VIRTUAL DRESS UP
with
AUGMENTED REALITY

Senior Design Project I

Dilay Sapmaz
Korhan Aladağ
Nur İmece

2021

MEF UNIVERSITY
FACULTY OF ENGINEERING

DEPARTMENT OF COMPUTER ENGINEERING

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Project Title	: Virtual Dress Up with Augmented Reality
Student(s) Name	: Dilay Sapmaz, Korhan Aladağ, Nur İmece
Date	: 22/01/2021

I hereby state that the design project prepared by Dilay Sapmaz, Korhan Aladağ, and Nur İmece has been completed under my supervision. I accept this work as a "Senior Design Project".

22/01/2021
Asst. Prof. Berk Gökberk

I hereby state that I have examined this senior design project Dilay Sapmaz, Korhan Aladağ, Nur İmece. This work is acceptable as a "Senior Design Project".

22/01/2021
Prof. Muhittin Gökmen

Head of the Department of
Computer Engineering

ACADEMIC HONESTY PLEDGE

In keeping with the MEF University Student Code of Conduct, I pledge that this work is my own and that I have not received inappropriate assistance in its preparation. I further declare that all resources are explicitly cited.

NAME	DATE	SIGNATURE
Dilay Sapmaz	22/01/2021	
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Nur İmece	22/01/2021	

ABSTRACT

VIRTUAL DRESS UP

with

AUGMENTED REALİTY

Dilay Sapmaz
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Nur İmece

MEF UNIVERSITY
Faculty of Engineering
Department of Computer Engineering

Advisor: Berk Gökberk

JANUARY, 2021

The main purpose of this project is to make people feel more comfortable by allowing them to try out all kinds of clothes without physically wearing them with the help of augmented reality. Nowadays, people are worried about going to the mall physically as people suffer from COVID-19. Dressing with Augmented Reality will also find a solution to these problems. This project solves the online shopping problem caused by wrong decisions. We plan to use a blender for 3D modeling and the union to create an environment for dressing. Next, we plan to use augmented reality with the help of Vuforia.

The target audience of our project is people who do not want to spend time shopping or who cannot spend time shopping because they are busy and cannot go out shopping. These customers can see the products they want to buy in 3D, examine the fabric, and check whether the outfit suits them while shopping on the phone. Over the years, people have become more and more used to online shopping. However, after ordering the clothes online, when those clothes do not come out as they want, they have to deal with product returns or use the clothes they do not like / want. Thanks to our project and application, this problem will be eliminated and customers will shop happier, faster and without any problems.

Keywords: Augmented Reality, Virtual Clothing, Computer Graphics, Fashion, Mobile Programming.

ÖZET

VIRTUAL DRESS UP
with
AUGMENTED REALITY

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OCAK, 2021

Bu projenin temel amacı, artırılmış gerçeklik yardımıyla insanlara her türlü kıyafeti fiziksel olarak giymeden deneme fırsatı vererek kendilerini daha rahat hissetmelerini sağlamaktır. Günümüzde insanlar COVID-19'dan muzdarip olduğu için, insanlar alışveriş merkezine fiziksel olarak gitme konusunda endişeli. Artırılmış Gerçeklik ile Giydirme bu sorunlara da bir çözüm bulacaktır. Bu proje, yanlış kararların neden olduğu çevrimiçi alışveriş sorununu çözmektedir. 3B modelleme için bir blender ve giyinme işlemi için bir ortam yaratmak için birliği kullanmayı planlıyoruz. Bundan sonra Vuforia'nın yardımıyla artırılmış gerçeklik kullanmayı planlıyoruz.

Projemizin hedef kitlesi alışverişe zaman harcamak istemeyen veya meşgul olduğu için alışverişe zaman harcayamayan, alışveriş için dışarı çıkamayan insanlarındır. Bu müşteriler alışverişini telefondan yaparken almak istediği ürünleri 3D olarak görebilmekte, kumaşını inceleyebilmekte ve kıyafetin kendine yakışıp yakışmadığını kontrol edebilmektedir. Yıllar geçtikçe, insanlar internetten alışveriş yapmaya daha çok alıştılar. Ancak kıyafetleri internetten sipariş ettikten sonra o kıyafetler istediği gibi çıkmadığında, ürün iadesiyle uğraşmak veya sevmediği/istemediği kıyafetleri kullanmak zorunda kalıyorlar. Projemiz ve uygulamamız sayesinde bu sorun ortadan kalkacak ve müşteriler daha mutlu, hızlı ve sorunsuz alışveriş gerçekleştireceklerdir.

Anahtar Kelimeler: Artırılmış Gerçeklik, Sanal Giyim, Bilgisayar Grafikleri, Moda, Mobil Programlama.

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LIST OF ABBREVIATIONS

AR	Augmented Reality
VR	Virtual Reality
MR	Mixed Reality
3D	3 Dimensional
2D	2 Dimensional
CG	Computer Graphics
RGB	Red-Green-Blue
UI	User Interface
GAN	Generative Adversarial Networks
GUI	Graphical User Interface

1. INTRODUCTION

We aim to develop this system based on the problems of today's people while shopping online. It is a profitable system not only for the customer but also for the seller. For this reason, it can be preferred by everyone. Virtual clothing allows customers to shop safely and save time without having to go to the store. When the customer purchases the dress by trying it online, the possibility of returning the product will decrease, and seller profit will increase.

1.1. Motivation

We wanted to work on this topic because VR and AR fields are important branches of the Computer Engineering department. Mobile programming (iOS) is an important area where we can improve ourselves. Also, people can virtually try on these clothes without going out or having an issue while buying clothes.

1.2. Broad Impact

Virtual Dress Up with Augmented Reality is an application that will provide profit to the seller economically. It aims to reduce the return rates by allowing the user to try on the outfit. It also saves time for the user and ensures that he is sure of the product he bought. Since the user is confident about the product, the rate of purchase increases. It will also affect the rates of going to the shop, saving time. Also, this practice will affect the number of employees. Customers will try out the clothes and will not disturb the order and the number of employees will decrease. This will make a significant profit for the employer as well. It will save time again, as the customer will not bother with trying clothes.

Many shops have been closed due to the Covid-19 virus and people are worried about going out. This virtual dressing room, which will provide a solution to this, is a very useful technology that prevents the virus from spreading. It also provides an important advantage in terms of hygiene as there is a possibility of leaving viruses on while trying clothes.

1.2.1. Global and Environmental Impact

Virtual clothing has significant environmental and global impacts. As customers do not have to go to the store, gasoline consumption will be significantly reduced. The reduction in gasoline consumption will also significantly reduce environmental pollution. It allows stores to make sales from many different places. In this way, it provides financial profit for both the customer and the seller.

Since customers do not come to the store, the staff will not be needed to take care of them, so the number of store tasks will be reduced. This number of unemployed people can create different business areas and affect the world globally.

1.2.2. Legal Impact

Virtual clothing has important legal implications for safety and health. Clothes tried in stores can play a role in the transmission of various diseases and put the health of customers at some risk. Thanks to the online trial, customers will not have to worry about the cleanliness of the clothes. The seller, on the other hand, will not worry about the theft of the clothes because the clothes are tried virtually. It is a reliable system for both the customer and the seller.

2. PROJECT DEFINITION AND PLANNING

2.1. Project Definition

The main purpose of this project is to make people feel more comfortable by allowing them to try out all kinds of clothes without physically wearing them with the help of augmented reality (AR). This application, which is planned to be AR supported, allows the user to view the outfit online on the model. There are many models in the application that the user can choose according to their size. It is planned that this model will offer the opportunity to see the outfit that it has determined from the application by dragging it or clicking on it. As people suffer from COVID-19 these days, people are worried about going to the mall physically. Dressing with AR will find a solution to these problems as well. It provides an advantage to customers who are concerned about hygiene. For customers who cannot find time to go to the store, it saves time and will also significantly reduce the return of the products they buy. This project solves the online shopping problem caused by wrong decisions.

We plan to use this app as a blender for 3D modeling and unity to create an environment for dressing. We have the chance to switch from 3D modeling to 2D modeling according to the course of the project. The models used will mostly be found and imported as ready. We then plan to use AR with the help of Vuforia. As an alternative to Vuforia, we can also use the EasyAr library. We are planning to make a virtual clothing application for the iPhone. That is why we plan to write our project with Swift.

2.2. Project Planning

Breaking down a project into small parts, completing them, and then assembling them is very important for the progress of the project and its fast completion. Also, we divided our project into small parts. We then tried to follow these steps.

Table 1. Sample project plan for 14 weeks.

Task	Responsible Person	Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Proposal Form	Korhan Dilay Nur														
Literature Survey	Korhan Dilay Nur														
3D Modelling 1	Korhan Dilay Nur														
3D Modelling 2	Korhan Dilay Nur														
Model and Clothing Interaction	Korhan Dilay Nur														
Final Report	Korhan Dilay Nur														

- **Project Proposal Form:** The Project Proposal Form is a form that shows the process of making the project step by step and shows the hardware and software requirements we will use.
- **Literature Survey:** Literature Survey is a form in which we search for all articles related to the subject of our project and summarize these articles. In this way, we examine previous studies and get an idea about our subject and the areas of use of our subject. We can find programs from the articles that we can use as examples.
- **3D Modelling 1:** We need to find models to use in our project. In this process, we will find samples of different sizes and thicknesses. When we cannot find as many as we want, we will design them. We will try to move the models.
- **3D Modelling 2:** We need to find or design a lot of clothes in different patterns, colors, and sizes to dress the models we find for our project. In this process, we need to find or design a lot of clothes such as shirts, dresses, trousers, shorts in many different sizes and different patterns.
- **Model and Clothing Interaction:** We need to match the clothes we find with the models. Dressing the clothes on the models should happen automatically. In this process, we will investigate how this is done, learn, and try to apply it.

- **Final Report:** We will deliver and present the final version of our report and presentation in this process.

2.2.1 Aim of the Project

The aim of this project is for people to wear and see clothes visually before buying them. In this way, problems such as a person not fitting in the clothes they choose, the clothes they choose to be loose, or dislike the fabric of the clothes they choose are prevented.

2.2.2 Project Coverage

The project will be made with Vuforia as our priority. Blender will be used for modeling clothes and mannequins. Modeling was first expected from the group members for the outfit and model. Because the models made in the Blender are very time and laborious, it was preferred to find a model instead of making it. Swift mobile programming was preferred. However, depending on the course of the project, this programming can evolve into a program that runs on a desktop. The application will be done on seeing the outfit that the user wants to try on the mannequin chosen. The user has no chance to see the outfit on himself. The user has the chance to see the clothes on the application on the model. He/she can modify the outfit as he wishes on the model. Modify feature covers the size and color of the garment. It is possible to try more than one outfit on the model according to the user's wishes. For the user to see the model in the desired place in the house, a flat floor and the marker desired by the application are required. When these conditions are met, the user can easily use the application. For a long-term project, models can be designed by Korhan, Dilay, and Nur at Blender.

2.2.3 Use Cases

In the virtual dress application, the user enters the application. Then the user enters their body measurements. There are two options here. The user enters the body measurements and the system automatically brings the model closest to these measurements. The second option is for the user to see the models and choose the one that suits him best. Depending on the course of the project, one of these two options will be preferred. Then the user gets the opportunity to see the product he wants to try on this model with the help of AR. The selected product can be dressed on the user by drag and drop or it can provide automatic dressing to the model when the dress is clicked. According to the course of the project, the appropriate one will be preferred or it will provide the opportunity to do both. Also, the user can rotate the mannequin with the help of a rotate button. In this way, he can easily decide how the outfit fits on the model and what size he should take. The user can try different sizes and colors of the outfit on the model. It also has the opportunity to see several pieces of products on the model at the same time. If the user wants to try another mannequin, the user is directed to the beginning of the application with the help of the back button. By repeating the same processes, the user finds the opportunity to buy the desired product.

2.2.4 Success Criteria

In this project, our first aim is to be able to create a virtual environment that is realistic because in AR we are mixing both the real world and the virtual world. If our virtual environment does not look like it belongs to the real world we can easily say that it is not successful. However, time is another crucial factor for our application because users would not want to wait lots of time to be able to wear the dress they want. Also, users want to try various clothes and they want to be able to modify these clothes if any kind of size problems occur.

2.2.5 Project Time and Resource Estimation

This project is planned to last 14 weeks in total. Blender and modeling will be done by Dilay and Nur, mainly by Korhan. All other steps of this project are planned to be done with equal distribution of tasks among all members of the team. The time allocated for writing the project proposal form is 1 week, 2 weeks for Literature Research and 3D Modelling or finding a person model, 7 weeks for 3D Modelling of Clothes, 4 weeks for Model and Clothing Interaction and Final Report.

2.2.6 Solution Strategies and Applicable Methods

Several 3D models will be found or modeled in this application. 3D models must fit properly on the mannequin, it must wrap the mannequin's body. The fact that the dress does not wrap the model creates an important problem. No solution has yet been produced for this. There is also the possibility that the user may not find a mannequin in the size entered into the system. This is an important problem for the user. There are two solution suggestions for this. The first is to change the way of the project completely, display the outfit on the user, and actively use machine learning. The second is to keep the model variety more and increase the possibility of the user reaching the model with close size. The second is more advantageous. Another problem is that the user cannot see enough clothing in the application. If the user cannot find enough clothes, he/she will not prefer this application for a few clothes. For this reason, the variety of clothes poses an important problem. A blender will be used to model the models (clothes, mannequins).

Every model created in Blender will be transferred to Unity. Vuforia will be used to create an AR project because there are many more resources in Vuforia than EasyAr. The mannequin process will be covered with the help of Unity dressing. User Interface (UI) design will be discussed with the help of Figma.

2.2.7 Risk Analysis

The biggest risk of this project is to be able to synchronize clothes with human body movements. If we won’t be able to synchronize it, changing to a 2D environment may be applied. Another risk is to be able to automatically fit the corresponding mannequin's body size. In this case, we will use molded models and clothes that have the same size as these molded models. If we can’t deal with mobile application creation with Swift, we may consider working on a desktop.

2.2.8 Tools Needed

For this project, our Software tools needs are Swift, Unity, Blender, Vuforia, and Figma. Our Hardware tools needs are a computer and a smartphone.

3. THEORETICAL BACKGROUND

The theoretical researches and summaries of the articles found on the topics to be covered by the Virtual Dress Up are mentioned.

3.1. Literature Survey

Three dimensional (3D) technologies are frequently used in the virtual dressing. Pachoulakis and Kapetanakis carried out the VFR project, which aims to be able to dress 3D garments without customers having to go to the store. (Pachoulakis and Kapetanakis, 2012). Product returns can be reduced to a minimum. Shopping can be a waste of time for some customers. Details of the clothes are simulated in a virtual store. It is aimed to automatically detect and create whether the clothes have pockets or patterns. Garment modeling is designed with the NURBS cutting curve and mesh cutting algorithm. The process is based on dressing a fabric figure on the mannequin and cutting and shaping the targeted picture. Clothing matching is done with 3D technologies. 3D technology is the process of transferring products that do not have computer-aided data to the computer environment. Experiments are carried out to ensure the fit of certain body models and the data obtained are combined with 3D technology. A 3D dress was created using a Bezier curve. Bezier curve is the curve shape used in computer graphics. And this method quickly leads to results. To replicate an outfit in 3D, all the information about the outfit is extracted from the photo where the outfit was taken. A uniform garment net is produced and the garments are then automatically sewn onto the visual mannequin according to the mass-spring pattern. KinectShop is an online AR shopping platform. The Xbox Kinect Sensor allows viewing the virtual accessory racks by showing the customers' movements on the screen. There is a mirror and it allows customers to try these virtual clothes from the mirror as in Figure 1.

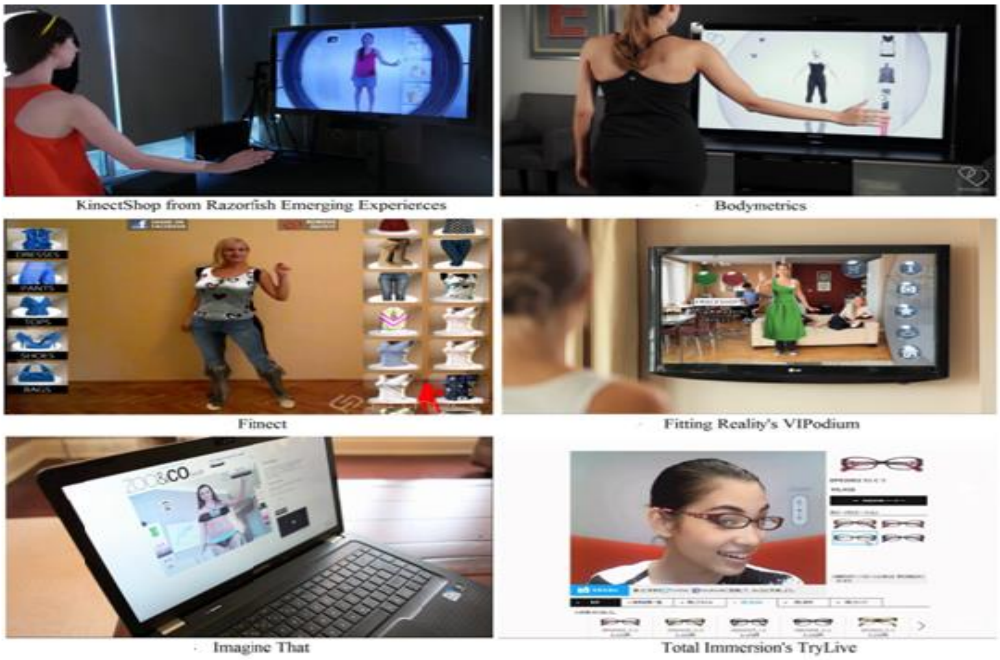


Figure 1. Virtual shelves in the store and testing clothes in the mirror.

Shopping from the store or waiting in the queue is not something every customer will like. In this case, a virtual fitting room project is in question. And in this article, Boonbrahm et al. review fabrics for the virtual fitting room (Boonbrahm et al., 2015). Microsoft's Kinect camera captures the movements and depths of people. The advantage of this technology: When the mannequin moves, the virtual cloth also looks more realistic for styling to suit the movement. The disadvantage of this method is that the garment appears two dimensional (2D) while the model is walking. If we want to see clothes on the human body, we must pay attention to two items: First, what is the clothing. Like shirts, t-shirts, dresses. Second, the type of fabric. Like satin, cotton, cashmere. For the first item, parameters need to consider the shape, thick and thin parts of the dress.

Figure 2. Stiffness and posture of fabrics (a), bending stiffness of fabrics (b).

Not all fabrics are the same and it is difficult to find them individually. One way to guess what the fabrics are is to compare them with the actual outfit. Up to Figure 3, it makes an appropriate estimation by comparing it with each other based on the interaction of a sphere and fabric.

Figure 3. Sphere interactions with jean fabric in reality and computer appearance (a), cotton fabric in reality and computer appearance (b), chiffon fabric in reality and computer appearance (c), satin fabric in reality and computer appearance (d).

As can be seen from these figures, a fabric can be shown very close to reality. According to this experiment, it is understood that the correct parameters must be selected for a fabric to look real. The results obtained from the experiment are shown in Figure 4.

