Novel Paradigms of Human-Fashion Interaction

Anastasios Papazoglou Chalikias
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
tpapazoglou@iti.gr

Elias Kouslis
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
kouslis@iti.gr

Orestis Sarakatsanos
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
orestiss@iti.gr

Andromachi Boikou
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
boikou@iti.gr

Stefanos-Iordanis Papadopoulos
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
stefpapad@iti.gr

Christos Koutlis
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
ckoutlis@iti.gr

Symeon Papadopoulos
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
papadop@iti.gr

Spiros Nikolopoulos
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
nikolopo@iti.gr

Ioannis Kompatsiaris
Information Technologies Institute, Centre of Resarch & Technology (CERTH), Greece
ikom@iti.gr

David Gavilan
Metail, UK
david@metail.com

Dongjoe Shin
Metail, UK
dongjoe@metail.com

Yu Chen
Metail, UK
yu@metail.com

Axl François
Bodidata, Belgium
axl@bodidata.com

Michaela Jauk
Odlo, Switzerland
michaela.jauk@odlo.com

Jamie Sutherland
We Are Unfolded, UK
jamie@thisisunfolded.com

ABSTRACT

In this paper, we discuss how we can re-imagine the interaction between users (i.e. fashion designers and consumers) and fashion items, by researching and developing technologies that allow virtual try-on of garments. In this direction we a) generate personal 3D avatars of the user, b) automatically simulate the interaction between 3D user avatars and digital garments (i.e. size fitting and visualization of interactions during body movements), and c) extract fashion insights from user preference data and generate fashion recommendations. Building on recent advances in the fields of artificial intelligence, computer vision and interactive devices, we try to modernize the way people create, consume and experience fashion items by offering novel Human-Fashion-Interaction (HFI) applications that enhance the creative process of garment design, revolutionize the way people interact with fashion in social media, and simulate the physical in-store experience for online shopping.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

SETN 2022, September 7–9, 2022, Corfu, Greece

© 2022 Association for Computing Machinery.

ACM ISBN 978-1-4503-9597-7/22/09…$15.00
https://doi.org/10.1145/3549737.3549803

CCS CONCEPTS

• **Human-centered computing** → *Virtual reality*.

KEYWORDS

human-computer interaction, augmented reality, virtual reality, artificial intelligence, fashion

ACM Reference Format:
Anastasios Papazoglou Chalikias, Elias Kouslis, Orestis Sarakatsanos, Andromachi Boikou, Stefanos-Iordanis Papadopoulos, Christos Koutlis, Symeon Papadopoulos, Spiros Nikolopoulos, Ioannis Kompatsiaris, David Gavilan, Dongjoe Shin, Yu Chen, Axl François, Michaela Jauk, and Jamie Sutherland. 2022. Novel Paradigms of Human-Fashion Interaction. In *12th Hellenic Conference on Artificial Intelligence (SETN 2022), September 7–9, 2022, Corfu, Greece.* ACM, New York, NY, USA, 11 pages. https://doi.org/10.1145/3549737.3549803

1 INTRODUCTION

In an era of significant breakthroughs in the fields of Artificial Intelligence (AI), Computer Vision (CV) and interactive technologies like Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), several sectors of the industry have benefited from these

new technological achievements by embodying them in new innovative products: from self-driving cars to cashier-less supermarkets and from VR-enabled flight simulators for training air-force personnel to the more mainstream VR-based gaming and to media sector applications [34]. The fashion industry has been one of the industries that have been slow in incorporating these technological advancements in their business operations, in order to enhance both the creative process of garment design and the consumer interaction with fashion items. Indeed, the available interaction pathways have changed minimally over the past decades and mostly in the direction of encapsulating the recent social media frenzy.

2 RELATED WORK

Ranging from e-commerce and 3D online shopping to virtual try-on and eco-fashion, digital fashion is incredibly broad and makes a strong and swift imprint [19]. We briefly analyze below relevant software tools and applications that are the most promising according to market analysts.

2.1 High-quality garment-avatar simulations

A vast number of 3D clothing design software was recently developed, enhancing the sustainability of fashion business by eliminating wasteful practices and carbon emissions, as they surpass the need for creating sample clothes and directly share the high-quality designs with their collaborators before the stage of production. The most significant cross platform software tools are listed below.

Browzwear [7] is a pioneer company in 3D fashion software, that mainly caters to corporate employees, providing a variety of 3D solutions for apparel design, development and merchandising through its modules: VStitcher [9], a 3D fashion design software using size ranges, graphics and photorealistic 3D rendering. Its 3D rendering feature enables real time inspection of any design changes, producing a photorealistic 3D representation of the designed garments. Lotta [6] is a patternless styling tool that enables a rapid 3D design process without the need to change existing workflows based on specific block patterns. Stylezone [8], a cloud-based platform for exhibiting and exchanging 3D prototypes provides a web and mobile collaboration tool that allows all stakeholders to engage at every level of the process, from design to merchandising. Finally the Fabric Analyzer [5] enables users to determine the physical qualities of garments and automatically load the values into VStitcher or other similar 3D software programs.

CLO [10] and Marvelous Designer [11], created by CLO Virtual Fashion Inc., enable users to create a variety of outfits and accessories, providing a drape-sensitive textile simulation of fabric. CLO is mainly used by fashion designers enabling them to present their digital garments interactively, export them and send them to manufacturing. Marvelous Designer aims to 3D artists who prefer to maintain all assets digital or online, enabling interoperability with 3D design software such as 3ds Max, Maya, Pose, and DAZ Studio.

