pons-Moll et al ., "ClothCap: seamless 4D clothing capture and retargeting, " ACM Transactions on Graphics vol. 36, 15pages, 2017. DOI:https://dl.acm.org/doi/10.1145/3072959.3073711

[17] X. Chen, B. Zhou, F. Lu, L. Wang, L. Bi and P. Tan, "Garment modeling with a depth camera, " ACM Trans. Graph. vol. 34 , 12 pages. 2015. DOI:https://doi.org/10.1145/2816795.2818059

[18] H&M, https://www.hm.com/. [retrieved: Oct, 2020]

[19] ZARA, https://www.zara.com/. [retrieved: Aug, 2020]

[20] D. Protopsaltou et al., "A body and garment creation method for an Internet based virtual fitting room, " In Advances in modelling, animation and rendering, pp. 105-122, 2002. DOI: https://doi.org/10.1007/978-1-4471-0103-1_7

[21] D. Li et al., "Automatic three-dimensional-scanned garment fitting based on virtual tailoring and geometric sewing." Journal of Engineered Fibers and Fabrics, vol. 14, 16 pages, 2019. DOI: https://doi.org/10.1177/1558925018825319

[22] H. Lee and K. Leonas, "Consumer experiences, the key to survive in an omni-channel environment: use of virtual technology, " Journal of Textile and Apparel, Technology and Management, Vol. 10, pp. 1-23, 2018.

[23] M. Yuan, I. R. Khan, F. Farbiz, S. Yao, A. Niswar and M. H. Foo, "A mixed reality virtual clothes try-on system, " IEEE Transactions on Multimedia, vol. 15, pp. 1958-1968, 2013 DOI: https://doi.org/10.1109/TMM.2013.2280560

[24] N. Magnenat-Thalmann, B. Kevelham, P. Volino, M. Kasap and E. Lyard, "3d web-based virtual try on of physically simulated clothes, " Computer-Aided Design and Applications, vol. 8, pp. 163-174, 2011. DOI: https://doi.org/10.3722/cadaps.2011.163-174

[25] Marvelous Designer, https://www.marvelousdesigner.com/. [retrieved: Oct, 2020]

[26] 3ds Max, https://www.autodesk.co.jp/products/3ds-max/overview/. [retrieved: Sep, 2020]

[27] Unity3D, https://unity.com/. [retrieved: Oct, 2020]

[28] Animator Controller, https://docs.unity3d.com/Manual/class-AnimatorController.html , [retrieved: Oct, 2020]

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