Physical Parameters for each fabric

High ⟵⟶ Low

Bending Stiffness	Jean Cotton Chiffon Satin		
Streching Stiffness	Jean/Cotton/Chiffon Satin		
Damping	Jean	Chiffon	Satin/Cotton
Friction	Jean/Cotton	Chiffon	Satin

Figure 4. Comparison of physical properties required to separate fabrics.

Another project about virtual dressing is dressing in front of the mirror. Yolcu et al. developed a project to find the harmony of both the color and the clothes without difficulty (Yolcu et al., 2014). The person selects the outfit from the screen by hand gesture and wears it from the screen. The system can produce different images for different people and different clothes. Also, an algorithm has been developed for human and clothing interaction. Microsoft Kinect SDK is used for user movements and clothing coordination.

Virtual outfits can be edited using Zhou and Kinect. Using Zhou and Kinect, virtual outfits can be edited. With Hauswiesner it gives a system that combines the user and preloaded cloth. With the help of the Kinect's library, when the user moves in front of the mirror, the garment moves accordingly. And again, with the help of this library, the clothes were properly combined. The colors can be changed after the clothes are worn by the user in front of the mirror. The color scale in the clothing photo is converted from red-green-blue (RGB) to HSV. In the HSV color scale, the H value indicates hue, the V value indicates vividness. When the color of the garment changes, the V parameter must be kept constant in the HSV color scale. Because if there is any change in the shade (brightness=vividness) of the cloth, the realistic appearance will be avoided. After the change is made, the photo is converted to an RGB format as in Figure 5.

Figure 5. Change the color of the outfit.

The system suit aims to properly place it on the created skeleton model. Kinect is used. Two people can be watched in front of the camera. The skeleton consists of joints as in Figure 6.

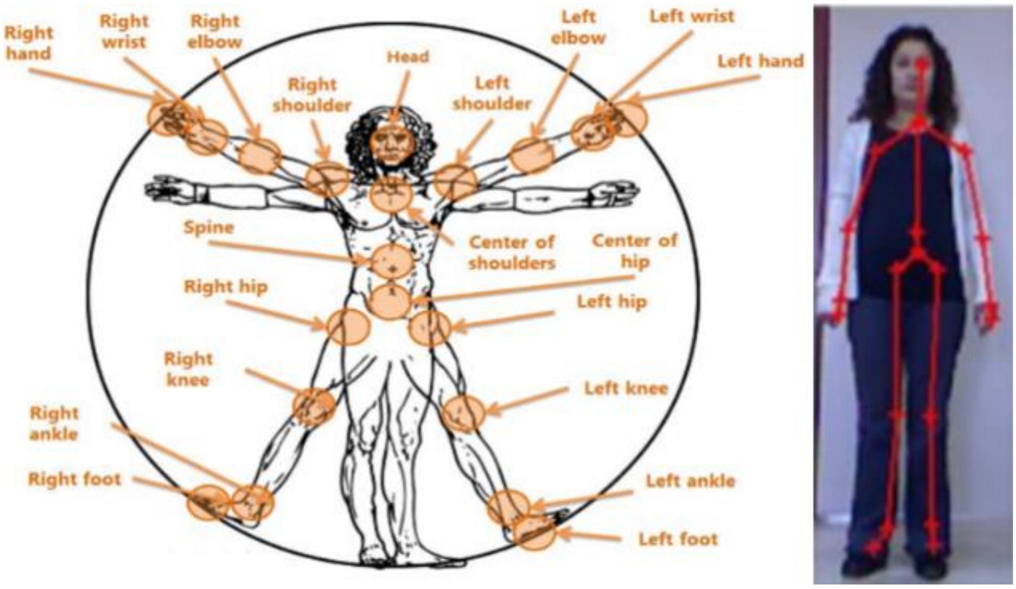


Figure 6. Skeleton and joints found by Kinect.

Kjærside et al. realized another project as virtual dressing under the name of ARDressCode. The purpose of this project is to have a projection screen instead of a mirror and the users can see the clothing they choose in front of this screen (Kjærside et al., 2005). There are two difficulties in using AR for outfit trials. The first is the development of a sensitive technique for tracking motion. The second is to dynamically integrate a clothing model into a kinetic body.

With the ARDressCode, the customer can choose his/her outfit in the store. However, instead of wearing it effortlessly in the fitting room, he/she wears it visually through AR. With ARDressCode, besides being able to try different sizes and different colors of the clothing, it also offers a combination suggestion. Besides, employees do not have to make an effort, as customers do not leave any clothes behind after leaving the fitting room.

The process of try clothes in the store is as follows for this project. Customers choose the outfit. They hang it on the rod in the cupboard to the left of the mirror. They put their cell phones in the box on the right. To try on a new outfit, customers just need to put the item in the yellow part of the bar. Figure 7 shows the process.

Figure 7. Illustration of how ARDressCode is used.

As shown in Figure 8, the clothes in the store must have an RFID tag. This tag is required to get the data required when the clothing is placed on the stick.

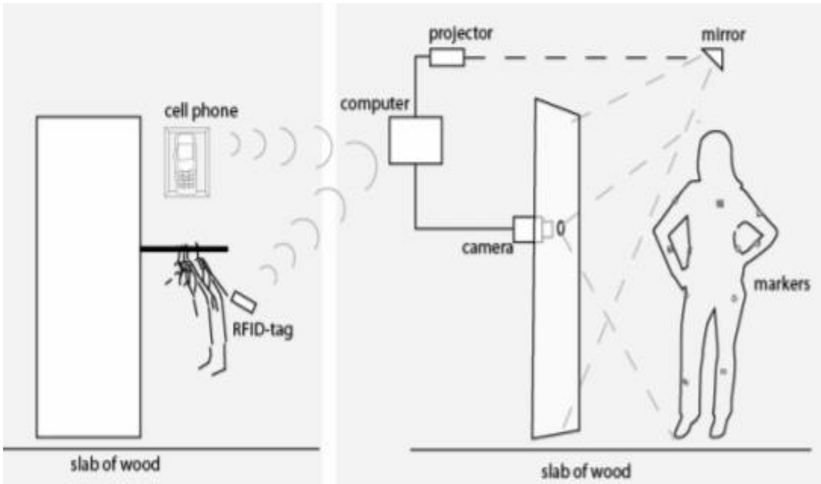


Figure 8. ARDressCode technical setup.

VRPN communication should be improved, as information will be received from mobile phones. ARDressCode can be used not only in the store but also at home. If the user wants to use it at home, necessary reference marks and a webcam are required. The user can try it in front of the computer.

When it comes to virtual dressing, we can either see the outfit on a real person or we can see it on a mannequin. In this article, Zakharov et al. explain how to make this talking head if a talking mannequin is to be used (Zakharov et al., 2019). Normally speaking pictures need to be trained on many datasets in many scenarios. This article explains how to resolve this situation with less effort. A personalized talking head can be created by transforming a picture with a different video. This situation is difficult for two reasons. First, the human head is very complex. Not only face modeling, but also situations such as mouth, hair, and clothes should be considered. Second, even a single mistake in the playable human head model can lose its realistic appearance. It has a low tolerance for error. Both classical warping fields and machine learning (including deep learning) were used in this project. Hours of GPU training with lots of large data are required for the talking head model.

Figure 9. Normal image (source), a video (target), and result.

Although modeling faces and modeling talking heads seem to be the same, different points need to be addressed to model talking heads (such as face and non-face parts, clothes.) The results of face modeling and mouth modeling can be added to a specific head video. But still, the head rotation movement cannot be done completely.

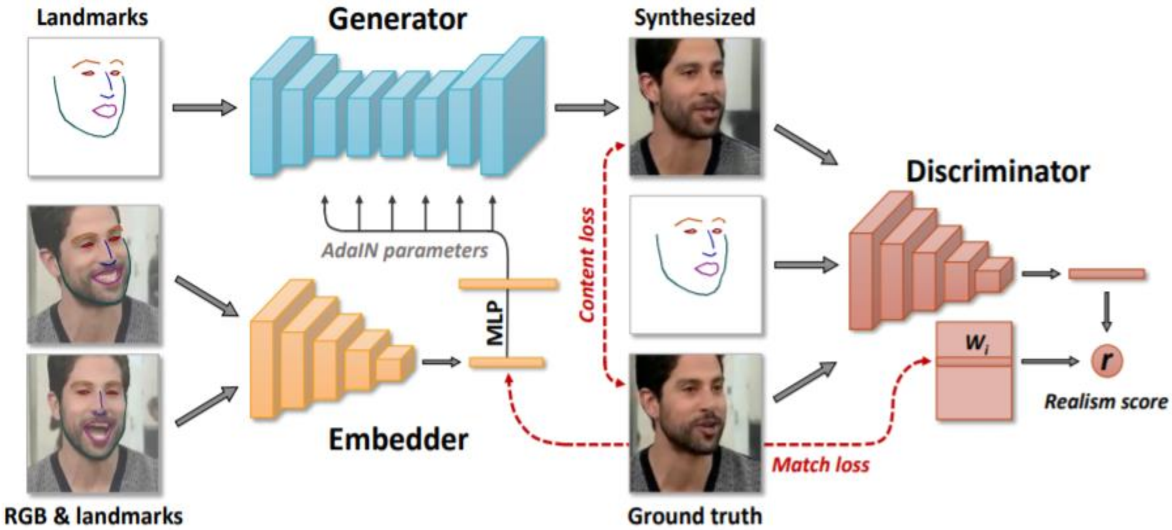


Figure 10. With the help of the meta-learning, head pictures are detected with facial signs. Face marks are brought into a suitable output state through the generator network. The frames captured from a video are averaged, and this is used to estimate the renderer's parameters. The image obtained is compared with the real photo and the facial marks of the different frames are passed through the generator.

Modeling 3D clothes is difficult and laborious. In this article, Sekine et al. describe their virtual application on 3D body shape, dressing 2D clothes. (Sekine et al., 2014 The application aims to catch the harmony of users with virtual clothes. Users stand in front of a large screen and try on virtual clothes as if standing in front of a full-length mirror. The system superimposes the clothing images over the image of the wearer's body. Two issues are important: First, how the cloth modeling will take place. The second is how to correctly place the clothing images on the wearer.

2D images are used to model clothes because 2D images are of better quality than 3D computer graphics (CG). In Figure 11, the diversity of the body shapes of the users and the different postures of the clothes can be seen. Even if each wearer is in the same pose, the appearance of the clothes is different. In this article, how the relationship between the wearer and clothing appearance will be discussed.

Figure 11. The posture of the clothes depending on the differences in body shapes.

First, the user's body shape is predicted. There are two stages: the pre-training phase and the run-time estimation phase. In the pre-training phase, a large number of 3D body models of the human body are produced for one pose. Subsequently, pre-trained depth images are created based on the 3D models. In the second stage, the run-time estimation phase, the 3D body shape model that matches the user is determined. In the last stage, a recording process is applied by minimizing the energy function of the selected model. The energy treatment is for the suit to fit the wearer. The body shape estimation process takes one second. After these processes are finished, it is time to choose a clothing model. A similar body shape model is searched from the clothing database. For the similar body shape model, the characteristic size is used in the body shape model shown in Figure 12.

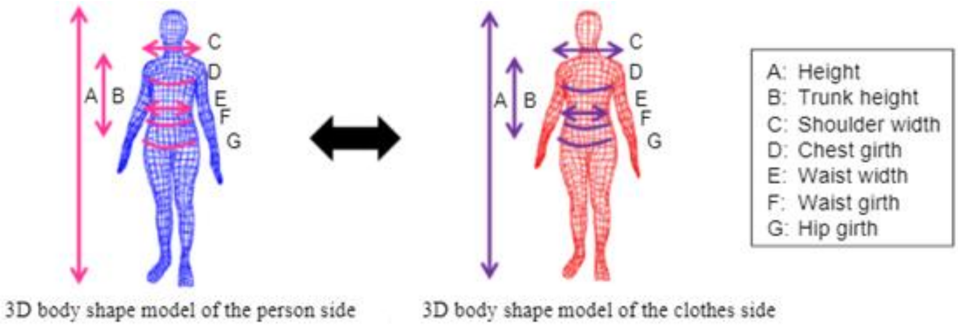


Figure 12. Search for images of clothing with a similar body shape.

For this system, its accuracy was tested using a 52-person test and 10 clothing patterns. Figure 13 shows examples of the results of placing the clothes.

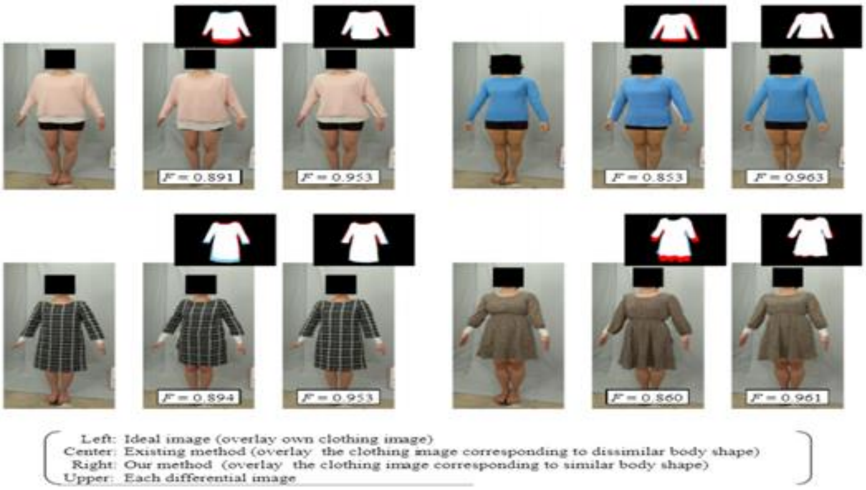


Figure 13. Clothes and user compliance examples.

The virtual trail system is shown in Figure 14 and Figure 15 can be seen. Positive sides of the system: Certain parameters are stored in the system, so getting results takes only seconds. Negative sides of the system: Users with body shape not included in the database were not satisfied because they could not get results. In this case, even more, various databases should be prepared.

Figure 14. Using a virtual fitting scene.

Figure 15. Virtual examples of the system.

In this article, Wedel et al. describe the role of VR and AR in consumer marketing. (Wedel et al., 2020). VR experiences can be used with various hardware such as head-worn virtual glasses (HDMs), cubic immersive spaces (CAVE), large screens (power walls), mobile devices, or computers. The difference between VR and AR is that VR creates reality entirely based on virtual knowledge. AR, on the other hand, enriches the real world perception with additional computer-generated visuals. The combination of both AR and VR is mixed reality (MR). You can see examples of Hololens, Oculus Quest, and Amazon AR View in Figure 16.

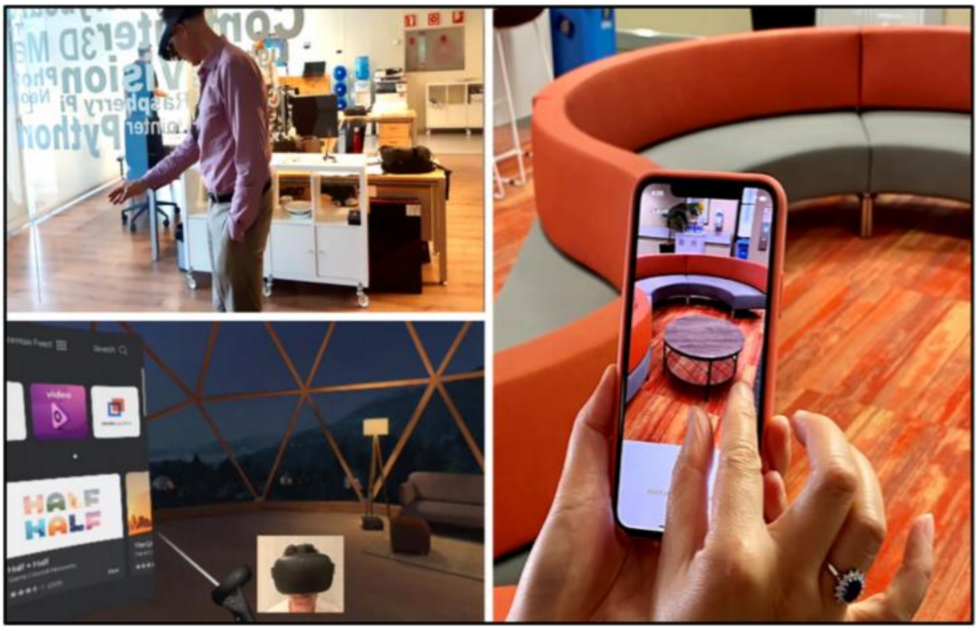


Figure 16. MR, VR, and AR applications.

As shown in Figure 17, consumers are using VR, and companies selling them. VR will become an ever-increasing experience. Wearable AR is expected to appear as eyeglasses in the future (Neal). Also, more sensors such as olfactory technologies, moving seats, 360-degree motorized treadmills (omnifinity.se) will be integrated into VR. Customers look at 3 items to adopt VR. The first is functionality and entertainment. Users can adopt VR based on experience and benefit. The second is the ease of use. If they can command the system/application with hand gestures, they adopt it more comfortably. The third is the consumers' desire to interact. Activities with multiple people or avatars, such as shopping with friends, watching sports with coaches.

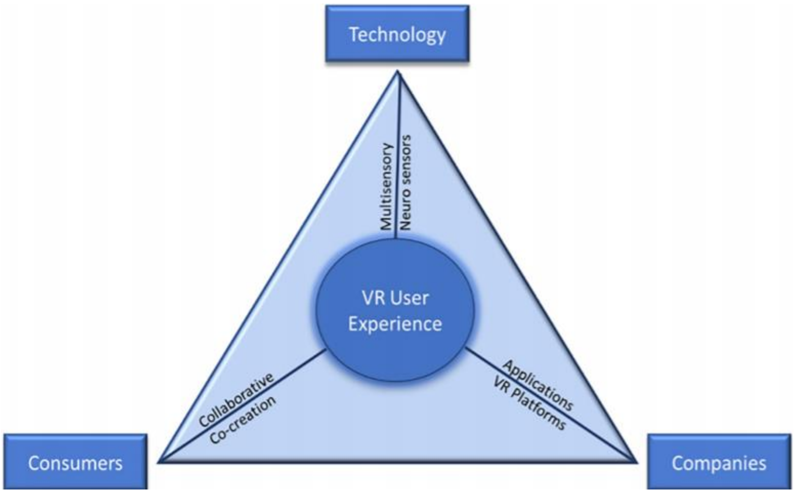


Figure 17. Aspects of the future VR experience relationship.

When dealing with AR and clothing, there are points to be considered in clothing. Lighting is important so that the result is as true as possible. In this article, Bradley et al. will talk about how garments can look real when you project on AR (Bradley et al., 2007). Being able to zoom in on clothes has led to its application in areas such as fashion and advertising. The project made in the article works with video images from the camera. Traceable marks are placed on the piece of fabric. The location of these marks is determined in each video frame. The operation of the system is shown in Figure 18.