Additional software tools that are available only for the Windows platform include: Optitex [20], which enables users to create and share photorealistic 360° pictures of a 3D virtual sample with customizable lighting, also offering a tension map for a more realistic inspection of the physical qualities of the garment; TUKA3D [35], which enables users to digitally present their 3D digital collections and inspect the garments fitting on a virtual avatar that simulates real time motion. It is also compatible with graphic design tools like Adobe Photoshop or Illustrator.

The digital transformation has impacted all aspects of the fashion industry. The use of digital fashion and digital garments that can be simulated to look like real clothing is also expanding. The Fabricant [13] is a digital fashion house that focuses on photorealistic 3D fashion design and animation. They create digital fashion merchandise through online platforms and digital channels. Motion capture, 3D animation software and body scanning are among the technologies they use, also offering an efficient alternative to photographic and film content.

2.2 VR/AR try-on fashion apps

The number of try-on fashion innovative apps is constantly expanding, with features from trying on clothes, to sneakers and makeup, enabling users to digitally inspect how everything looks on themselves. Virtual fitting software facilitates the fashion industry to improve the customer experience by suggesting items with the best fit or even on the customization of a sizing chart. Some of the most significant developments in regards to garment digital try-on are listed below:

DRESSX [12] is a digital fashion retailer and provides a digital wardrobe, a “metacloset” of digital fashion items. With the DRESSX app (Android, iOS) users can virtually try-on digital fashion items with their digital items applied in AR on real-time videos and photos and they are able to share this content to social media and other platforms. The Modern Mirror [18] (Web) creates seamless, intelligent virtual fit experiences servicing not only consumers, but also designers, manufacturers and retailers. Aiming to the luxury apparel industry, the platform enables users to digitally try-on clothes by scanning their body and capturing their precise measurements, motion and images, further providing sizing recommendations, while validating the fit and movement of a garment in photorealistic visualizations. In addition, the platform enables the creation of virtual runway shows using digital models captured by Modern Mirror’s 3D imaging system or a single photo, wearing the latest collections in digital form. The GoodStyle [1] app (Web, iOS, Android) is a digital fitting room with a personalized virtual stylist feature, enabling users to try on garments before making a purchase. A photorealistic avatar can be created by providing the user’s physical dimensions and taking a selfie. The same procedure is also used for PICTOFiT [2] (Web, iOS), which includes a large selection of apparel from various companies for virtual try-on. WEARFITS [38] provides a virtual closet with an AR and 3D web viewer, supporting OBJ and ZPAC files and providing easy clothing digitization from DXF patterns with sizing and fabric data. It also provides a size advisor feature, with a custom silhouette and accurate body avatar generator, integrating the virtual fitting room with e-Commerce and mobile through APIs and SDKs. However, AR try-on technology is currently mostly used on accessories and shoes rather than garments, namely products with rigid shapes where AR try-on immersive technologies are popular (Wanna [37], SneakerKit [27]). In addition, an increasing number of top fashion brands are integrating virtual try-on AR solutions either directly through their e-commerce channels or through Snapchat AR lenses

and other mobile applications and choose these technologies for their marketing and promotion strategy. Some indicative cases are Converse, GAP, Lacoste, Gucci, Tiffany and Co., Rayban, Adidas, Nike and Crocs. Moreover, Topshop offered a VR application where customers could attend a fashion show in London and are able to inspect the qualities of the clothes in the virtual space.

2.3 Consumer profiling, trend detection and personalized recommendations

Fashion industry highly invests in fashion forecasting services in order to follow current trends and gain a significant part of the market. Moreover, the size-fit problem is crucial in order to avoid returns from online purchases. Given a garment and the shopping history of a user, personalised recommendation methods predict whether a given size will fit them correctly, overcoming potential lack of size consistency between brands. Information extraction from fashion imagery is a challenging task due to the inherent diversity and complexity of fashion categories and attributes [24]. A brief analysis of the most relevant developments is listed below.

T-Fashion [31] offers customized fashion analytics and data-driven trend insights to produce/buy the right product at the right time. Using AI-powered trend forecasting, T-Fashion gathers trend dynamics through billions of interactions taking place online through social media and other data resources, providing trend prediction, fashion analytics and useful insights for designers and merchandisers. Heuritech [16] is another AI–powered solution that uses predictive analytics on several aspects that may be used for the accurate measurement of demand and fashion trends by studying real-world photographs posted on social media. WGSN [39] provides consumer trend forecasting insights, delivering effective retail and communication strategies and predictive data analytics. More precise trend forecasts are offered in Trendzoom [33], capturing emerging trends from catwalk and street style photographs. Various fashion insights agencies are also active in consumer profiling and trend detection and top trends in material and fabric qualities (TOBE Doneger, Fashion Snoops, F-trend).

All above paradigms however mainly constitute B2B services providing overall trend insights, rather than a trend recommendation to fashion designers for the specific garment they currently work on, or even personalized recommendations for the clothes an influencer would consider trying on and promoting.

3 NOVEL PARADIGMS OF HUMAN-FASHION INTERACTION

For our goal to create new Human Fashion Interaction (HFI) solutions, we rely on technologies that can automate content generation for fueling novel interaction devices (VR, AR, mobile phones). More specifically, we researched into technologies that can: digitize full human bodies into 3D avatars using mainstream devices (i.e. smartphones), automatically simulate and visualize how digitally designed garments fit and look on avatars in terms of size, style and motion, and extract fashion insights such as emerging trends using data from actual consumers and provide fashion recommendations to users. By bringing together all these technologies in three innovative applications, we transform the creative, social and shopping experience of users when they interact with fashion items as described below.