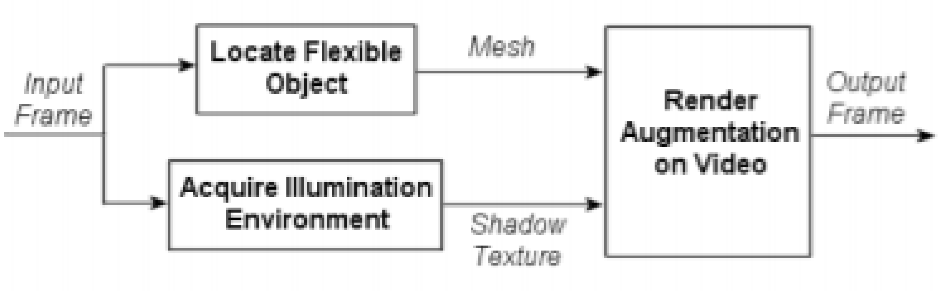


Figure 18. Augmented clothing system functioning.

Circular marks are placed on the surface to locate the fabric. These signs are shown in Figure 19. Sections outside the ring represent a 10-bit binary code used to identify the pointer. The system works as follows: By finding the contour regions of a gray-background input image, it calculates the contour centers of these regions. Then, these centers are triangulated and a cluster is formed by combining contour groups belonging to the same target. The closest contour to the cluster centers resembling the ellipse is chosen as the center again for each cluster.

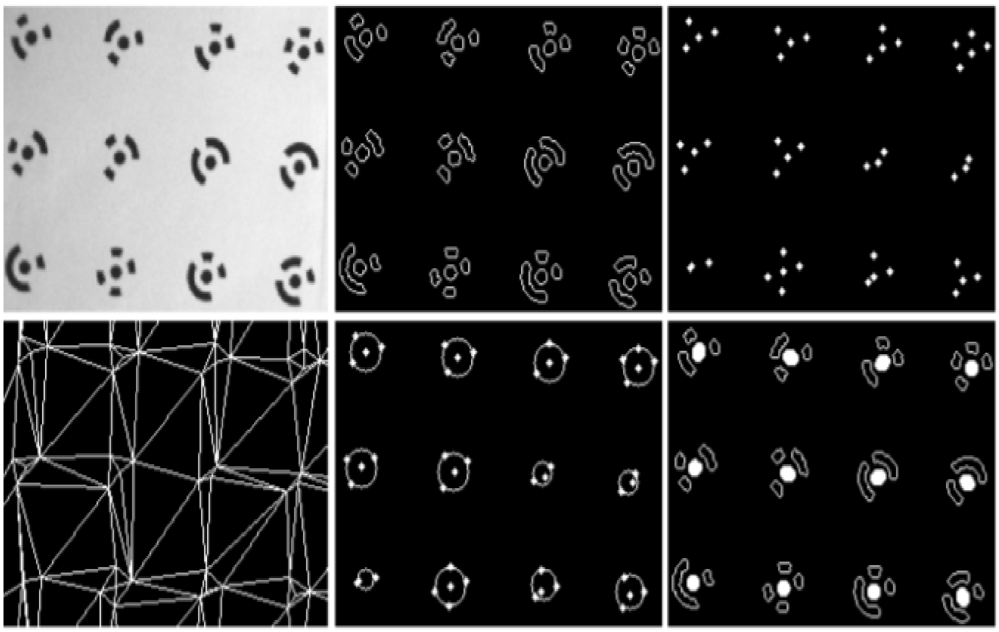


Figure 19. Starting from the top left entry, finding contours, finding contour centers, triangulating contour centers, clustering results, and finding target centers.

Zooming in an outfit takes 2 steps. The first step is to process the textured mesh. The second step is to redraw the mesh using the shadow texture and OpenGL blend. Figure 20 shows the illumination magnification in terms of a flexible sheet. Figure 21 shows the magnification of the wavy and wrinkled fabric.

Figure 20. Lighting example. Own shadow (left), full shadow (right) of an object (hand).

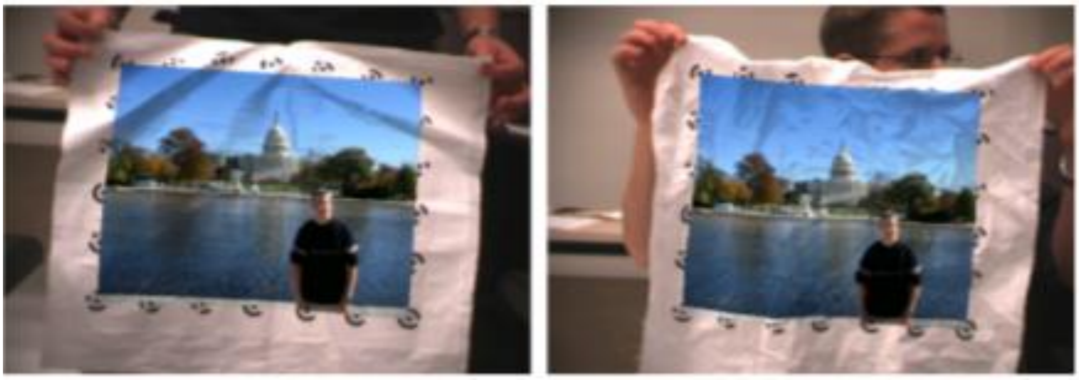


Figure 21. Wavy fabric (left) and wrinkled fabric (right).

The interface of the application of the AR clothing system is also shown in Figure 22. The user wears a T-shirt with a logo. Users can choose from different logos, expands on the shirt. In this case, the user can interactively select a logo or print on the shirt. This allows the user to create the desired design for his t-shirt. This area can be used for sports uniforms, museums for advertisements.

Figure 22. AR t-shirt logo application interface.

There are many projects on virtual dressing rooms. This article focuses on Eisert, and Hilsmann, interactive clothing for virtual dressing rooms (Eisert and Hilsmann, 2011). The user is watched by the camera and displayed on the screen by wearing a virtual suit. The following problems need to be addressed: The correct monitoring of fabric and body posture, and the realistic presentation of new garments in the correct poses. 3D computer graphics should be modeled. If you want to give a realistic and natural look, attention should be paid to details.

Instead of fitting the garment over the video, the garment is separated and checked for deformed parts on the surface of the garment. If there is, this is corrected separately. If the fabric is to be changed (its shape or color), then shading is done again for the fabric to regain a natural appearance. This situation is shown in Figure 23. Due to the individually structured fabric, very natural results are obtained.

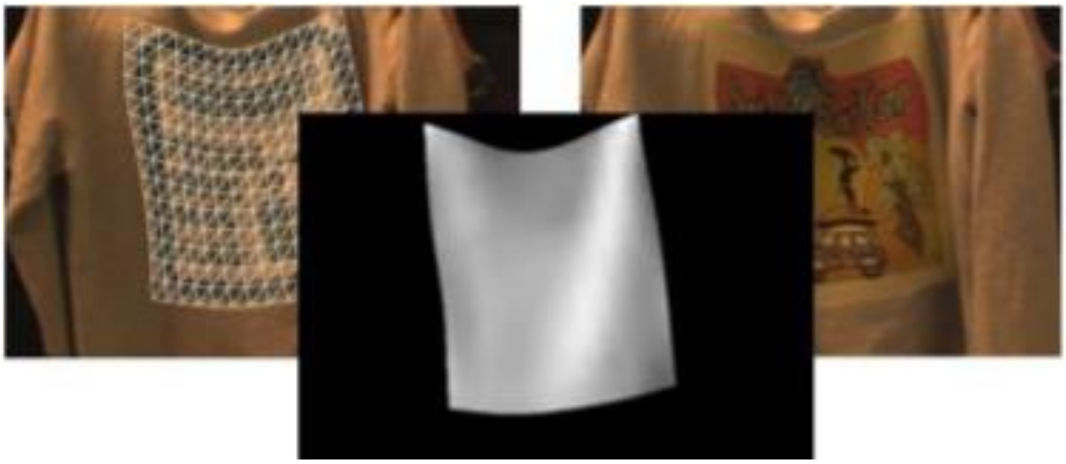


Figure 23. Separating and reshaping fabric from video.

Figure 24. The user in the virtual outfit in the video.

Virtual try-on of clothes is an AR application that will affect shopping. Especially customers, those who do not want to wait in line or those who want to shop at home will love this area and use it with interest. Instead of modeling the clothes in 3D, a new method such as removing the existing clothing from the video and arranging the deformed parts separately was mentioned.

Virtual dressing rooms is a project whose first steps were taken in 2010. However, research on the design and development of a virtual dressing room is not that much. The virtual dressing room application, which is based on visual monitoring of human body movements, which researches this subject, was mentioned (Erra et al., 2018). An experimental questionnaire was conducted to evaluate the validity of its applications. Mainly, the following question has been investigated: “To what extent does an AR technology for a virtual dressing room application impact the way customers shop?"

Two technologies are used: Microsoft Kinect 2 (a.k.a Kinect One) and Unity 3D. Microsoft Kinect is a device for the Xbox game console that detects users' gestures and spoken commands and enables them to be processed in the app. Unity 3D, on the other hand, is an engine used to create 3D content. These two technologies combine to allow the AR locker room to run on various operating systems. The usage planning for the Kinect project is shown in Figure 25.

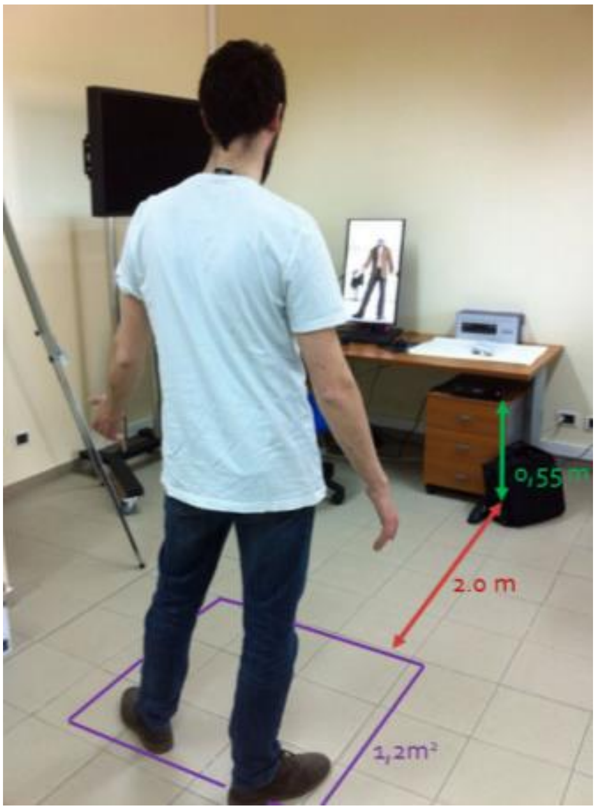


Figure 25. The intended installation of the virtual dressing room.

In the approach based on kinetic movements, the gland on the wearer's body is mapped in 2D. Therefore, when the wearer moves, the garment also moves in such a way that it can have non-aesthetic consequences. To overcome this problem, the suit was chosen to adopt the 3D model. For this approach to be used, a skeleton animation phase must be created on the 3D model of the suit. A 3D computer graphics program provides a skeleton to animate humans. 3D Studio Max was used for this purpose in this project. According to the dress, not all parts of the skeleton are used. For example, the lower leg is not used for a dress or skirt. The posture of these limb samples on the dress is shown in Figure 26.

Figure 26. A 3D dress is made. Then the skeleton is placed in the suit to match.

Euclidean distance from the head to one of the ankles is used to estimate the user's width, right-left shoulder span, and height. Then the application prepares a new skeleton frame. Clothes are 3Dl. Therefore, the user can move easily in front of the camera. However, the disadvantage of this is that when the user makes a move such as folding his arms, an artifact will appear. The 20 joints in the Kinect framework are monitored by Natural User Interfaces as in Figure 27.

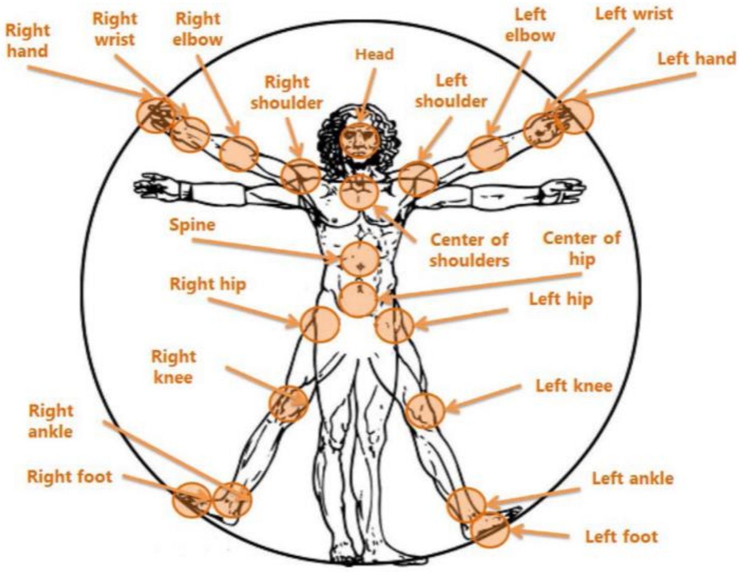


Figure 27. The skeleton consisting of 20 joints is used to better understand the body figure of the users.

Han et al. developed a project called VITION in an image-based virtual test network. (Han et al., 2018). VITON, an image-based Virtual Experiment Network, creates the image of the same person in the same pose with a rough synthesis of the desired garment. The aim here is to synthesize the photograph and the real photograph. The outfit tried by the model can take shape according to the pose of the model. Even when looking at the garment, it is shown in Figure 28 that it includes not only color but also texture and features such as embroidery and logo. From here, it is understood whether the texture of the clothes is hard or soft. Making these features without using 3D information is one of the biggest difficulties of this network.

Figure 28. The different clothes postures in different poses.

VITION uses a multitasking coder-decoder network to do this synthesis so that natural deformations and detailed visual patterns are conveyed. Figure 29 shows how VITION does a realistic virtual experiment in two stages. While doing this virtual experiment, 2D images are used as input.

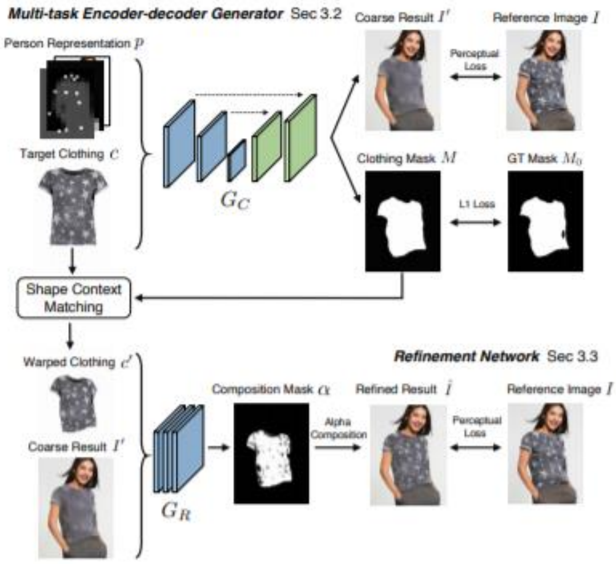


Figure 29. The first stage of the VITON an encoder-decoder generator stage, the second stage is refinement.

Conditional Generative Adversarial Networks (GAN) is one of the generative models that create image synthesis, editing, and images. While modeling, the focus was on 2D images that are more computationally efficient than 3D measurements for photo-realistic images. VITION aims to synthesize the targeted outfit according to the position in which it is positioned. The most challenging process of virtual trial synthesis is modeling the target garment by the pose of the model. While modeling, both the model and the target outfit must preserve its authenticity, for example, Figure 30.

Figure 30. Output of different clothes and models.

As a result, RGB images must be used to transfer the garment item to a person in the VITION trial net. While doing the synthesis, first a rough sample is created with a multitasking encoder-decoder. This rough image is enhanced by the enhancement net. 2D images can be used as an alternative to 3D-based methods while developing. How the clothing on the model is deleted is shown in Figure 31, and how the target clothing is synthesized on the model in Figure 32.

Figure 31. Removing pose and body shape from the person's representation.

Figure 32. Effectively renders the target clothing on to a person.

Visual harmony synthesis is very important for fashion analysis. Confirming this in virtual shopping is a difficult process. Han et al. developed a project for compatible and diverse fashion image inpainting (Han et al., 2019). Fashion Inpainting Networks is a two-step image-rendering framework, a shape-forming network capable of in-painting, and a view-building network. This network will play an active role in fashion synthesis. However, the texture and colors of the items that complement each other when brought together are extremely important. The modeling of this fashion compatibility can also be applied to real-world applications. This system, formulated as a harmonious dyeing problem, synthesized many colors of the model and the target garment without deformation, as shown in Figure 33.

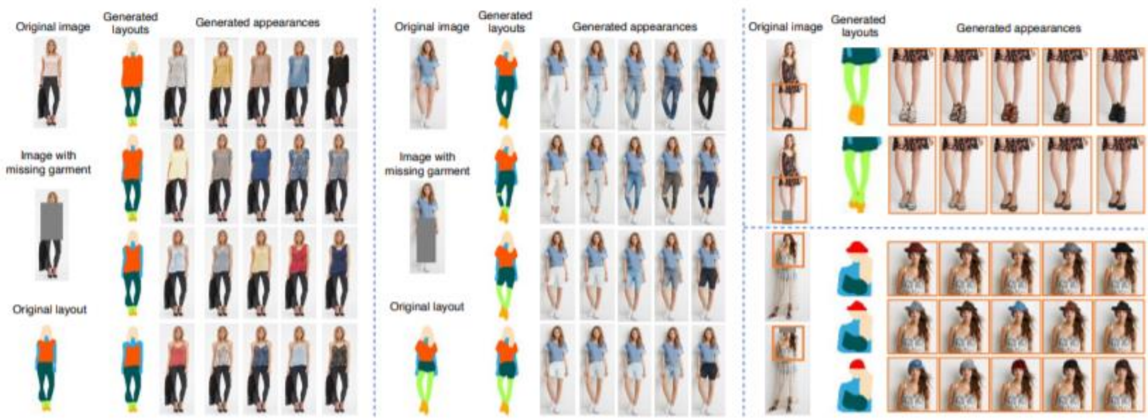


Figure 33. The combination of different colors of clothes on the same model.

As a result, FiNet is a two-stage generation network and synthesizes fashion images. It can paint the clothes in the target area in desired shapes and looks Also, the compatibility module is integrated into the network. This is limited by its proximity to clothing items. Sensitive and harmonious fashion design aims.

Wang et al. designed a project that aimed to further develop the virtual test network projects and did not find it sufficient to just try on the model (Wang et al., 2018). In virtual trial applications, it is not enough to show only the clothes on the model. At the same time, the texture of the garment should preserve the originality of the embroidery of the logo. While the suit is integrated, it should not lose its identity. Unlike previously tried methods, a network that aims to protect this identity is the CP-VTON. By using the Geometric Matching Module (GMM) and the trial module, it aims to lighten the artifacts in the image and to transform and integrate them to fit the body. How the clothes are integrated is shown in Figure 34.

Figure 34. Realistic image-based virtual try-on results.