Creative experience: Currently, fashion designers can create digital garments in professional software like VStitcher, Optitex and CLO as we described in related work. This software allows the fitting of garments on avatars that are typically static, which means that the designer has limited information on how the garment will look and behave in reality. Only recently, in February 2021, Browzwear announced and released an update to VStitcher [7] that enables animations, which is rather heavy in terms of required processing power. Based on the feedback we got from over 20 fashion designers, animation is an important asset both for the design process itself, but also at later stages for presenting the garment designs to other departments like sales and upper management, while the limited processing power is one of the main bottlenecks.

Our first application, the VR Designer aims to enhance the creative experience of fashion designers, through a VR application for immersive garment fitting. More specifically, a user-friendly VR interface is developed using the Unity game engine [32] that enables designers to get a better overview of their designs, by providing them with realistic simulations on how the garments fit on their own fitting avatars. Besides the increased realism offered by the immersive VR environment, designers are able to view a plethora of animations and capture their own unique virtual fashion runaways, in an easy and computationally efficient way. To improve the visual fidelity and user immersion, a state of the art virtual reality headset (Meta Quest 2) [17] is utilized as a human interface device (HID) for the aforementioned application.

Social experience: The wide adoption of social media platforms like Instagram has changed several aspects of the fashion industry, including the way clothes are presented, marketed or designed. However, people still interact with the fashion items in the same way, i.e. they have access to the physical clothes that they wear to shoot the photos/videos, and then post them in their social media accounts. People try on clothes from their existing wardrobe or order new items that have already reached production phase. During this fashion transformation, most of these clothes are bought for a one-off show, which is unsustainable as it becomes rather expensive for the users to maintain an up-to-date profile, while certain outfits are out of reach due to cost. Instagram influencers usually receive free sample clothing from brands, so the cost of manufacturing and transporting them as well as its environmental impact falls to the brand, because the clothes are unlikely to be retained and worn for a long time. The fashion industry is currently designing, launching and producing collections of garments carefully selecting the items of the collection based on the expected adoption by the consumers due to the production cost as well as the limitations in materials. As a result, the creativity of the designers is significantly constrained, since other factors like cost and materials dictate limitations of garment designs.

To that end our second application, Dress Me Up, allows a range of users like fashion consumers, models, influencers and fashion lovers in general to upload a photo, choose a garment they like from a variety of digital ones and the application returns a synthesized media file with the digital garment realistically simulated on their body. The end result can then be uploaded to social media networks. Moreover, this opens the opportunity to try and market garments

that were unreachable before, e.g. garments worn by actors in movies, or by sports icons.

Shopping experience: The consumer has the ability to buy fashion items online by browsing through a list, viewing the items through photos of models wearing the clothes taken from various angles/poses, or in the best case, through videos showing the models walking, and selecting a size from sizing charts. Lately there have also been some attempts in introducing virtual fitting in online shopping by allowing consumers to visualize clothes virtually tried-on on predefined avatars with manually inserted measurements. The user has considerable difficulties finding the right fashion item in terms of size-fit, color, style and quality. Indeed, according to surveys [26], over 50% of online shoppers return clothing because of poor fit. Other problems include poor quality, for example images of the products are taken at best lightning and position conditions, and may not represent the actual product accurately, and the full product details are not available when shopping online. For the fashion industry, the impact of this is twofold. First, people still prefer to buy clothes in-store with online to in-store rates being 40% vs 51% respectively [29], which entails larger operational costs. People would shop apparel on a platform if the size fit, garment quality and style problems were solved. Second, even for online buyers, there is a high percentage of returns (56% of online customers buying clothes return at least one product [4]), which entails a cost of combating return rates as high as 50% [25].

Considering the above, our third application, Magic Mirror aims to adopt the latest advancements of AR for improving the overall experience of virtual garment fitting. The users of this AR mobile application are able to scan themselves at home using their phone camera and observe in real-time through the screen of their mobile device how a particular garment fits their body. To achieve this result, the AR framework AR foundation [36] offered by Unity technologies is the leading tool for the development of the application. Moreover, to further improve the virtual try on experience, the application recommends a variety of garments that seem as a best fit for the consumer's profile based on user's favorited garments.

3.1 Fashion Trend Detection - Garment Recommendations

Fashion is a dynamic domain, continuously changing and ever-evolving. Fashion trends and styles are highly time-dependent; they may be short-lived - quickly appear and dissipate - while others may stay relevant for years. Systematic analysis of fashion trends is not only useful for individuals who want to be up-to-date with current trends, but is also vital for fashion designers, retailers and brands. Being able to predict the longevity of fashion trends or being able to foresee emerging trends is essential for fashion brands, in order to plan their production cycles, their marketing campaigns and create products that customers will find relevant and interesting when they hit the shelves. Furthermore, fashion could also be considered a primarily visually-driven domain. Textual descriptions of products, brand awareness, available sizes, etc. may all be contributing factors in attracting customers. However, it is the visual elements, the appearance and style of the garment that are arguably one of the most important factors in attracting customer attention and leading to purchases.

Our rationale is that while new garment designs, by definition, do not have historical data, they still belong to a particular fashion category and have multiple fashion attributes. Hence, modelling the aggregated attribute-level popularity time-series as informative proxies of the garment's popularity together with the visual characteristics extracted using deep learning models from the product's image would be valuable and could provide accurate garment-level predictions at design-time [22, 23].