The image-based virtual trial system offers an economical way because it does not require using more effective and expensive devices without the need for 3D knowledge. Synthesis takes place as follows: First of all, the target outfit is dressed on the model, the body shape and pose of the model are preserved, the outfit is bent by the model's body, and while the bending is provided, the texture of the garment is protected, such as embroidery. The most striking application in image conditioned virtual testing is VITON, but it did not adequately capture the harmony between clothing and body. Increasing the harmony between experiments and images is provided by CP-VTON. Includes a thin plate curve transformation for more robustness and alignment via the Geometric Matching Module. If there is no lack of alignment, it uses the Trial Module to dynamically combine skewed results. It aims to align the outfit with the geometric matching module (GGM) and the Shape Context Matching Module (SCMM). The trial module, on the other hand, ensures that the texture of the clothes is embroidered, in short, its identity is preserved. He showed how he did this m-synthesis in Figure 35.

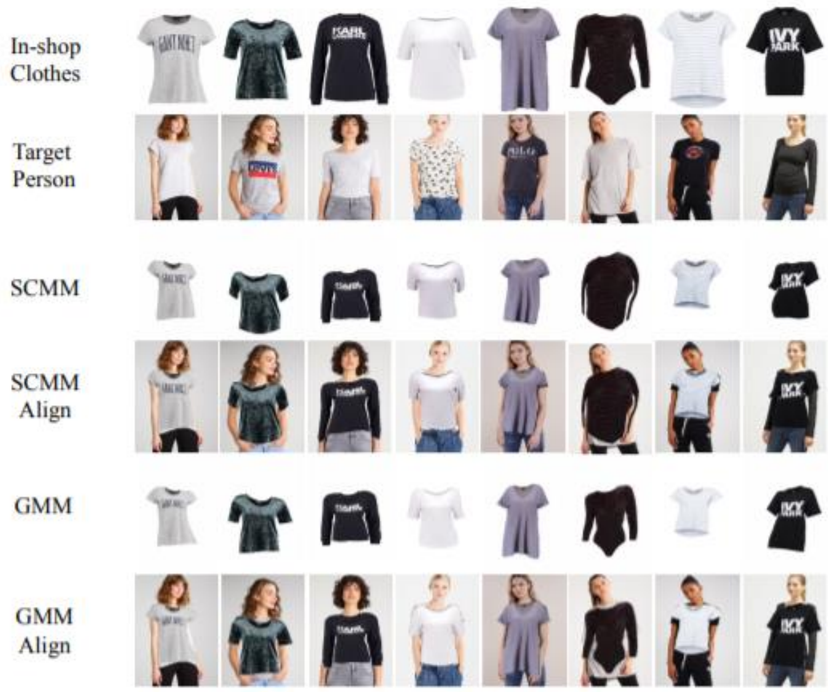


Figure 35. Matching results of SCMM and GMM.

Kore et al. planned the virtual dressing application based on AR (Kore et al., 2020). Time is one of the resources being used up in the developing and growing world. Most people do not have the time to go to the store and try on clothes for hours to find the right clothes. For this reason, online shopping is preferred for classic shopping. However, although online shopping can be done today, customers often have question marks about how they will look in the outfit. It is possible to use AR to eliminate this problem, to ensure customer satisfaction, and even to increase store sales considerably. In this way, customers will be able to view 2D clothes in 3D on themselves through the camera of their smartphones while shopping online, for example, Figure 36.

Figure 36. Object recognition as a marker.

There are slight differences between VR and AR. Virtual reality offers its users another world isolated from the real world. The AR we are talking about combines the virtual world and the real world most simply. Supporting AR applications with a cloud system such as ARCloud; It is also possible to use ARKit and ARcore to give a healthier result of the amount of light and body movements in the image.

Another research was done by Isikdogan et al. in a real-time virtual dressing room using Kinect. (Isikdogan et al., 2012). This article describes a virtual dressing room application using the Microsoft Kinect sensor. The virtual dressing room offers faster and easier shopping. It makes this possible by identifying the user's body from the video stream thanks to the Kinect sensor. We are facing some problems in practice, it is correct overlap. We see a real-time virtual dressing room application that does not require visual labels in Figure 37.

Figure 37. A set of poses that are used in the evaluation of the performance.

Holte et al. have written about making virtual dressing rooms more usable (Holte et al., 2015). In this article, there is information about how the virtual dressing room should be, based on the expectations and evaluation of the user. Various studies have been conducted in these rooms that should be user-centered, and their results have been reported and cited. Most people today hesitate when buying clothes online and sharing body measurements. The reason for the return of the clothes is that the clothes do not fit properly. In this way, both retailers and customers experience problems. This room to be built addresses this problem. In this way, consumers have the opportunity to virtually try out 3D clothing before purchasing the clothes. The virtual dressing room consists of two modules. The first of these is the front-end module and the avatar of this person is created according to the person's body size. Since this avatar has the approximate size of the person, it will be easily seen how the targeted clothes look. The second part is each back-end module and enables the production of digital clothing. It uses the 3D scanning method while producing this dress. You can also see this virtual dressing room in Figure 38.

Figure 38. Virtual dressing room.

The Front-End Avatar Solution measures the user's body shape using the Microsoft Kinect sensor. The results from the measurement are used to transform the user's avatar in real-time while creating it. We can accept the avatar created in this way as a reflection of the user. The user will be able to dress this avatar in any outfit he wants. Many issues have also been considered when optimizing so that the user can see how it will fit on the chosen outfit before purchasing it.

The Back-End 3D Cloth Scanning uses the Microsoft Kinect sensor as well as the front-end. The reason for using it here is to digitize real clothes. It performs this process in approximately 60 seconds. While performing, the surface scanning process is performed and RGB images are used. If any problems are encountered while the image is being created and the textures are missing, it is determined by artificial intelligence (K-Nearest Neighbors). A virtual clothing room was created using computer vision, 3D imaging, and 3D scanning, and the System Usability Scale (SUS) was used to investigate usability. The reality of the avatar was appreciated by the user, although it did not get full marks. It was suggested that the identification of the user with the avatar should be improved.

The anatomy-based article on virtual suits was also written by Meixner et al (Meixner et al., 2016). In product development in the ready-made clothing industry, no kinematic human models, the results obtained by people in an upright position are taken into account. Product development also requires consideration of the characteristic posture of the person for high functionality, especially in medical/orthopedic applications. The main purpose of research here enabling the creation of a kinematic human model for clothing engineering from the scanning data of individual persons and for more useful products, one's characteristic posture was taken into account. Kinematic information was transferred to 3D surfaces to get a better service for the users. In this way, different body postures were achieved. Also, a kinematic template based on MRI data and anatomic basic principles was created to adapt the movement automatically to different body postures. In this research, the creation of movement sequences is based on the anatomical structure that was previously from the system. Thanks to this anatomical structure, 3D garments are created and affect the fit of the garment. Since the general rules are followed, there is an approximate harmony. As seen in Figure 39, the cylinder model is examined and verified. Thanks to this cylinder, 3D surface data is animated and allows the use of templates representing the kinematic model. It also starts from a simple structure like a cylinder because it is easier to test and moves from simple to complex. Since the process will be performed for the scanned surface data of different people at the last stage, sample models are created for different body postures.

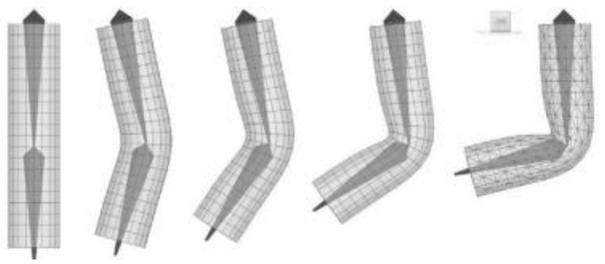


Figure 39. The cylinder model is examined and verified.

For proper animation, the steps shown in Figure 40 should be followed. To adjust the body proportions correctly, the lengths of bones and muscles must be measured and the template must be interactively adjusted according to the scanned surface data and the person. Considering the research results, it revealed that anthropometrically accurate reproduction is possible.

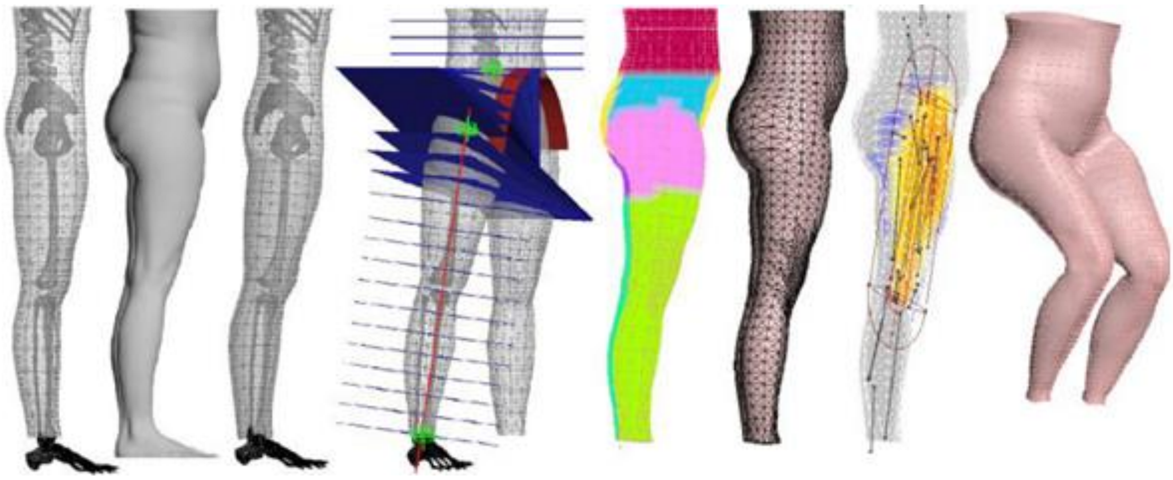


Figure 40. How to make the animation step by step.

Liua et al. investigated the feasibility of the virtual clothing trial based on digital printing data. (Liua et al., 2016). With the development of e-commerce, shopping for clothes on the Internet has increased, and this has brought the problem of virtual clothing testing. In this research article, he mentions an AI-based model to assess garment fit. The model is based on Naive Bayesian and takes digital garment pressures of different body parts generated from 3D garment CAD software as input. The output is how the fit is. To be able to print this compliance quickly and automatically, data on digital garment printing and compliance were collected first. The test results showed that one of the evaluation methods, machine learning-based clothing fit had higher accuracy. 3D virtual clothing systems (such as Clo 3D, Lectra 3D Prototype) generally have the same structure. First of all, they need a 3D mannequin model. Then to the target outfit for this mannequin. It uses a 3D parametric mannequin module to quickly model the human model and creates it quickly and automatically. This module meets customers' body shapes and sizes. Through virtual experimentation, it can be easily determined whether the style of clothing suits it, but it cannot give an accurate garment fit assessment. After a customer uploads his/her photograph to the system, the system adjusts a parametric human model according to the user's body structure. As seen in Figure 41, patterns, clothes are found from the company's database according to body measurements, and clothing patterns are assembled on an adjusted digital human model and the patterns are combined. It is sewn together to create 3D virtual clothing. Finally, digital clothing pressures are measured at predefined key positions, and digital garment prints are included in the garment fit assessment. As a result of this research, it showed that the use of machine learning is useful to predict clothing fit, but we may have difficulty getting accurate results when using it in real life due to the very small data set.

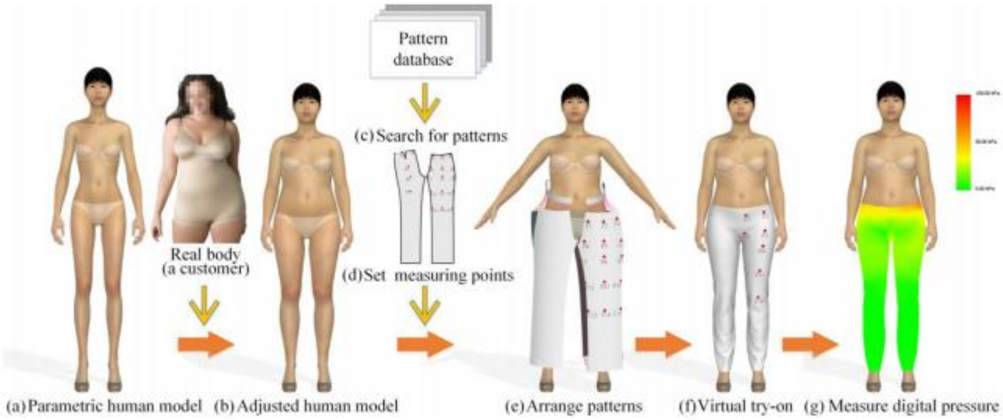


Figure 41. 3D human model adjustment and virtual try-on.

Another virtual dressing room project was done by Adikari et al. using a single depth sensor. (Adikari et al., 2020). In this article, physically trying clothes will cause a waste of time for the user and will cause extra difficulty for the employees. In this article, a virtual dressing room is presented as a solution to this problem. 3D clothes and AR were used for virtual dressing room applications. Since the body measurements of each user are different, Microsoft Kinect V2 was used to obtain user body parameter measurements. The system aims to place the 3D clothes on the user in real-time and react to the movement simultaneously. It offers customers who want to experiment, the opportunity to experiment in front of a large screen. It has also been observed that these ways attract the attention of customers and increase sales. A virtual fitting room enables customers to leave more satisfied. With the single depth sensor, the suit moves synchronously according to the movement of the user. Equipped with several sensors, capable of capturing RGB images and sound. The Kinect V2 sensor has an internal processor. Thanks to this processor, the workload is reduced. The application consists of two parts: The Windows Presentation Foundation (WPF) application and Unity3D. WPF detects the user's body features and measurements with Kinect's sensors. The gender of the user is determined according to the measurements.

The WPF application performs non-contact body parameter measurements with the user standing in the T-pose. In Figure 42, we see the t position, it is enough for the user to stay in this way for 5 seconds. The 3D model is fitted to the user's body in real-time as seen in Figure 43. This application provides a realistic experience for the user by adding physics animation to the suit according to the physical movements of the user.

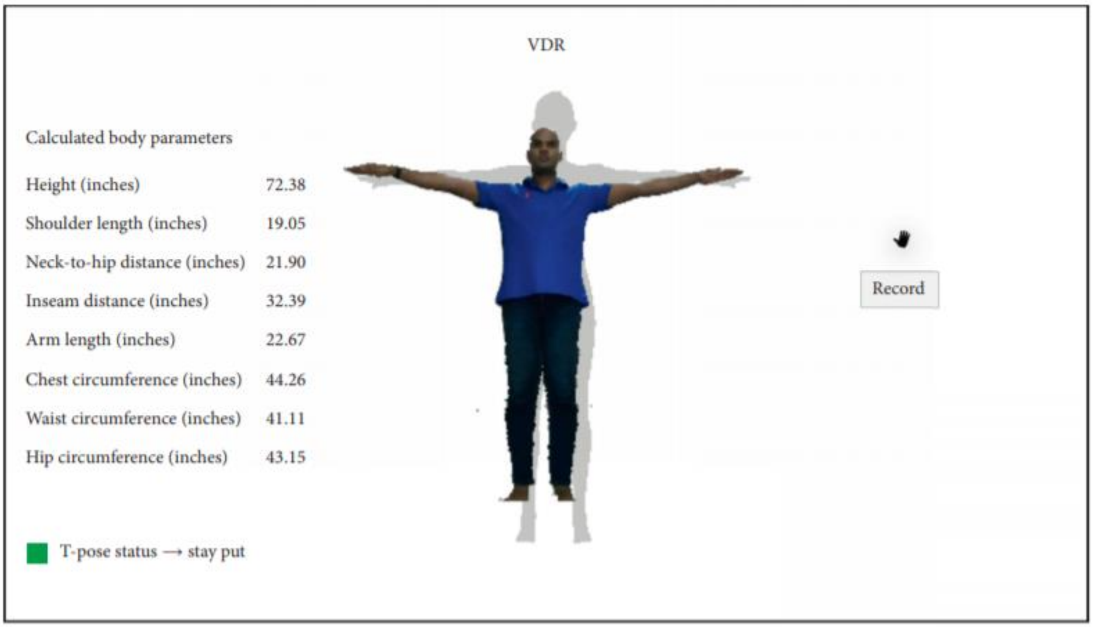


Figure 42. T-pose facing towards.

Figure 43. Virtual dressing room for 3D clothes simulation.

Erra et al. researched the AR virtual dressing project. (Erra et al., 2015). In this article, we will talk about the virtual mirror's experience with 3D model clothes and AR. Thanks to this technology, the customer will be able to understand whether the dress is suitable for him or not without trying the rhyme. Also, thanks to Microsoft Kinect and Unity 4 Pro, the customer will be able to continue their experience even if they move. Thanks to its advanced user interfaces and high-quality 3D scanning feature, it was preferred in this sector. The user interface allows the selection of clothes by hand gestures. Still, it needs improvement. Similar approaches to an augmented dressing room have been made before. Cecilia Garcia Martin et al designed their approach to be compatible with the webcam. The algorithm starts with sensing the user's face and body. After determining the reference points, the clothes are dressed. It is allowed to use 2D images to make this dressing happen. In another approach, it suggests a tag-based approach with manual markings. With these labeling systems, the AR of customers is created by using image processing techniques. In another approach, small colored marks are used on certain connection points of the user. These marks are placed manually. The ability of this approach to work also depends on the location of the user, if it is lateral the system will not work. Another approach scales according to the distance between the user and the Microsoft Kinect based body tracking sensor. In the study in the article, skeleton animated 3D suits are provided by using Microsoft Kinect-based body tracking technologies. This feature also provides the flexibility of movement.

A section is given in Figure 44 from the example of the application. The buttons on the left and right are for dress selection. The user can change his dress by hand movement. It is enough to wait two seconds for the dress to change. The top right button controls the size of the user. In this article, we see that Unity Pro and Microsoft Kinect are used when designing the AR dressing room. They are preferred because they are inexpensive and easy to use. Each inventory item needs to be modeled and textured.

Figure 44. Some examples of dresses.

Since MR can simulate 3D objects and environments, taking the user into a virtual world, using conventional media allows for more perspectives than are seen. To simulate a real fitting room, MR can be added where the user can put on a virtual dress without taking off any of their clothing. Users can try on virtual clothing as a mirror image by simulating a virtual garment superimposed on the user body, with many viewable angles as they move (Kaewrat and Boonbrahm, 2017).

It was found that making a good virtual fitting room depends on two significant factors such as the method of detecting the scale, location, and movement of the user's body and the method of displaying the virtual clothes superimposed on the body of the user. MR covers AR and VR just as can be seen in Figure 45.

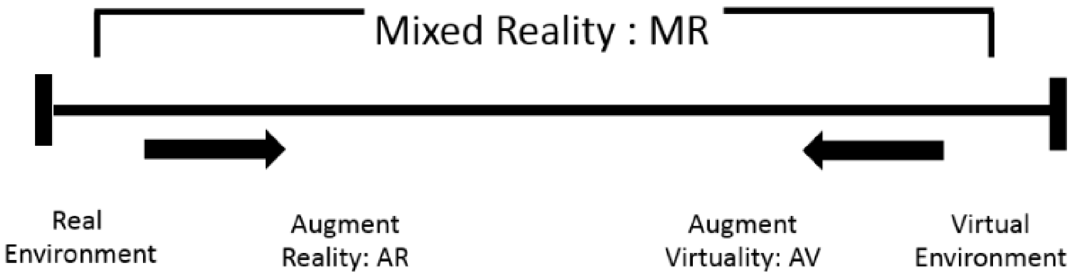


Figure 45. Visualization of AR and VR.

There are 2 aspects of AR technology to consider as the Detective aspect and the Display aspect. The Detective aspect enables a virtual entity to be viewed in a real-world location. For this, 2 methods can be used. The first uses "Maker", which is a technique based on markers. When a marker is identified, it will be processed to simulate the appropriate location of virtual objects. The second technique does not use a marker ('marker-less') but uses a camera and software such as Kinect to track movements of objects or bodies. They have to consider 3 specific areas to create a perfect virtual fitting room: the method of measuring the size of the user body, the method of adding realism to the show, and the method of realistic movement.

To body measuring, the main purpose is to find the user's correct size so that it will not happen to pick the wrong virtual clothing size. The basic sizes of garments that consumers can choose from are S, M, L, and XL in the real world. According to their body shapes, clients can select any size. Using a tape measure, calculating body proportions in the real world can be achieved easily and then comparing those parameters with tables that can say the size of clothing that will suit the consumer better. There are several common clothing sizes, such as the common US clothing size and the standard Asian clothing size, since people's body sizes are different in different parts of the world. As an example, Asian people have smaller body sizes than people in the US. Microsoft Kinect is required to make realistic movements of garments that move along with the body. Microsoft Kinect's camera and depth sensor are shown in Figure 46. Kinect can track the user's skeletal movements and can specify bone positions, as can be seen in Figure 47.

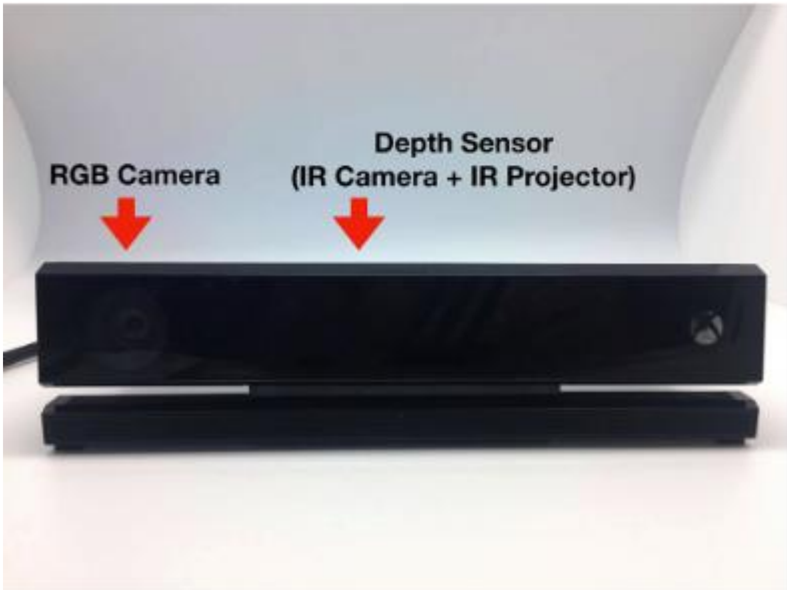


Figure 46. Microsoft Kinect camera and sensor.

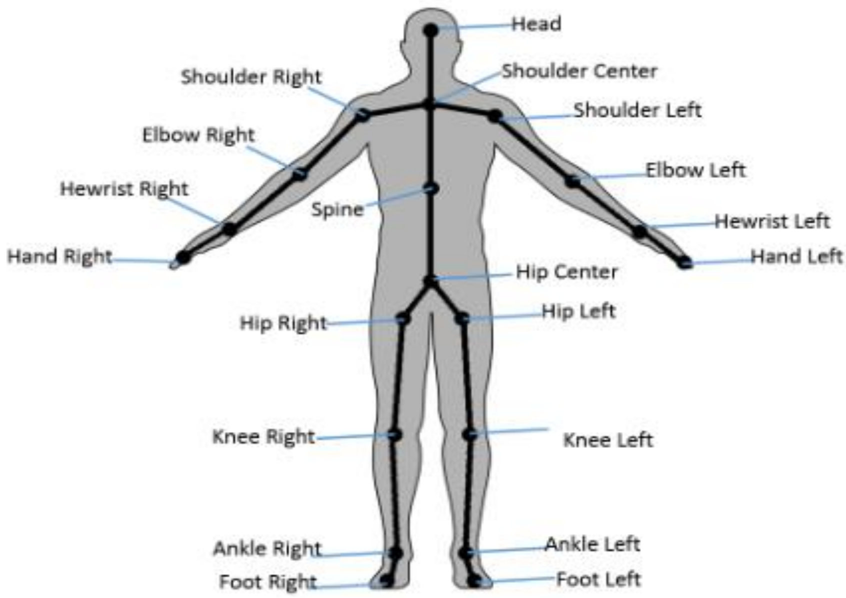


Figure 47. Skeleton joints of a human body.

A user can touch or wear real garments in the typical fitting room, and the clothes can change following the movement of the user. However, it is just a view, or a visual display, of the garment that the user will encounter in the virtual world. The user can interact with virtual garments by adding realism to virtual reality or making virtual garments move realistically. For this reason, much of the show should typically be wide enough so that the user's whole body, wearing virtual clothes, can be seen, just as in a typical fitting space. A display of the entire user's body and virtual garments can be seen by the use of large-screen monitors or TVs. They have found from the literature survey that for virtual fitting rooms, i.e. 2D and 3D, there are two types of garment displays available. A 2D image of the garment will be added to the user with the 2D display of virtual garments. The 2D virtual garment will not move along with the body if the user changes their position, or just move along with a small angle, which makes it an inaccurate visualization. The user will see various views of what he or she is wearing using a 3D image of the clothes superimposed on the body of the user, and if the user moves, the virtual clothing follows. Therefore it is an important part of simulating a virtual fitting room to produce a reality show, and many researchers have tried various techniques to do that.

The business of today is witnessing the fourth industrial sector textile and clothing revolution, in which there are specific revolutions digitization and virtualization are under consideration. This process is implemented based on the most important research priorities – virtual modeling and design of fibers, fabrics, and garments. Therefore, in the past decade, 3D body scanning systems and 3D CAD systems with virtual try-on software gained considerable attention. Virtual prototyping with virtual try-on software provides significant benefits to the apparel manufacturers. Virtual prototyping of 3D garments represents not only fit to the body, which is the main purpose, but also garment pattern design, style, colors, virtual human body, and mechanical properties of fabrics. 3D CAD systems are used for 2D apparel pattern assembly and draping on 3D virtual mannequins for prototyping of garments, virtual fitting sessions, and fabric behavior imitation. Today the majority of apparel CAD software provides 3D virtual try-on modules (Lagė et al., 2020).

Virtual mannequin preparation is one of the most important parts of the garment virtual try-on process. To get the best result of garment fit to the human body, precise anthropometric data are necessary. Many researchers compared the real garment appearance on the human body with the 3D virtual garment appearance on the virtual mannequin using 3D scanning and 3D CAD systems and evaluated garment fit taking into account the structural and mechanical parameters of the fabrics. There are mainly two methods to evaluate garment fit and comfortability through virtual try-on.

First of them is a visual assessment of 3D garment fit when pressure, stress, and fit maps are generated by virtual try-on software. The second method is to measure the ease of allowances in the selected girths or air layer thickness between the garment and the human body showed a way to solve the problem of garment ease distribution using 3D scanning data of a clothed and unclothed body. Calculated the distance ease – the shortest distance from the body curve to the garment curve in cross-sections of scanned clothed and unclothed mannequin.

Researchers try to combine 3D scanning and virtual try-on technology to design the best fit of a garment. For effective practical use of virtual try-on, it needs to be investigating how practically garment fit is simulated by the particular technology and whether there is a gap between the real and virtual garment. However, most of the scientists focus on comparing the garment fit of a real and virtual body model with a parametric mannequin using a 3D CAD system. There is another approach for evaluating a garment fit to use the actual scanned 3D body model.

Ashdown investigated whether 3D virtual try-on technology can effectively visualize the fit and silhouette of pants. Results showed that the accuracy of virtual try-on is quite useful, especially for pants with a good fit, but not to the extent that experts could fully use it as a visual fit analysis tool. Lee compared the pants fit for obese women using the 3D virtual and real garment. They stated that 3D virtual garment simulation was reliable because there was no significant difference in appearance caused by materials between a real and virtual garment.

The ease of virtual and real garment was similar. Virtual try-on and 3D body scanning technologies are efficient, convenient, and valuable tools for visual fit analysis. It is very important to prove virtual try-on matching with the real garments. The bust girth of the mannequin passes through the highest points of the bust, while the waist girth is at the narrowest part of the waist. Bust and waist girths on the garment correspond to bust and waistlines in the 2D basic block pattern. 2D dress patterns and 3D dress with marked bust and waist girths on a garment is shown in Figure 48.

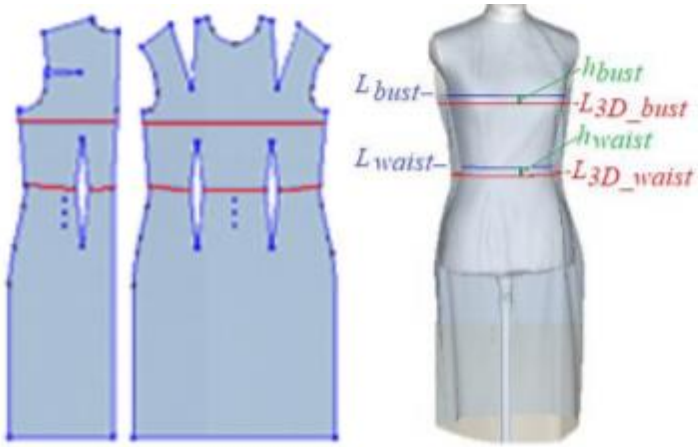


Figure 48. 2D dress patterns and 3D dress with marked bust and waist girths on the garment. The red color is for waist girths on the garment, the blue color is for the mannequin and the red color is for mismatches between girths.

It was defined that differences between the length of real and virtual dresses perimeter lines at bust girth L3D_bust varied from 0.1% to 3.4% and from 0.1% to 4.9% at waist girth L3D_waist. However, 3D distance ease values had higher differences comparing virtual and real garments. From 12.3% to 48.3% lower than real dresses for all mannequin sizes. These dresses occurred with wrinkles in the bust area because of the highest shear rigidity G what might be not simulated precisely and caused differences compared with other fabrics. The lowest differences in distance ease in all sizes showed fabric 05. The difference of distance ease between real and virtual dresses at waist girth ES3D_waist varied from 7.3% to 43.3%, except fabric 03 in all sizes. The difference ES3D_waist of fabric 03 varied from 31.2% to 47.3%.

Online apparel shopping offers the convenience of shopping from the comfort of one's home, a large selection of items to choose from, and access to the very latest products. However, online shopping does not enable physical try-on, thereby limiting customer understanding of how a garment will look on them.

For 3D methods, conventional approaches for synthesizing realistic images of people wearing garments rely on detailed 3D models built from either depth cameras or multiple 2D images. 3D models enable realistic clothing simulation under geometric and physical constraints, as well as precise control of the viewing direction, lighting, pose, and texture. However, they incur large costs in terms of data capture, annotation, computation, and in some cases, they need specialized devices, such as 3D sensors. For conditional image generation methods, multiple-garment approaches treat the entire outfit in the training data as a single entity. Second, they are trained on data that is nearly unfeasible to collect at scale. In the case of paired data, single-garment images, it is hard to collect several pairs for each possible garment. In the case of single-data, multiple-garment images it is hard to collect enough instances that cover all possible garment combinations.

GANs have demonstrated promising results in image generation and manipulation. Conditional GANs try to address this issue by adding constraints to the generated examples. Besides, the composition of images has been demonstrated using GANs, where content from a foreground image is transferred to the background image using a geometric transformation that produces an image with a natural appearance (Neuberger et al., 2020).

CP-VITON uses a convolutional geometric matcher to determine the geometric warping function. All the different variations of the original VITON require a training set of paired images, namely each garment is captured both with and without a human model wearing it. In, a GAN is used to warp the reference garment onto the query person image. No catalog garment images are required, however, it still requires corresponding pairs of the same person wearing the same garment in multiple poses.

The works mentioned above deal only with the transfer of top-body garments. Initially, it generates a warped segmentation of the query person to the reference outfit and then overlays the outfit texture. This method uses self-supervision to learn shape and texture transfer and does not require a paired training set. However, it operates at the outfit-level rather than the garment-level and therefore lacks composability. The recent works also generate fashion images in a two-stage process of shape and texture generation. Figure 49 provides the details of shape generation.

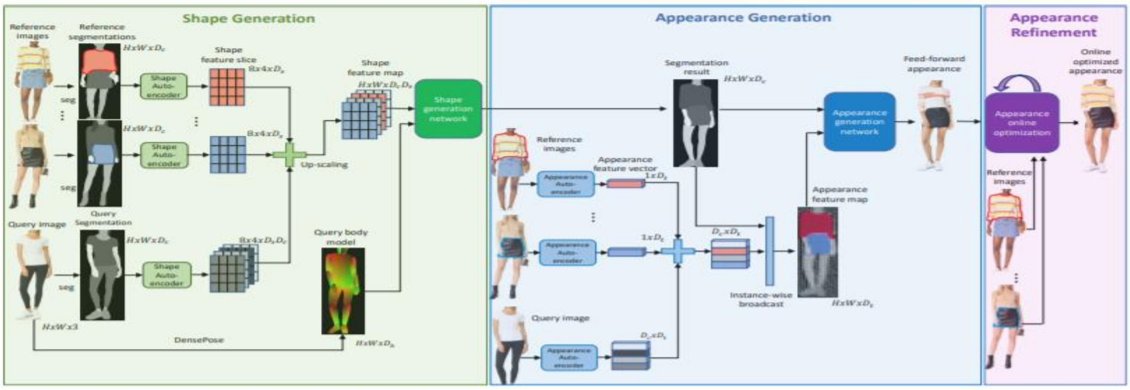


Figure 49. An overall diagram of shape generation, appearance generation, and appearance refinement.

A photo-realistic virtual try-on system would be a significant improvement for online shopping. Whether used to create catalogs of new products or to propose an immersive environment for shoppers, it could impact e-shop and open the door for new easy image editing possibilities. The training data they consider is made of paired images that are made of the picture of one cloth and the same cloth worn by a model. An early line of work addressed this challenge using 3D measurements and model-based methods. However, these are by nature computationally intensive and require expensive material, which would not be acceptable at scale for shoppers. However, this method fails to generate realistic results since these networks cannot handle large spatial deformations. In VITON, the authors use the shape context matching algorithm to warp the cloth on a target person and learn an image composition with a U-net generator. To improve this model, CP-VTON incorporates a convolutional geometric matcher which learns the parameters of geometric deformations to align the cloth with the target person. The warping U-net is composed of two connected modules as shown in Figure 50 and the Comparison of their method with CP-VTON is given in Figure 51.

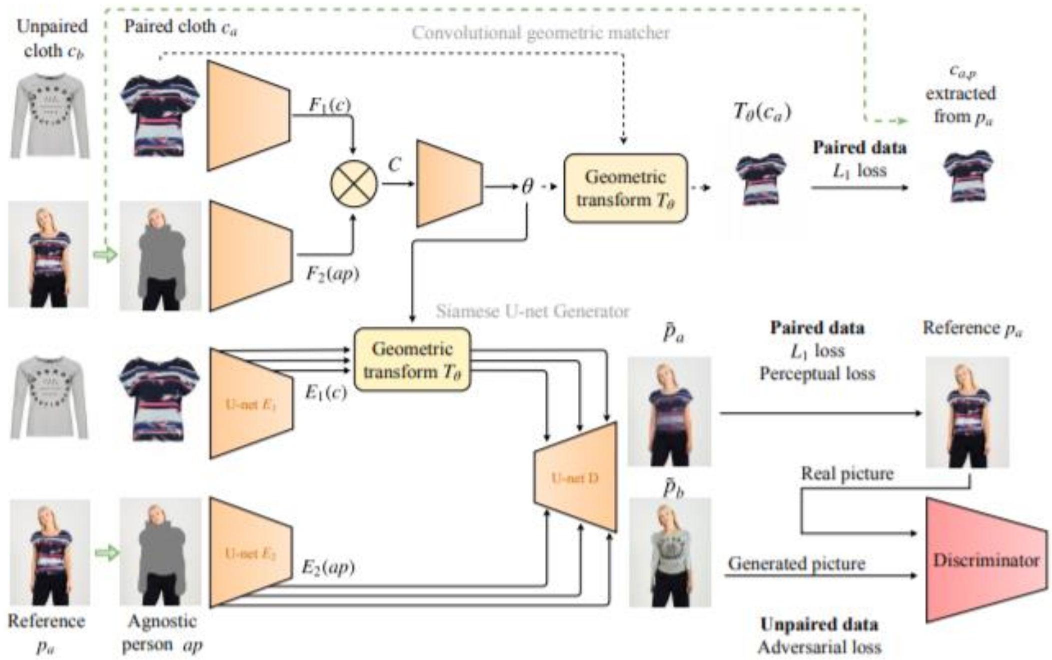


Figure 50. WUTON: Proposed end-to-end warping U-net architecture. Dotted arrows stand for the forward pass only performed during training. Green arrows stand for the human parser. The geometric transforms share the same parameters but do not operate in the same spaces.

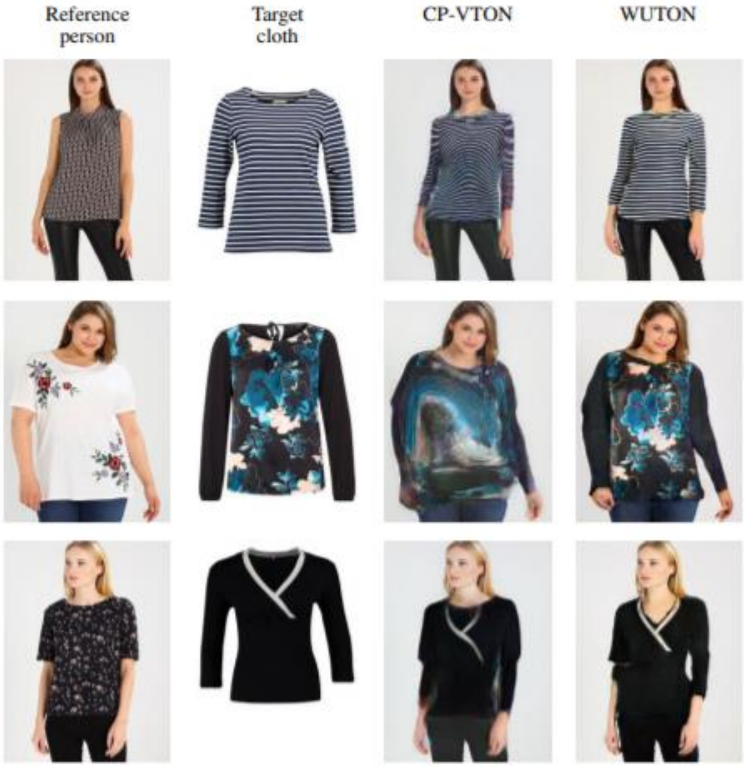


Figure 51. Comparison of the mentioned method with CP-VTON.