Recommendation systems are filtering mechanisms that attempt to select the few most relevant items - from the total corpus - based on users' preferences. Recommendation systems can generally be classified into three broad categories: collaborative (CF), content-based (CBF) and hybrid filtering (HF). When developing a working recommendation system for the pilot versions of the applications we decided to use the text-based CBF method. This method gives very reasonable results in the qualitative analysis when retrieving 'most-similar' products, does not require any actions when new users are added in the application and is very efficient and requires fewer resources.

More specifically for each of our use cases:

- **VR Designer**: Provide predictions about how popular a certain design is in the market for the subsequent seasons. The predictions are offered for different segments of the market, namely different genders and age groups.
- **Dress Me Up**: Targeting social media users (influencers) who will receive market-segmented popularity predictions similar to the VR Designer app.
- **Magic Mirror**: Targeting fashion consumers in e-commerce, where the popularity scores will inform the underlying recommendation engine.

3.2 VR Designer

The VR Designer desktop application is a virtual reality application aimed at designers to inspect the fitting of garments in a variety of bodies, referred to as avatars or mannequins, in real time using static or dynamic poses (animations). The designer uses a VR headset to be able to navigate the three-dimensional virtual space.

3.2.1 Implementation. Figure 1 features the interconnection of roles and parts of the VR Designer system.

User roles:

- Designer - A garment designer who uses VStitcher to develop garment designs and export alembic files.
- Developer - The developer of the app that creates the VR Designer tool and handles the import of alembic files to the app.
- Product Manager - Responsible for selecting designs and guiding their improvement and development to optimise market success.

Based on requirements gathered from discussions with designers on how the VR application can best satisfy the requirements of a design team, two key decisions were reached to showcase the garments in the best way:

(1) 3D fit avatars need to be used in the application, rather than scans of fit models. This is necessary to ensure consistency and dressability. Because the garments are designed on these

fit avatars, the garments fit and are styled exactly as intended and there is no high frequency 'bumps' which affect how the garment looks.

(2) The garment simulations are exported directly from VStitcher to ensure that the VR application shows the garment physics as realistically as possible. Unlike Magic Mirror, which we will analyze in a subsequent section, which requires freedom of movement, the animations for this application are preset. This means we can directly use the cloth simulation generated by VStitcher.

Preparation steps:

(1) The designer creates a 3D garment inside the VSticher design software. The garment is dressed and styled on an existing avatar, male or female. An animation is applied on the dressed avatar and the final product is exported as an .abc (alembic) file which contains the avatar, the garment, the animation and the textures.

(2) The alembic files are imported in Unity and all the textures (garment colors, human skin texture, etc.) are applied. All the files are then available to use from the UI inside the VR Designer app.

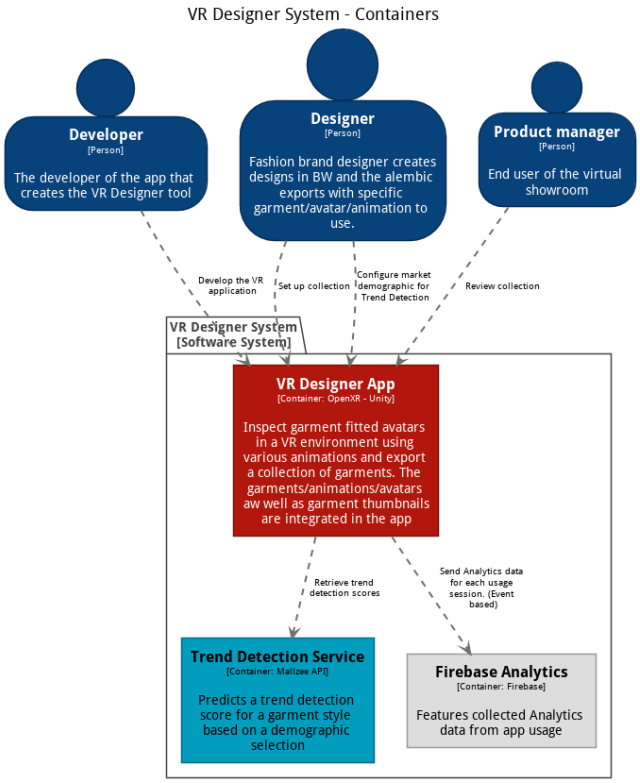

Figure 1: VR Designer System Containers

3.2.2 Interface. The VR Designer application is distributed as a standalone Windows executable file, which the user can run and interact with, while wearing a compatible VR Headset which is connected to a Personal Computer (PC). The VR environment is shown in Figure 2, which has been thoroughly tailored using various 3D objects to resemble a retail store. Users can move freely inside the space by moving with their body physically, or using the VR headset's controller joysticks in case of restricted physical space.

Figure 2: VR Designer System User Interface

Users are able to perform a variety of actions by using the floating UI presented in front of them (Figure 2). More specifically, in the left hand side of the interface there is the demographic selector, where the user can input a demographic range option in order to receive a popularity score for a garment. The popularity score is then shown right below in the left side of the UI in the form of a percentage score. The whole process behind the calculation of the popularity scores is documented in Section 3.1. In the middle UI column, the fashion designer can switch between available avatars, male or female, and then apply a garment and an animation selection to it. There are some components at the bottom of the middle column that control the animation speed and toggle the animation play/pause state, as well as toggle the display of the selected avatar on and off. The favorites section is located at the right column. A designer can save avatar/garment/animation combinations for easy access, in order to quickly revisit them or present them to a product manager. It supports import and export functionality so the designer can easily swap between their favorite collections.