In this second line of approach, a common practice is to use what they call a human parser which is a pre-trained system able to segment the area to replace on the model pictures: the upper-body cloth as well as neck and arms. In the rest of this work, they also assume this parser to be known. The recent methods for a virtual try-on struggle to generate realistic spatial deformations, which is necessary to warp and render clothes with complex patterns. Indeed, with solid color tees, unrealistic deformations are not an issue because they are not visible. However, a tee-shirt with stripes or patterns will produce unappealing images with curves, compressions, and decompressions (Issenhuth et al., 2019).

Figure 52 below shows these kinds of unrealistic geometric deformations generated by CP-VTON. To alleviate this issue, they propose an end-to-end model composed of two modules: a convolutional geometric matcher and a siamese U-net generator. They train end-to-end, so the geometric matcher benefits from the losses induced by the final synthetic picture generation. Their architecture removes the need for a final image composition step and generates images of high visual quality with realistic geometric deformations.

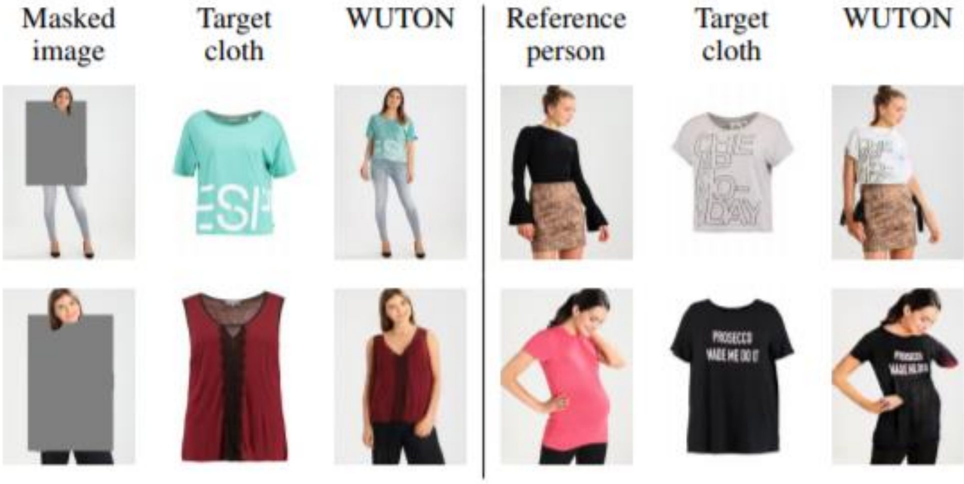


Figure 52. On the left side, the method can handle low-quality masks at the cost of a generic arm pose. On the right side some common failure cases of the method. Detection of initial cloth can fail beyond the capacity of the U-net generator (first row), and uncommon poses are not properly rendered (second row).

For Conditional image generation, Generative models for image synthesis have shown impressive results with the arrival of adversarial training. However, these models cannot handle large spatial deformations and fail to modify the shape of objects, which is necessary for a virtual try-on system.

Most of the approaches for a virtual try-on system come from computer graphics and rely on 3D measurements or representations. Drape learns a deformation model to render clothes on 3D bodies of different shapes. The task they are interested in is the one introduced in CAGAN and further studied by VITON and CP-VTON.

Learning to synthesize the image of a person conditioned on the image of clothes and manipulate the pose simultaneously is a significant and valuable task in many applications such as virtual try-on, virtual reality, and human-computer interaction. In this work, they propose a multi-stage method to synthesize the image of a person conditioned on both clothes and pose. Given an image of a person, the desired clothes, and the desired pose, they generate the realistic image that preserves the appearance of both desired clothes and person, meanwhile reconstructing the pose, as illustrated in Figure 53. The head of the person fails to identify while conditioning different poses.

Figure 53. Some results of the model by manipulating both various clothes and diverse poses. The input image of the clothes and poses are shown in rows, while the input images of the person are shown in columns.

The aim is to learn a mapping function from an input image of a person to another image of the same person with a new outfit and diverse pose, by manipulating the target clothes and pose. Although the image-based virtual try-on with the fixed pose has been studied widely, the task of multi-pose virtual try-on is less explored. Besides, without modeling the mapping of the intricate interplay among the appearance, the clothes, and the pose, directly using the existing virtual try-on methods to synthesize images based on different poses often result in blurry artifacts. Targeting the problems mentioned above, they propose a novel Multi-pose Guided Virtual Try-on Network that can generate a new person image after fitting both desired clothes into the input image and manipulating human poses (Dong et al., 2019).

Their MG-VTON is a multi-stage framework with generative adversarial learning. To seamlessly fit the desired clothes on the person, they warp the desired clothes image, by exploiting a geometric matching model to estimate the transformation parameters between the mask of the input clothes image and the mask of the synthesized clothes extracted from the synthesized human parsing. As a result, they present a refinement network utilizing multi-pose composition masks to recover the texture details and alleviate the artifact caused by the large misalignment between the reference pose and the target pose. To demonstrate their model, they collected a new dataset, named MPV, by collecting various clothes images and person images with diverse poses from the same person.

GANs consist of a generator and a discriminator that the discriminator learns to classify between the synthesized images and the real images while the generator tries to fool the discriminator. And the discriminator focuses on distinguishing between the synthesized and real images. Inspired by those impressive results of GANs, they also apply the adversarial loss to exploit a virtual try-on method with GANs

For Person image synthesis, Skeleton-aided proposed a skeleton-guided person image generation method, which conditioned on a person image and the target skeletons. V-UNET introduced a variational UNet to synthesize the person image by restructuring the shape with a stickman label. The reason behind that is they ignore to consider the interplay between the human parsing map and the pose in the person image synthesis.

For virtual try-on, VITON and CP-VTON all presented an image-based virtual try-on network, which can transfer a desired clothes on the person by using a warping strategy. FashionGAN learned to generate new clothes based on the input image of the person conditioned on a sentence describing the different outfit. CAGAN proposed a conditional analogy network to synthesize person image conditioned on the paired of clothes, which limits the practical virtual try-on scenarios. To generate the realistic-look person image in different clothes, ClothCap utilized the 3D scanner to capture the clothes, the shape of the body automatically.

In this work, they make the first attempt to investigate the multi-pose guided virtual try-on system, which enables clothes transferred onto a person's image under diverse poses. Their MG-VTON decomposes the virtual try-on task into three stages, incorporates a human parsing model is to guide the image synthesis, a Warp-GAN learns to synthesize the realistic image by alleviating misalignment caused by diverse pose, and a refinement render recovers the texture details. Extensive experiments demonstrate that their MG-VTON significantly outperforms all state-of-the-art methods both qualitatively and quantitatively with promising performances.

The simulation of textiles has been a topic of extensive research in the computer graphics community for well over 20 years. Most cloth simulation techniques assume that the garment consists of only a single type of homogeneous material. note that most sewing approaches in cloth simulation systems merely merge the border vertices of the seam line. They focus on the simulation of seams and present an approach that can accurately represent the effects caused by their presence. A women's dress simulated using the relevant techniques are shown in Figure 54.

Figure 54. Dress simulated using the techniques that were proposed using measured tensile and bending material data.

The literature on cloth simulation is abundant and it is impossible to provide a complete list of related work due to space constraints. Bending Most cloth simulation systems take the approach to treat in-plane deformations independently from out-of-plane deformations (Pabst et al., 2008).

First, they describe their bending model and several issues related to it. They show how to deal with cases where the mesh resolution is too low to properly model the seam. They use a virtual bending testing device to show that the seam model is accurate. Finally, they examine how the seam model enhances the realism of the simulation of a women's dress by comparing it to its real-world counterpart. They close with a critical analysis of the strengths and shortcomings of their approach and point to promising future work directions.

For cloth models, like many other cloth simulation systems, they take the approach to treat the in-plane deformations independently from the out-of-plane deformations. Out-of-plane deformations will be treated in more detail in Section 3. In-plane deformations are handled using a continuum mechanics formulation of linear elasticity theory.

For the bending model, their treatment of out-of-plane deformations is, as are many other models, based on the dihedral angle formed by two adjacent triangles.

For bending stiffness, their approach is related to the one proposed by Bridson et al. However, the elastic bending stiffness parameter used by Bridson et al. lacks a physical foundation and it is not clear how one would compute the parameter for a given textile sample in their approach. They, therefore, propose a bending model based on the moment-curvature relationship of fabrics.

As a result, to demonstrate the validity of their approach, they perform three kinds of tests. Secondly, they perform draping tests using the simulation and compare their outputs to actual draping experiments. Since they are interested in the simulation of fabrics using measured material properties, the linear bending stiffness factor is set to $\beta = 1.0$ for all simulations presented in this section and thus does not have any influence.

The use of a mirror environment enables the augmentation of the user with artificial objects without the user being forced to wear special glasses. At their innovation center, a customer cannot choose only shoes from the shelf but design personalized models. A camera captures the customer wearing regular shoes. The display is mounted such that the shoes/legs appear at the same position, where the user would expect to see them when looking into a real mirror. An example of a virtual mirror is shown in Figure 55.

Figure 55. Virtual Mirror presented at the IFA 2007.

To enhance the virtual feeling of the framework, the background is segmented and replaced by a synthetic environment. A novel 3D motion tracker estimates the position and orientation for each foot using a model-based approach that is very robust and can easily be adapted to new shoe models. Once the exact feet positions and orientation in 3D space are known, the computer graphics models, that have been configured and colored according to the customer’s wishes, are rendered and integrated into the video stream such that the real shoes are replaced by the virtual ones. Special care has to be taken for this augmentation since the real scene in the 2D video should occlude parts of the virtual 3D shoe models. Therefore, visibility for all parts of the shoe has to be computed for a given position. Since all algorithms have been implemented with real-time constraints, the customer can move freely and watch himself/herself with the new shoes that have been designed just some moments earlier (Eisert et al., 2008).

For system description, the system mainly consists of a single camera and a display showing the output of the Virtual Mirror. The camera is mounted close to the display and looks down, capturing the feet of a person standing in front of the system. The legs of the user are segmented from the background and displayed on the screen after mirroring the video signal horizontally. The placement of the display and the viewing direction of the camera are chosen such that an average-sized person sees about the same as he/she would expect when looking in a real mirror located at the same position as the display. Visualization of the virtual mirror architecture is shown in Figure 56.

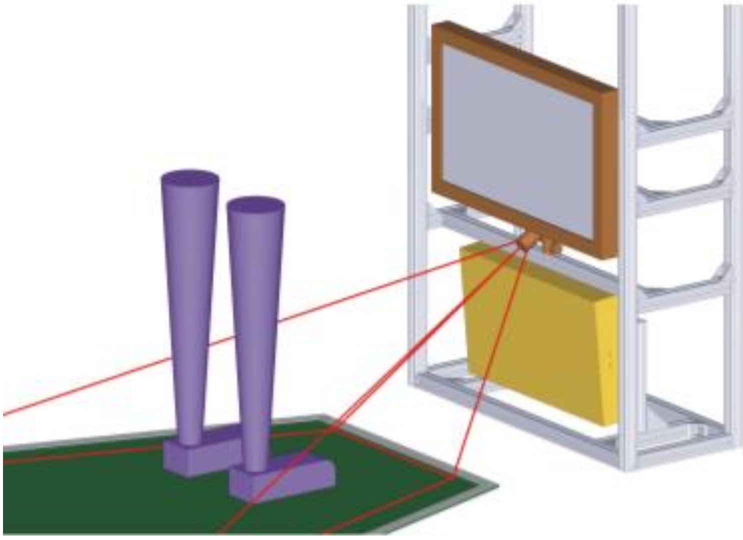


Figure 56. Virtual mirror architecture.

For image processing, the calibrated camera of the Virtual Mirror continuously captures the space in front of the system and transfers the images with a resolution of 1024 by 768 pixels to the image processing components. To avoid interference with artificial illumination, the shutter time is synchronized with the flickering of the lights. This idle state is determined by a change detector that exploits information about the Spatio-temporal variations in the video signal. After the camera gain has been adjusted to the current lighting situation, a background image is computed by averaging 10 consecutive video frames. The image pyramid of background segmentation is given in Figure 57.

Figure 57. Background segmentation is shown with an image pyramid.

For 3D tracking, Both cases are difficult to describe by texture-based tracking while the silhouette still provides enough information for tracking. In total, 12 parameters are estimated using an analysis-by-synthesis technique similar to the face tracker described in. 3D computer graphics models specifying the shape of the shoes are rendered into a synthetic image approximating the camera frame. By reading out the z-buffer of the graphics card, information about the shoes' silhouettes and their dense depth information is obtained.

The innovation concept is so recognized that it also became a part of the cultures. Innovation ability has become a characteristic of every successful company in almost all industries. Retailing also benefits from innovation. Retailers need to integrate technology and innovative approaches in their strategy to become dominant in the competitive industry environment (Köse and Akgül, 2016).

In this study, by mentioning the dynamics of the fashion industry, a few of the innovative approaches are explained. While there are many ways to use innovation in fashion retailing, this study focused on radio frequency identification, body scanning, virtual-try-on, AR, and magic mirror. It is aimed to prove the importance of innovation for fashion retailing and also state the benefits provided by the innovative approaches.

In AR techniques, virtual and real objects are integrated into a real environment. AR systems need to run interactively and in real-time, and an alignment of virtual and real objects is one of the most significant issues. They intend to apply an AR technique to a virtual clothing system, in which a user can watch himself/herself wearing clothes even if the user is not wearing those clothes. In the virtual clothing system, an AR technique is used to overlay arbitrary texture patterns onto the surface of clothes (Ehara and Saito, 2006).

Related systems based on overlaying virtual patterns onto real surfaces have been proposed previously, such as overlaying virtual patterns onto a planar surface and curved surface. There are several kinds of studies on virtual clothing. An example of an approach is to overlay texture onto the surface of a user by using computer graphics techniques. An approach using motion estimation of a person from an image sequence was also proposed.

Motion estimation is a method to transform a certain model into a corresponding image of the person and recognize the human motion with the transformed model shape. An example of research using motion estimation for 3D human body modeling using the spatial and temporal gradient method is described in. These approaches do not need a 3D model in advance, so they reduce the computational burden of constructing a model of each object or person and run in real-time.

The setup of their virtual clothing system is shown in Figure 65. A user wears a plain T-shirt and stands in front of a blue curtain. Then, a prepared texture image of the clothes that the user wants to try on is transformed and overlaid onto the captured image.

In the learning phase, they train their system on the relationship between the positions of the markers and the silhouettes of the T-shirt with various shapes. The texture image of the clothes is appropriately transformed and overlaid onto the input images according to the deformation of the T-shirt. Here, they assume that the deformation of the T-shirt depends on the silhouette of the T-shirt, which can be extracted from the input image. An outline of the proposed method is shown in Figure 58.

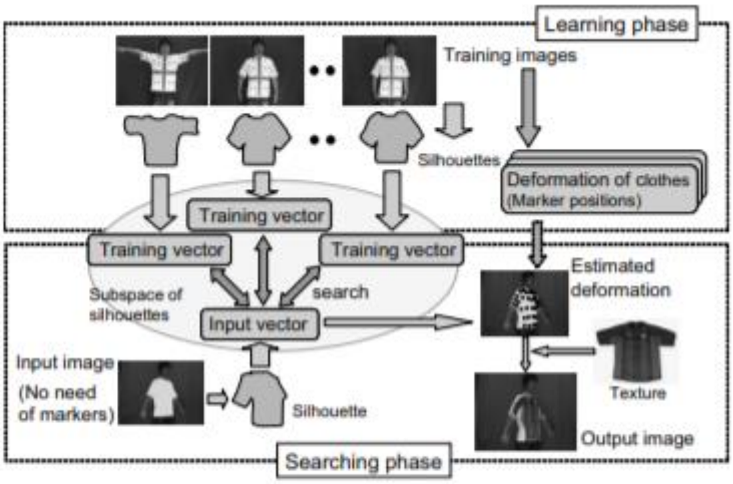


Figure 58. Method outline.

In the learning phase, a person wears a special marked T-shirt shown in Figure 59. They trained their system with the silhouettes of the T-shirt shown in the training images used in this phase. T-shirt in the training image, as described below. After extracting the silhouette of the T-shirt from the training image, they transform the outline of the silhouette into 360 sample points in the polar coordinate system.

Figure 59. Marker T-shirt.

Next, scale the size of the outline so that the average value of the 360 distances of the scaled outlines of each training image is equivalent to each other. This scaling process enables us to use training images with any outline size. Use Principal Component Analysis to represent the silhouette feature dθ of the training image with a small number of principal component scores. The dimension of the silhouette features is reduced when the sum of contribution ratios is greater than 90%. They call the feature vectors of the training images the training vectors. These positions are manually retrieved.

The texture image of the clothes a user wants to try on is transformed to fit the silhouette in the input image and overlaid onto it. In the same way as that of the learning phase, the silhouette is extracted from the input image and transformed into 360 distances, which are the silhouette features of the input image. These features are transformed into the feature vector in the subspace computed with PCA. They call this feature vector of the input image the input vector.

Then, a search for the training vectors, which are within a certain distance of the input vector in the subspace, is conducted, and a predetermined number of training vectors are selected beginning with the closest one to the input vector. The silhouettes that correspond to the selected training vectors are supposed to be similar in shape to the silhouette in the input image.

In the experiment phase, nonetheless, a user can wear a plain T-shirt without any marker on the surface in the searching phase, they use a T-shirt with markers like that used in the learning phase in these experiments to verify that the deformation of the T-shirt in the input image can be estimated properly. Training images with the body leaning sideways and arms moving up and down are shown in Figure 60 and training images with the rotation of the body are shown in Figure 61.

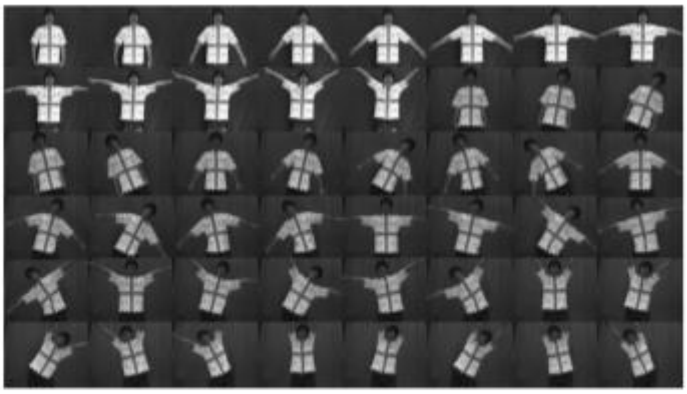


Figure 60. Training images with body leaning sideways and arms moving up and down.

Figure 61. Training images with rotation of body.

As a result, they proposed a method for overlaying arbitrary texture images onto a surface of a plain T-shirt in real time for a virtual clothing system. The deformation of the surface of the T-shirt was estimated from the silhouette of the T-shirt taken from the input image based on a pre-collected database of several shapes of the T-shirt. They performed experiments for virtual clothing based on the proposed method for estimating the deformation of the surface of the T-shirt.

AR is a technology in which a user's perception of the real world is enhanced with additional information generated from a computer model. AR allows a user to work with and examine the physical world while receiving additional information about the objects in it through a display. In a typical AR system, a user's view of a real scene is augmented with graphics. Estimating the pose of the camera, in which some augmentation takes place, is the most important part of an AR system (Genc et al., 2002).

The vision-based trackers used in AR are based on the tracking of markers. The use of markers increases robustness and reduces computational requirements. Direct use of scene features for tracking instead of the markers is much desirable, especially when certain parts of the workspace do not change in time. The use of these rigid and unchanging features for tracking simplifies the preparation of the scenarios for scene augmentation as well.

They are sometimes used for increasing the accuracy and the range of the tracking in the presence of a marker-based tracking system or combination with other tracking modalities. They describe a general system that tracks the position and orientation of a camera observing a scene without any visual markers. In the first stage, a set of features is learned with the help of an external tracking system while in action. The second stage uses these learned features for camera tracking when the system in the first stage decides that it is possible to do so.

Some of these use a mobile camera to track a set of markers in the visible spectrum, and some track retroreflective markers in the infrared spectrum. More involved systems use stationary cameras to track markers attached to objects, e. Attempts to use scene features other than specially designed markers have been made in the literature. Most of these were limited to either increasing the accuracy of other tracking methods or extending the range of tracking.

Other methods that are based on image matching techniques have also been proposed. Work in computer vision has yielded very fast and robust methods for object tracking. However, none of these is particularly useful for the accurate pose estimation required by most AR applications. Pose estimation requires a match between a 3D model and its image.

The method suggests a general method for feature-based pose estimation in video streams. It differs from the existing methods in several ways. First, the proposed method is a two-stage process. The system first learns and builds a model of the scene using off the shelf pose and feature tracking methods.

After this learning process, tracking for the pose is achieved by tracking these learned features. The outcome of the learning process is a set of 3D features with some associated uncertainties. Finally, an advantage of their method over the model-based ones is that they can use features on the textures and highlights. Their method builds an implicit model using only the most salient features observable in the given context.

The proposed vision-based marker-less tracking system aims at the use of real scene features for estimating the pose of a camera. The user could start using the system in his or her usual environment. As the user works with the current system an automated process runs in the background. This process remains hidden until the feature-based system decides to take over the pose estimation task from the other tracker.

While the AR system together with another tracking system is in use, the system uses any available feature extraction and tracking methods to detect reliable features2. These may include basic features such as points, lines, circles, and planar patches or composite features such as polygons, cylinders, etc. The system tracks each feature in the video stream. Once a feature is reasonably tracked over several frames, the system uses the

6 DOF pose provided by the existing tracking system to obtain a 3D model for this particular feature. At this point, the feature tracking, for this particular feature, becomes a mixed 2D-2D and 3D-2D matching and bundle adjustment problem. The general idea of learning or training is presented in Figure 62.

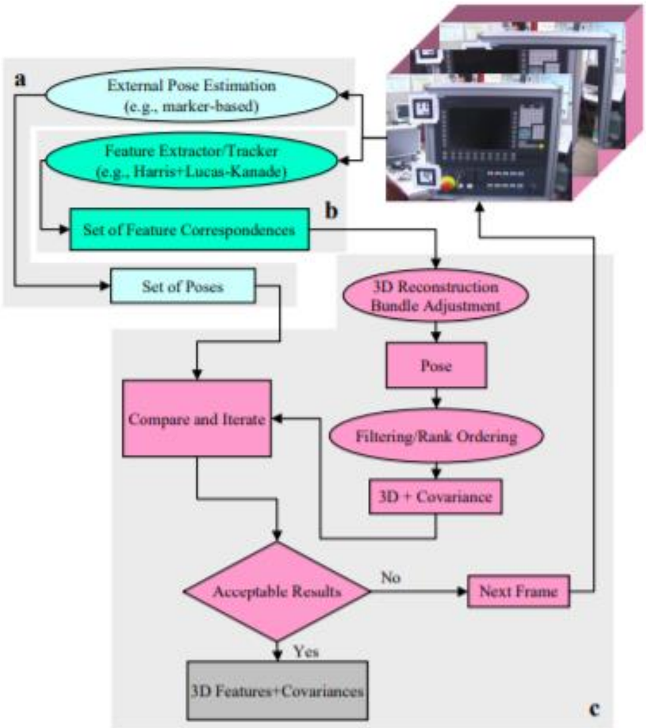


Figure 62. The phase of learning or training of the proposed system.

Once a model is available, the marker-less tracking system uses the available feature extractors and trackers to extract features and match them against the model for the initial frame and then track them over consecutive frames in the stream. Once the tracking system has been initialized, i.e., the pose for the current frame is known approximately, it can estimate the pose for consecutive frames. Initial model matching can be done by an object recognition system. This task does not need to be real-time, i.e., a recognition system that can detect the presence of an object with less than 1fps speed can be used. This process is shown in Figure 63.

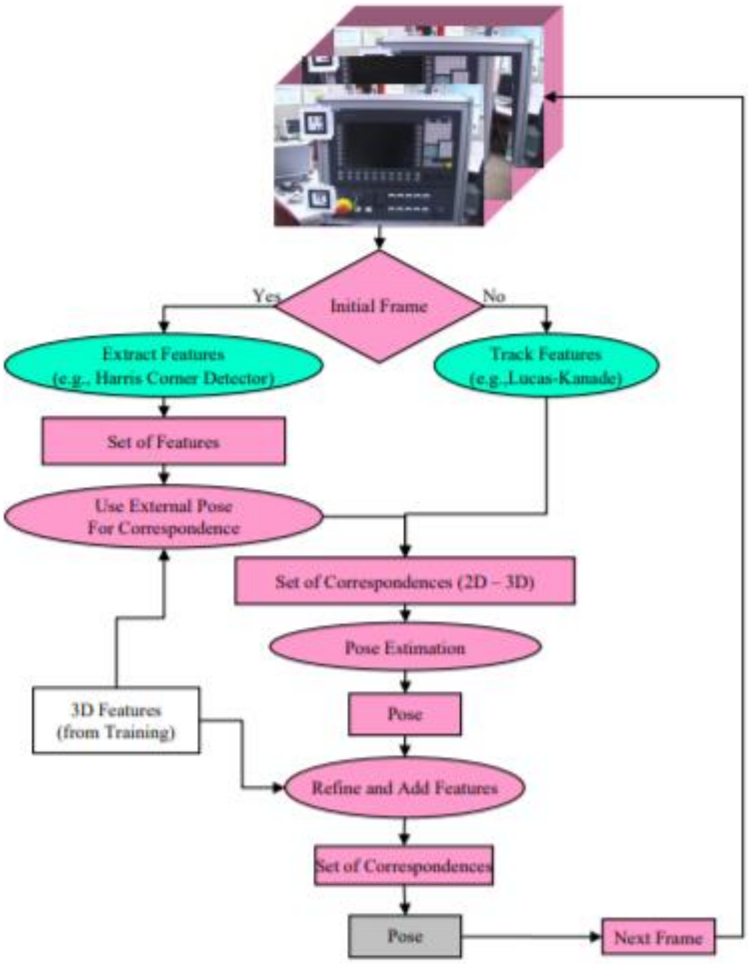


Figure 63. The tracking process in the proposed system.

As a result, the system first learns the scene structure by utilizing an external tracking system. This training step results in an implicit model of the 3D scene. This model includes the scene coordinates of salient features as well as their uncertainties.

Once the model is learned, the system computes the pose of the camera observing the scene in real-time. Experimental results showed that the method is quite robust even in the presence of moving nonrigid objects occluding the actual scene. Further improvements will be sought to improve the real-time performance of the system which may include processing lower resolution images.

The methods we mentioned above are productized. These products are examined below. The Home Depot application allows many items from the refrigerator to the handset, the consumer to have a 3D visual of a product in any space they want to see a product in. Figure 64 can be seen in how the items in Home Depot are put in the desired location.

a b

Figure 64. The placement of items according to the camera angle (a), placing items from the mobile phone (b).

In the Ikea application, take a photo of the room you want to design with the Ikea Place application. With this photo, the application measures the area and recommends the furniture suitable for this area. Figure 65 shows how Ikea items are positioned.

a b

Figure 65. The placement of the selected armchair (a), the placement of the selected armchair(b).

In the Wayfair application, users can only access Wayfair furniture and see how it will look in their home using their mobile phone. Figure 66 shows how to adjust the seat position.

Figure 66. The positioning of the armchair according to the camera angle.

Target application offers its customers the opportunity to view their products in 3D on its website. With this digital platform, AR took its place in furniture shopping applications. Customers had the opportunity to see the product they wanted at home. Figure 67 shows step by step how the user should use the application.

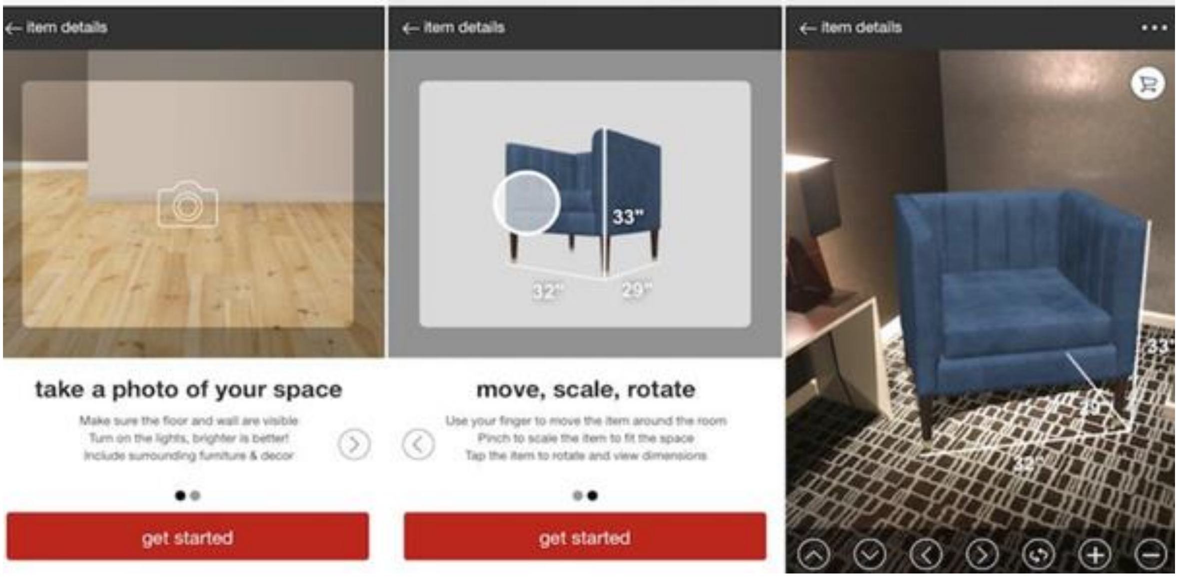


Figure 67. How to use the Target application step by step.

In the Sephora application, it offered many new possibilities to its customers with its virtual application. Customers scan their faces with the application, so that makeup products can be simulated on the user's face online. In this way, the customer can try the desired product online and if he likes any of the simulated products, he can buy it through the application. The application also offers makeup training as an option. Figure 68 shows the application of some makeup items on the model's face.

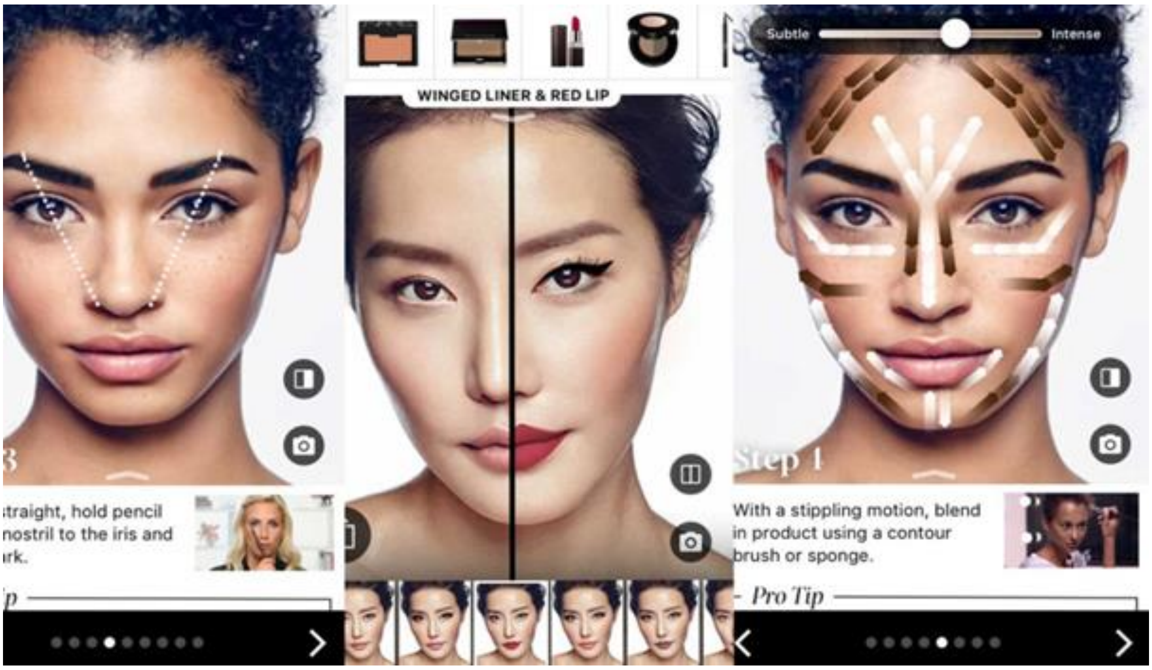


Figure 68. How to apply makeup items correctly.

Amazon is collaborating with L'Oreal to bring AR to its app. In Amazon's shopping application, users will be able to try on themselves the lipsticks they want to buy online. First, the user is asked to upload his / her photo or video to the system and then try the desired product. If the user wishes, he can also try lipstick on the model he finds close to himself. An example of this is shown in Figure 69. Currently, the application is limited to lipstick only. It will also be possible to test it in other products in the future.

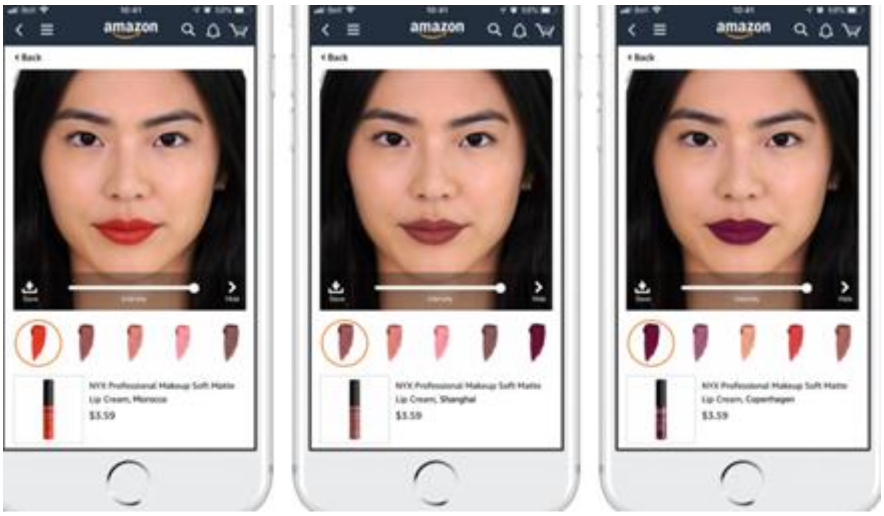


Figure 69. Testing lipstick colors in the Amazon app.

By adding AR features to its Nike application, it offered its users the opportunity to shop more comfortably. With this application they call Nike fit, it is enough for the user to point the camera at his foot, in this way, the shoe size will be determined. How the application works are shown in Figure 70. Customers will be able to find the right shoe sizes and complete their shopping in no time.

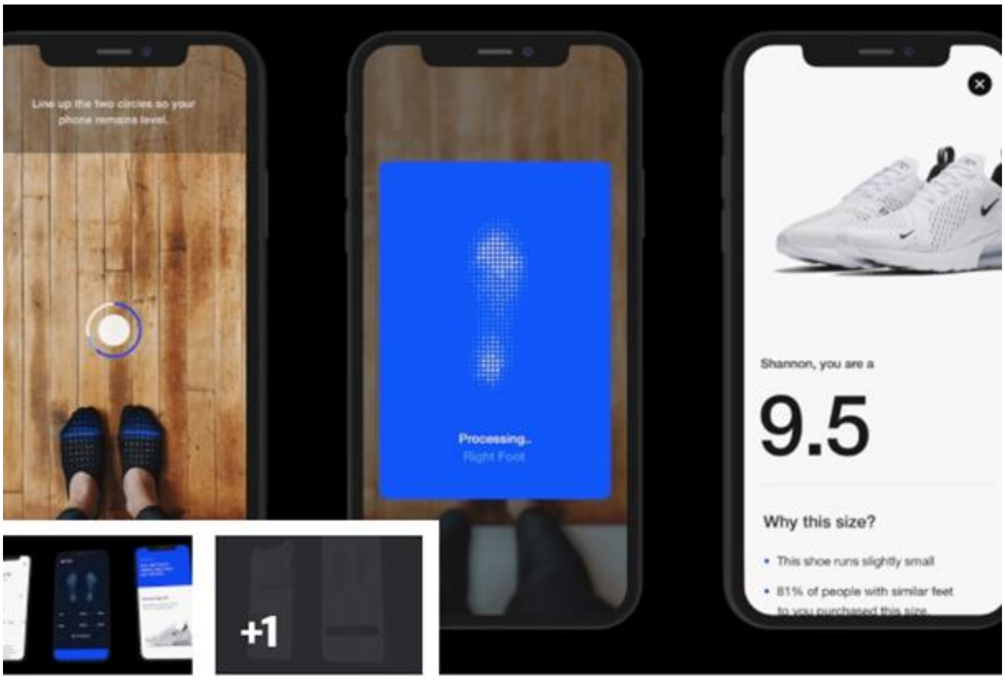


Figure 70. How to choose the correct shoe according to the size of the foot.

Warby Parker started using the AR feature in its app to offer its customers the opportunity to digitally test the glasses. In this way, customers can easily access a wide range of products. Figure 71 shows the models that tried the glasses in the application.

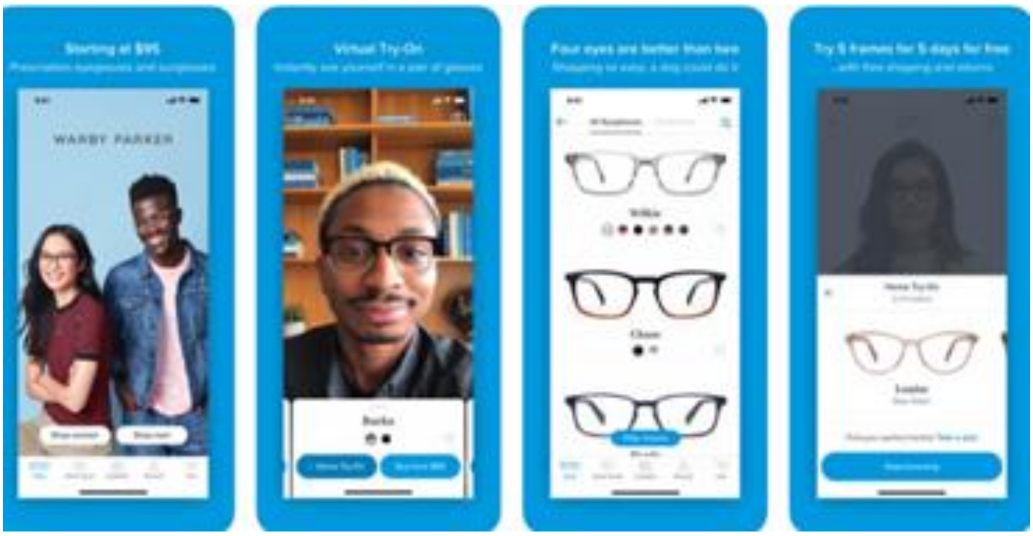


Figure 71. Testing the glasses with AR.