3.2.3 Usage Scenario. A user wears the headset and runs the executable on their personal computer. After the application is loaded the user is materialized inside the VR scene. The User Interface is open, so by pointing the blue beam inside the VR space using the right controller and pressing the uppermost trigger, the user selects the female avatar. Right below in the garments section, the area is populated by the available garments for the selected avatar. The user selects the fifth garment, an orange t-shirt. From the animation section below the user selects the Run animation. Using the slider in the bottom right, the user adjusts the speed of the animation to half in order to see how the garment responds to movement in greater detail. The user closes the interface and proceeds to inspect the garment worn on the avatar from all angles and see how it drapes or stretches in each different body movement. The body avatar is also switched off in order to check the inside texture of the garment. The designer is pleased with how the garment responds, so the garment is saved in the favorites section by pressing the "+" button. The above process can be repeated for many avatar-garment combinations in order to create and save a collection by clicking on the

"Save" button. Then the user exits the app and removes the headset. A product manager can then wear the headset, open the app and load the collection saved by the designer so they can inspect it themselves and decide which garments should move to the next phase of design/production.

3.3 Dress Me Up

The Dress Me Up application is a web app, targeted at social media influencers, but usable by anyone. The concept is simple - the users scan their bodies once, then can upload photos of themselves and select digital garments to apply to those photos. The idea of dressing a photograph with digital garments exists to some extent already[1].

However, it is different in two key ways. These are garments that will never exist physically and there is a large amount of manual effort in creating these images. Our application addresses both of these points, having better quality on garment representation than social media app filters and involves minimal manual processing to final image composition, being nearly completely automated.

3.3.1 Implementation. The Dress Me Up web application relies heavily on an image composition service in order to successfully create a synthesized photo. Before feeding the composition service the required data, users must first scan their bodies in order to create a 3D model where the garment will be simulated on.

Regarding generating personal 3D avatars, this functionality has been integrated inside the Dress Me Up application, with the only limitation being that it has to be accessed from a mobile device. This is because when generating the avatars, data from multiple device sensors are used to facilitate the 3D reconstruction of the body. In order to translate the human body to an accurate digital representation, it was decided to use the STAR body model [21], to compare the silhouette of a person with the silhouette of the STAR body model. The first step was to have very accurate human body segmentation using precise background removal. The next step was to minimize the distance between the two silhouettes. The generated 3D avatars were then saved to Google's Firebase Storage in order to be accessed by the composition service.

Based on the defined Dress Me Up system input of:

(1) A 3D body scan of the subject (acquired via user scanning)
(2) A frontal view user uploaded photo in a common pose and viewpoint (e.g. stand / contrapposto)
(3) An identifier of a user selected garment

We developed an automated end-to-end process which is outlined in the steps below:

- Automatic rigging of the 3D body scan and 3D offset calculation.
- Auto foreground/background segmentation.
- 2D body joint detection in frontal view.
- 3D body joint detection in frontal view.
- Multi-stage single-view avatar 3D pose fitting and optimization.
- 3D garment model PBS and ray-tracer rendering of photo-realistic 2D garment sprites with shadows.
- Automatic 2D image warping.
- Blending the processed 2D garment sprites onto the original input user photo to compose the final visualisation.

We relied on React.js [28] for the development of the client facing application in a way that the same user experience is retained on all users accessing it from different kind of devices and screens.

3.3.2 Interface. The Dress Me Up web app is hosted on Google Firebase so it can be accessed by any user from a predefined URL. After users sign in they can navigate to three areas using the bottom navigation bar, the Collection screen, the Add new collection item screen and the Account screen. To proceed, they must first enter garment preferences and scan their bodies by accessing the Account screen (Figure 3).

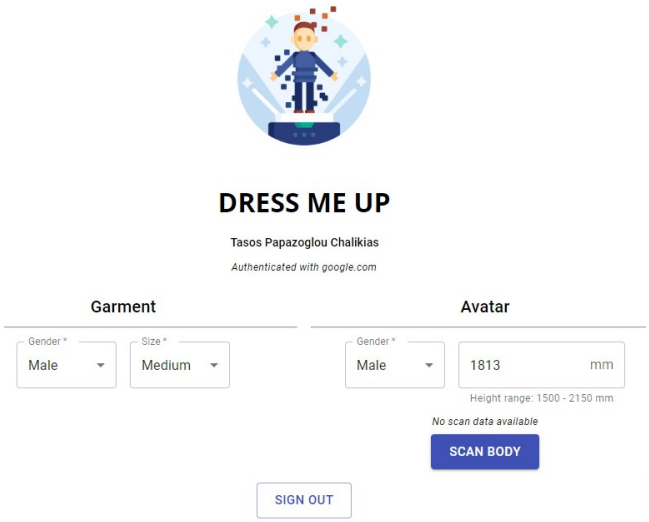

Figure 3: Dress Me Up - Account View

There, users must enter the gender and size for the garments that the application will load in order for them to select from. Also the gender and height of the user must be entered in the Avatar section before hitting on the Scan Body button. Then an interface guide is launched that helps users scan their body in the most effective way possible using a mobile device camera. The user also has the option to sign out of the application from the Account screen.

Selecting the 'New' option from the navigation bar at the bottom, users can initiate the process to create a virtual try on photo, which is called a collection item. By clicking on the Camera button to the bottom right, users can either use the camera of a device or a presaved photo of themselves to use for a new collection item (Figure 4). By clicking on the Next button in the top right, the user is transported to the garment selection screen where a populated list of available garments is loaded (Figure 5). Each garment also features a popularity score so the user can select a garment based on fashion trends to boost their online presence when sharing the result.

After selecting a garment and clicking on the Next button once again, the last step of the new collection item upload process is

[1] https://www.instagram.com/thisoutfitdoesnotexist/

Figure 4: Dress Me Up - Add new collection item step 1

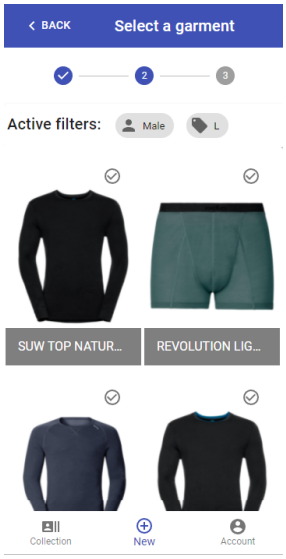

Figure 5: Dress Me Up - Add new collection item step 2

shown, which features the selected photo, the selected garment and a text box for the user to provide a title for the uploaded item (Figure 6). By clicking on the Upload button, a new collection item is submitted to the system.

After a new collection item has been successfully uploaded, a user can go to the 'Collection' screen of the app, where all pending and ready items are available (Figure 7). Once ready, an item can be viewed, downloaded and subsequently shared to social media.

3.3.3 Usage Scenario. A user logs in the app from their mobile phone and navigates in the New screen using the bottom navigation bar. There by clicking on the Floating Action Button (FAB) in the bottom right the user takes a photo using the devices front facing camera and clicks on the Next button on the top right. In the garment selection screen the user selects the light blue base layer shirt and clicks on the Next button in the top right. In the next screen the user provides a title to the new collection item and clicks on the Upload button. After the upload process has been completed successfully the user clicks on the Collection bottom navigation bar button in order to be taken to the Collection screen. There, in the pending section the user can see the submitted collection item. After approximately an hour the user logins to the app again and can see the synthesized collection item in the ready section of the Collection screen.

3.4 Magic Mirror

The Magic Mirror application is a mobile app for augmented reality virtual garment fitting. It is an AR dressing room for virtually trying on clothes at home with the capability to buy them through an interconnection to an e-shop.

3.4.1 Implementation. In order to achieve a high quality augmented reality virtual garment fitting experience three key factors were taken into account:

Figure 6: Dress Me Up - Add new collection item step 3

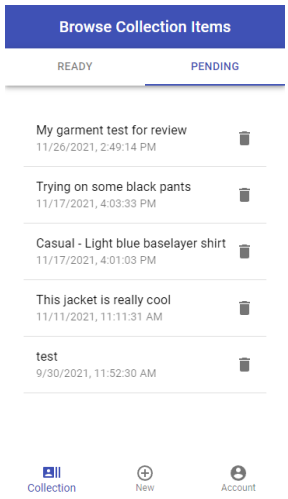

Figure 7: Dress Me Up - Collection (Pending items)

(1) The garment needs to fit the user's body not only when the user is stationary but during movement as well.
(2) The garment should look as realistic as possible when the user moves.
(3) The user must not wait for any computation to be completed and the whole experience must take place in real time.

The Unity game engine was selected for the development of the mobile application. Unity supports mobile application development, features a vast selection of potential resources that can be used and can be exported to all major mobile platforms. AR Foundation is the Unity framework that is used when developing AR software. It supports Apple's ARKit [3] and Android's ARCore [14] platforms. There is however the limitation of no support for body tracking from the ARCore library, thus making the application currently iOS only. The body position tracking capability of ARKit was utilized, enabling the correct tracking of a person's body, allowing the correct fit of a garment to the user at all times. As a baseline garment rendering tool, skeleton based animation was adopted. With skeleton-based animations, which are also called "skinning animations", a skeleton is embedded in a target 3D model and the new vertex position is estimated based on the underlying skeleton

movement. Additionally, the embedded skeleton has to be compatible with ARKit and Unity. Furthermore, an additional similar skeleton is employed as an occluder in order to hide the neck area of the garment, thus improving the observable fit on the user's body. Up to this point, only the first key factor has been taken into account, with a garment being fitted on a user's body. However, the skeletal animation on its own does not offer substantial realism. The underlying cause is that local shape changes over time cannot be shown.

To counter this issue, particle based simulation has also been utilized along with skeletal based animation. In particular, particle based simulation reduces physics related computations, which boosts performance. In order to achieve this, it approximates a target garment with a sparse set of particles distributed uniformly across surface meshes. It is applied on top of the skeleton animation. As a result the dynamic local movement of a garment is captured. The Obi [30] physics engine has been chosen as the main engine for real time garment simulation. Every asset, which includes a garment, has the Obi physics engine integrated, with the integral Obi related information parameters calculated and optimized beforehand, so as to improve the final result. The resulting experience features a variety of virtual garments that the user can browse through and try out in real time.

Google's Firebase [15] has been used to save personal data for each user in the form of individual profiles. For each user, gender and size options were saved in order to be used when browsing garments or selecting a different size during the AR try on experience. The application can also recommend garments to the user based on the 'favorited' garments by the user.

One special requirement that is in place because of ARKit's limitations is that only the back facing camera of the phone is compatible with the augmented reality try on functionality, which means that users must either stand in front of a mirror or connect the phone to a larger screen wirelessly in order to see themselves trying on the garment effectively.