3.2. Solution Method (Change this title according to your solution method)

In augmented reality, there are several tools and techniques. In this project, we have started with EasyAR but we have seen that EasyAR is inadequate in terms of resources. After that, we started to work on Vuforia Engine to be able to work on the project but in some time we felt the same thing as EasyAR. As of last we have decided to work with AR Foundation which was the best fit for our project.

After that, we have started to look into details of AR Foundation and we have seen that AR Foundation has some very useful packages and plugins such as ARCore XR Plugin, ARKit XR Plugin, and AR Subsystems package. We have learned that ARCore is supported by Android devices and ARKit is supported by IOS devices. AR Subsystems is a package that provides some interfaces for some subsystems and these subsystems are Session, Raycasting, Camera, Plane Detection, Depth, Image Tracking, and Face Tracking. We have used Session, Raycasting, Camera, and Plane detection subsystems in our project.

We wrote mainly 5 c# scripts and these are ButtonManager, DataHandler, InputManager, Item, and UIManager. ButtonManager is responsible for button management and button actions. It gets inputs such as button, itemID, Sprite_buttonTexture, and button image as raw image. DataHandler is responsible for handling data such as models and furniture and it also plays a role in adding buttons dynamically with the help of item iteration. It gets inputs such as GameObject, buttonPrefab, button container, and list of items. InputManager gets some inputs such as AR Camera, ARRaycastManager, GameObjects, Touch, Pose, and ARRaycasthits. Also, it checks if the pointer is over UI. And it helps object spawning. Item is responsible for creating the asset menu and gets some inputs such as itemPrefab and item image. UIManager is responsible for UI interaction with buttons and the sliding bar. It gets inputs such as GraphicRaycaster, PointerEventData, EventSystem, and selection point.

After the Coding process, we were able to spawn objects and our UI was working perfectly but there was a problem which is the location of the object to be spawned. When we try to spawn the object we were seeking the area to be able to see where we spawned the object. To get rid of it we have found an asset called “Placement Indicator” and we have implemented it into our project. With the help of it, we have started to spawn our desired objects on top of the Placement Indicator.

After that, we wanted to work on scaling, rotating, and deleting issues. We have found an asset called “LeanTouch” which allows us to use objects as we want with finger or mouse movements. And we used “Lean Touch” in our project to be able to scale, rotate and delete the desired object.

During the Lean Touch phase, we have encountered some problems, one of them was the finger count. Because when we spawn the objects with one or two fingers after the spawning period if we try to scale or rotate the object the application senses one or two fingers. As a result of that even though we try to scale or rotate the object we spawn another object unwillingly. To get rid of it we came up with an idea that spawning objects with 3 fingers. With the help of this idea, the application does not sense the spawning function when we try to scale or rotate.

4. ANALYSIS AND MODELLING

4.1. System Factors

Since our project will affect the cloth and furniture market, this project's main factor is model and furniture diversity. Stores may buy our project and they can share their products with us by an agreement. And these products can be very effective for being recognized globally.

4.2. How System Works

We have started to look into details of AR Foundation and we have seen that AR Foundation has some very useful packages and plugins such as ARCore XR Plugin, ARKit XR Plugin, and AR Subsystems package. We have learned that ARCore is supported by Android devices and ARKit is supported by IOS devices. AR Subsystems is a package that provides some interfaces for some subsystems and these subsystems are Session, Raycasting, Camera, Plane Detection, Depth, Image Tracking, and Face Tracking. We have used Session, Raycasting, Camera, and Plane detection subsystems in our project.

Our project is a visualization application with AR. We did this project with AR Foundation. The application does plane detection first. Visualizes, rotates, adjusts the size of objects previously loaded into the application with AR. Thus, the positioning of the objects is implemented. Multiple objects can be placed.

4.3. Modelling

The user opens the application from the phone. Then he/she clicks on what he wants to select from the objects displayed at the bottom of the screen. And that object appears on the indicator. The user can rotate and zoom in-out with 2 fingers. He/she can add a new object with 3 fingers. We correlated the number of fingers with the functions.

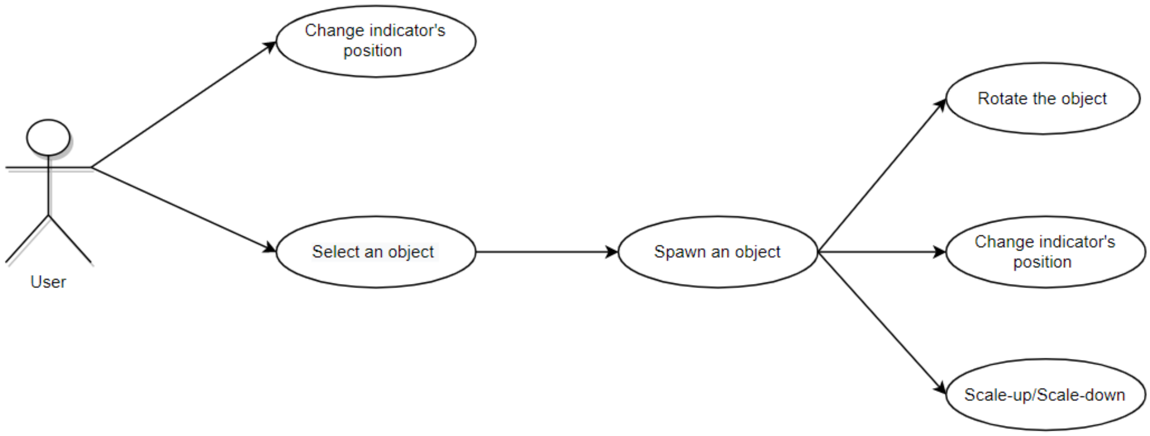


Figure 72. Use Case Diagram of the project.

4.3.1. System Architecture

While doing our design, we first provided plane detection by using the AR Foundation package. Later, we imported the models that will spawn on this plane to unity. We adjusted the rotation of the objects. We have created a dynamic structure to enable the user to reach the object with the buttons. We have provided scale, rotate, and delete with the Lean Touch package. The most important part of this project is to establish a connection between the outfit and the model and to ensure that they act together. For this reason, we will try to establish a connection between these two objects in Senior Design Project2, and then we will make the android application of our project because the AR foundation is android supported.

5. DESIGN, IMPLEMENTATION, AND TESTING

5.1. Design

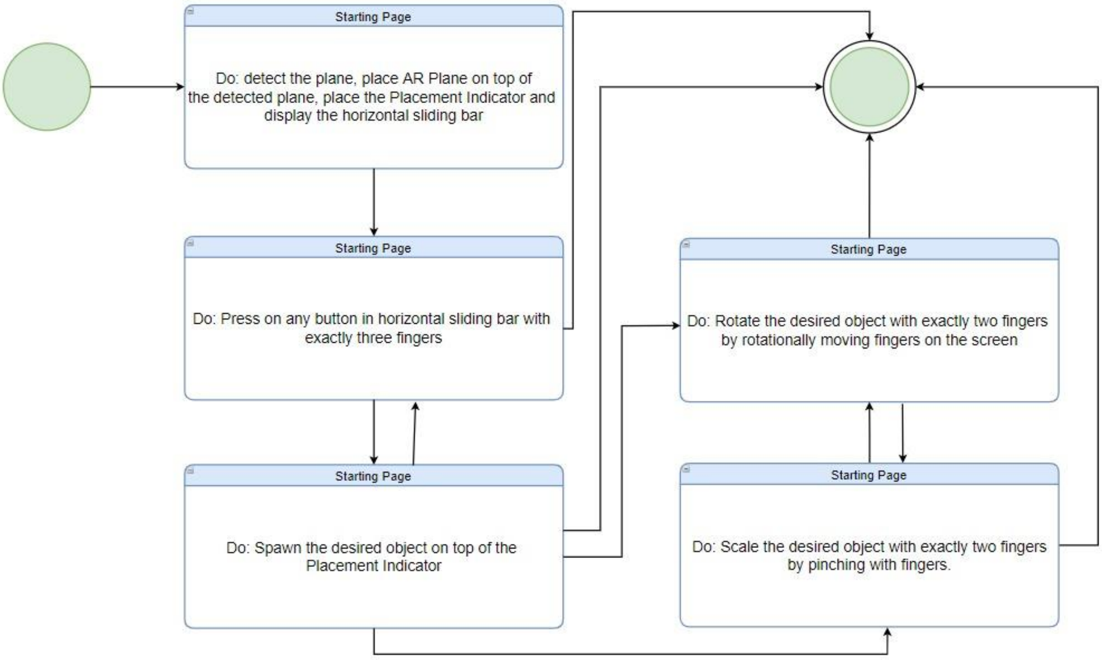


Figure 73. State Diagram of the Application

5.2. Implementation

First, we found a lot of models and items suitable for our project It must important that all the files extension must be fbx. Then we scanned a lot of resources to create the commands we wanted in the project. We tried them all and changed the source when we got errors. When we found a resource we liked and encountered problems, we found the person who posted the resource and contacted him. We tried to solve our problems.

We did plane detection. The application's camera was supposed to be able to detect the plane without the image target. After detecting, we put the indicator. When the models and items are selected, they should appear above the indicator. After this stage, we imported the models and items we found into our project and checked whether they were visible or not. The next step was to run the rotate and scale up-down commands. We searched many sources, but we couldn't find an up-to-date video that works with plane detection (without the image target). Then we made these commands work through a library (Lean Touch). To develop the project, our goal is to make a delete key and move movement.

5.3. Testing

When the user opens the app, he/she see Figure 74. It is the GUI of the app. The user first sees the plane detection on the screen here. Then the indicator appears on the screen. The blue round shape is the indicator. An indicator allows putting objects on top. The indicator appears in the middle of the screen. Users can change the location of the indicator by changing the camera angle. Then, the user can select the object user want to show from the buttons at the bottom of the screen shown in Figure 74.

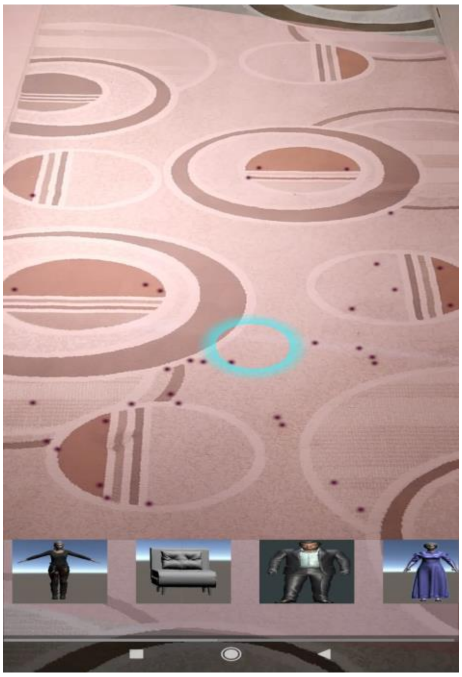
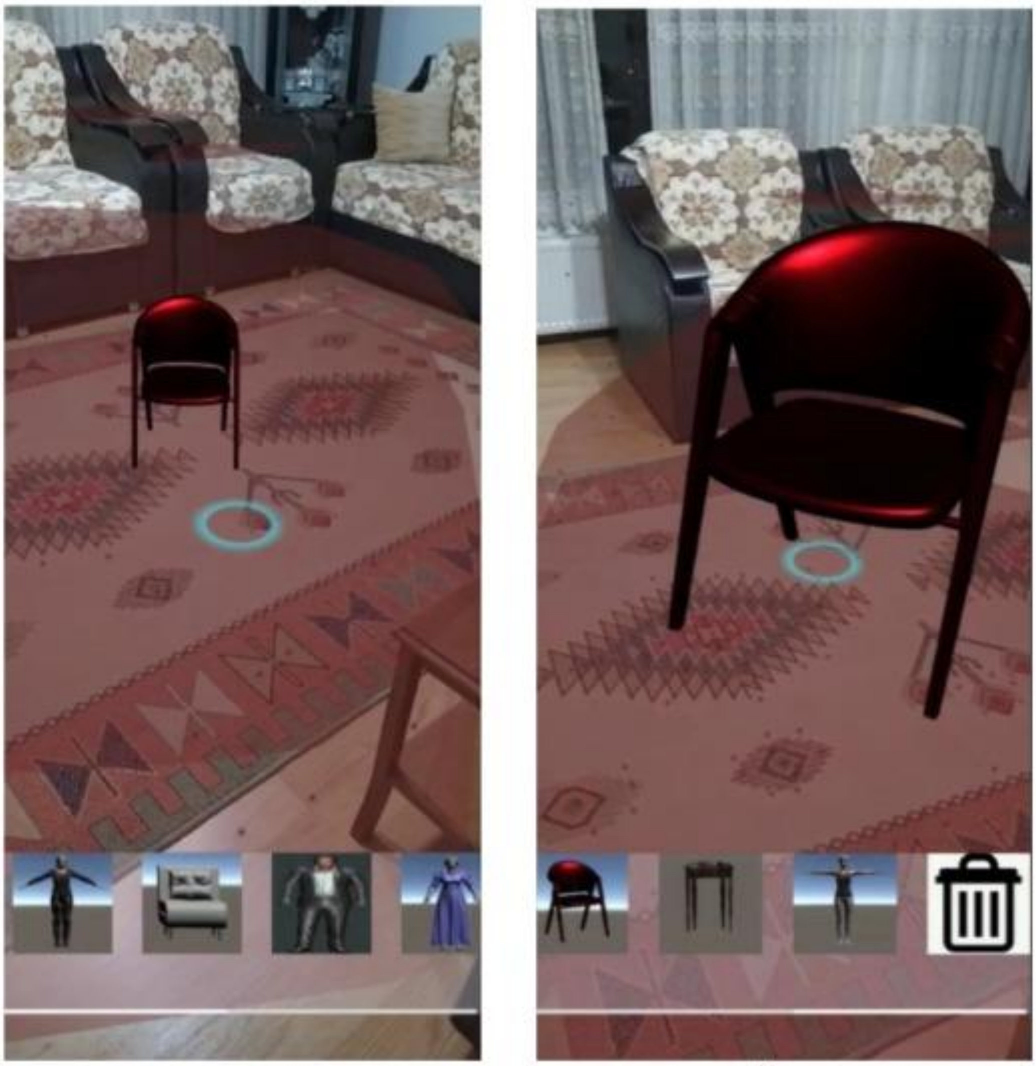


Figure 74. Graphical User Interface(GUI) of the app

When the user selects the object, this object appears just above the indicator. We can scale or rotate this object up and down by placing 2 fingers on the screen at the same time. In Figure 75, we can see that an object is scale up-down.



a b

Figure 75. Scale-up and down of an object.

Objects are added when we click the buttons with our 3 fingers. A large number of objects can be added. In Figure 76, you can see the human-sized position of an object on the indicator. Since the camera angle has changed, the indicator is in the middle of the screen. We can scale up-down female mannequins.

Figure 76. A female mannequin object.

6. RESULTS

You can run our application from an android phone. When you click the application, a camera and items in the sidebar meet us. You select the item you want from the items we have previously loaded and place it on the screen as much as you want. With the help of the indicator, you determine the place where you will put the items. You can rotate and scale these items. We matched the finger numbers with the commands. When you click with 1 finger, you put an object, and you can rotate and scale with 2 fingers.

There were a few critical points. Deleting an object and moving it after placing the object were among our plans. In the continuation of the project, we will touch on these issues while developing the project.

7. CONCLUSION

The problem we looked into was model and furniture recognition with Augmented Reality. We did this using Unity. Our project continues to develop. We can visualize as many models and furniture as we want, rotate them, and move in and out of them.

7.1. Life-Long Learning

Technology and every field related to technology is developing day by day. New programs, new languages, new projects. As this area develops, the previous version is faced with the disappearance and becomes useless. Therefore, a computer engineer must accept that there are always changing conditions and be committed to continuous improvement. As it develops itself, its studies and projects should also improve in terms of usability.

We also learned a lot in the field of Augmented Reality for this project. On the Unity platform, there were a lot of resources that we tried by mistake and error, and we learned something from each of them. Since our project was unique to us, it was not possible to find the codes we needed directly. That's why we stayed with each other as a team most of the time. We did a lot of work we had to do to move forward. We found the required codes by trial and getting errors, researching, spending hours, brainstorming. Besides, when we cannot find what we are looking for, we may have to broaden our perspective and search in a wider area and different versions.

7.2. Professional and Ethical Responsibilities of Engineers

Each profession has a set of rules that must be followed. Engineering students and graduates are also expected to act by engineering ethics. Some of the principles of engineering ethics are avoiding misleading actions, using open resources objectively and realistically, keeping the safety, health, and welfare of the public at the highest level. Our project has been created according to the rules of engineering ethics. We have a project that everyone can use and access. We have been objective and realistic in all of the resources we used in our project. We followed the most reliable and correct steps for our project. For this, we scanned a lot of resources and tried them all. We have been fair and honest with each other in our team. We have constantly improved ourselves, each other, and our project. And we will continue to improve.

7.3. Contemporary Issues

At the beginning of our project, we were aiming to make an iOS program. Due to the progress of the project and insufficient resources, we decided to proceed through the android environment. We have completed object demonstration and additional work with Unity AR. We used AR Foundation, Unity's platform for Augmented Reality. We used AR Core because it is a project on the Android platform. We spend more and more time online every day. Games use more and more AR and VR spaces. We tried to introduce AR into our lives in the field of product purchasing and shopping. In the later stages of our project, we can make improvements in our project by touching on Machine Learning or Deep Learning areas. Or we can try to move our project to an iOS environment.

7.4. Team Work

We worked as three people in the Senior Design Project. We tried to work together as much as we could in the steps of SDP1. We were in constant communication. We held a meeting with our advisor on a specific day every week. We showed what we did that week. We saw our problems and determined what we should do next week. When a friend of ours was busy in our group, our other friends worked together and closed the gap. Then, to our busy friend, our other friends told the missing part or he/she examine the progress and fill the gap. As a result, we all have full knowledge of the progress of the process.

We felt the advantage of teamwork during our busy times. This situation has contributed a lot to us in terms of progress. During the whole process, we supported each other and made up for our shortcomings. Although we faced many difficulties, because we were disciplined and progressed step by step, we did not encounter any major problems.

ACKNOWLEDGEMENTS

We are grateful to Berk Gökberk, who took care of us during the Senior Design Project 1, advised us, helped us with our problems, and guided us.

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