3.4.2 Interface. In the Magic Mirror mobile application, users can browse through the full catalogue of garments that are available in an e-commerce e-shop, browse through a subset of aforementioned garments that are available for virtual try on, and browse through their 'Favorites' which features a list of all the favorite garments a user has added, in order to be easily accessible.

Figure 8 shows the garment list that the user can browse through. Each garment item features a preview image, its name and price as well as a heart shaped icon button that adds it to the user's favorites. Users can sort the list based on garment category and tailored fashion recommendations based on their selection of garment favorites. The garments are loaded dynamically by scrolling through the view.

When tapping on a garment item the user is shown the product details view (Figure 9) where a larger image of the garment is shown, with the option to add the garment to favorites as well as perform three actions. Users can virtually try on a garment on themselves using Augmented Reality (Figure 10), view the garment on a 3D viewer with the freedom to zoom in/out and rotate it (Figure 11) and visit the e-commerce website in order to purchase the garment. There is also the capability to change the size of the garment from inside the AR try on or 3D view, using a drop-down

Figure 8: Magic Mirror - Garment list

Figure 9: Magic Mirror - Product details

Figure 10: Magic Mirror - Augmented Reality try on view

Figure 11: Magic Mirror - 3D garment view

menu. Additionally, there is the option to switch between available garment colors.

3.4.3 Usage Scenario. The user opens the app and successfully logs in and browses through all garments that can be tried on via AR. The user taps on the Filter drop-down to the right and selects the 'Pants' category. The garment list is now filtered to show only

pants. When the user finds a pair of pants they like they tap on the garment item. In the product details view the user taps on the AR try on button, in order to see how the garment fits their body. The AR viewer is launched and the user is positioned across a mirror in order to see the garment fitting the body reflection. After inspecting the garment using various poses, the user exits the AR viewer and enters the 3D viewer in order to look at the garment from all angles that were not accessible while wearing it, due to body movement restrictions. The user now satisfied with the garment returns to the product details page and taps on the 'Visit e-shop' button and is transported to the product page in the e-commerce website where the garment can be purchased.

4 PILOTS & EVALUATION

Three piloting sessions are organized, each targeting a different end user group, while aiming to recruit the most suitable testers for all three applications. The evaluation data will be gathered in the form of Google Forms questionnaires that will be filled out by the users after each session is over. The questionnaires will be analyzed using different methods in order to feed the last phase of app development.

4.1 VR Designer pilot testing

For the VR Designer App the target group are professional designers and artists from the fashion industry as well as individuals who tend to present their creative work to an audience like product managers. The pilots are taking place at the headquarters of a sportswear company, where all necessary hardware (VR headset and peripheral equipment, PC) will be available in a space specifically organized for VR-testing, in alignment with all safety health protocols for COVID-19. Users can wear the VR headset and access all the functionality inside the VR Designer app, enabling them to inspect the avatars, garments and animations.

Evaluation: After thoroughly testing the platform and its functionalities, users will answer the evaluation questionnaire, available through Google Forms. Most of the questions are ranking-questions with a few multiple-choice and drop-down lists, evaluating the overall utility, accuracy, interface, user experience of the app and the range of assistance it provides to fashion designers in the garment design and presentation process. The Pilots' outcome will be employed to evaluate, refine and improve the functionalities of the VR Designer software. Statistical evaluation criteria will be applied for extracting the analysis and providing insights of the tester's feedback.

4.2 Dress Me Up pilot testing

For the Dress Me Up App, the target group comprises influencers, fashion lovers and enthusiastic brand followers. The focus group however is much wider in this scenario, as anyone interested can participate by using the app on their smartphone or PC, without the need to visit a specific place for testing. This selected group will have the chance to test and virtually try regular and special garments. Online and physical consumers will be specifically addressed in order to access Dress Me Up and explore its functionalities. Any device can be used to log in as the app is hosted online. The baseline of this process for users will be to access the app and register, scan themselves through their smartphone and upload it in the application, where their 3D avatar will be created, take a photo of themselves in a pose they like and then select from a list of available clothes for the one that they want to try on. The garment will be automatically fitted on their photo and, optionally they can share the generated content through their social media accounts.

Evaluation: After testing the app, users will answer the evaluation questionnaire, available on Google Forms and in Microsoft Forms Analytics, whose outcomes will be combined upon the end of the pilots. Users will evaluate the overall utility, accuracy, interface and user experience of the app. Outcomes will form insights and analytics for the final evaluation and overall refinement of the app during the last stage of the project.

4.3 Magic Mirror pilot testing

For the Magic Mirror App, the target group are regular shoppers and consumers. This is a rather wide group as it includes all consumers not limited to any professions or interests. This mobile app is simulating the physical shopping experience through a smartphone. The pilots are taking place at the headquarters of a sportswear company, where all necessary hardware (iPhone, smart TV and peripheral equipment) will be available in a space specifically organized for testing sessions, in alignment with all safety health and security protocols. After the standard registration process, users can navigate through a vast garment catalogue and save any preferable garment by adding it to favorites. User can choose AR – enabled garments, loaded dynamically by scrolling, which are available to inspect either in a 3D view – projected in real dimensions, through their smartphone's camera, where user can zoom and rotate with the buttons available or by physically walking left or right, or digitally try it on themselves in AR and inspect how the garment will fit on them real time. In order to inspect the garments, users can either use a regular mirror and back camera of the iPhone, observing results though their phone, or use a screen, which can be rotated into a portrait mode and can be connected with the iPhone via air link, in order to observe results through the screen.

Evaluation: After testing the app, users will answer the evaluation questionnaire, available on Google Forms. Most of the questions are ranking-questions with a few multiple-choice and drop-down lists, evaluating the overall utility, accuracy, interface, user experience of the app and the extend of the convenience it provides to consumers for their online purchases. Outcomes will form insights and analytics for the final evaluation and overall refinement of the app.

5 FUTURE WORK

In this paper we have presented three HFI applications that enhance the creative process of garment design, revolutionize the way people interact with fashion in social media, and simulate the physical in-store experience for online shopping respectively. However, apart from the user feedback that we will gather in each pilot, that will definitely drive changes in features, functionality and the interface, there is also a plethora of future work suggestions to be considered for each application.

Despite the VR Designer application being already in a feature complete state, we continue to explore how we can further improve and expand the app and see what else can be implemented to enhance the user experience. Apart from constant performance and visual refinements in the whole spectrum of the software, one major option we will explore is the multiplaying functionality. This is a feature to allow multiple users being present in the same VR session. The users could act as observers, being visible as digital avatars or not, and would assemble in a watching room from inside the VR app, so that a user could present a complete design collection to an audience, with everyone participating from inside the same virtual space. In order to make the VR Designer app more flexible, we could add a feature for the software to be able to read the alembic files that the designer has exported that include avatars, garments and animations, from a remote location like for example an online server. This could make the VR Designer app more plug and play, by setting a server URL on the app's settings and then automatically populating the VR UI based on a remote location's server assets. Another functionality that could benefit the application and the end user would be the option have a virtual space builder inside the app. With this builder the user could change or decorate the virtual space as they see fit, for example to follow a specific theme or season, in order to create a tailored environment that is stylistically matching to a fashion collection.

For the Dress Me Up application a great new feature could be the user to be able to upload a short video instead of a photo, thus the app synthesizing a virtually fitted moving garment. If we treat a photo as a video still, then the assumption is that the whole photo synthesis process that is outlined in the Dress Me Up section must be performed multiple times for all the frames of the short video. This could give new insight to users as to how the garment responds to their personalised movement patterns. Another feature that could elevate the user experience is automatic size fitting, which means that the platform could automatically calculate the user size and subsequently the garment size based solely on the body scans.

The Magic Mirror application offers a virtual garment fitting experience from a mobile device. To further improve this experience, the 3D view of the garment could feature more interactive features. For example, when the garment is shown it could be dragged, stretched or moved by finger gestures, thus allowing the user to gain a better understanding about the garment by witnessing how different kinds of physics apply on it. To have the garment fit better to the user, in the AR viewing of the garment, a body scanning option using the camera of the mobile device could be investigated so as to get better body measurements thus improving fitting. When using the AR try on functionality, a tensor map could be useful, which is an overlay on top of the fitted garment, that highlights areas where the garment is too tight or too loose on the body. This could aid the user on selecting the right size if they prefer a looser or a tighter fit. Additionally, the feasibility of a user trying out a set of garments in a session could be looked into. This would help users understand how different garments match together on themselves, essentially creating outfits, helping in the decision making process regarding a purchase, and actually supercharging it by persuading the user this way to purchase outfits instead of single items. The app is currently limited to iOS users only, but it could also be available for Android devices, when Google's ARKit framework adds support for body tracking functionality.

REFERENCES

[1] Goodstyle app. 2022. Virtual Dressing Room app. Retrieved June 28, 2022 from https://goodstyle.app/

[2] PICTOFiT app. 2022. Fashion powered by Augmented Reality. Retrieved June 28, 2022 from https://pictofit.com/pictofit_new/

[3] Apple. 2022. Augmented Reality ARKit. Retrieved June 27, 2022 from https://developer.apple.com/augmented-reality/arkit/

[4] BBC. 2016. Most online clothes shoppers send something back. Retrieved June 27, 2022 from https://www.bbc.com/news/business-36395719

[5] Browzwear. 2022. Fabric Analyzer Module. Retrieved June 28, 2022 from https://browzwear.com/products/fabric-analyzer/

[6] Browzwear. 2022. Lotta Module. Retrieved June 28, 2022 from https://browzwear.com/products/lotta/

[7] Browzwear. 2022. New animation and smart pattern tools added to VStitcher. Retrieved June 24, 2022 from https://browzwear.com/pr-browzwear-2021-1-edition/

[8] Browzwear. 2022. Stylezone Module. Retrieved June 28, 2022 from https://browzwear.com/products/stylezone/

[9] Browzwear. 2022. VStitcher 3D Apparel Design Software. Retrieved June 24, 2022 from https://browzwear.com/products/v-stitcher/

[10] CLO. 2022. CLO: 3D Fashion Design Software. Retrieved June 24, 2022 from https://www.clo3d.com/

[11] Marvelous Designer. 2022. making, editing and reusing 3D clothes. Retrieved June 28, 2022 from https://www.marvelousdesigner.com/

[12] DRESSX. 2022. First multi brand retailer of digital fashion clothing. Retrieved June 28, 2022 from https://dressx.com/

[13] The Fabricant. 2022. Digital fashion house. Retrieved June 28, 2022 from https://www.thefabricant.com/

[14] Google. 2022. AR Core. Retrieved June 28, 2022 from https://developers.google.com/ar

[15] Google. 2022. Store and sync app data at global scale. Retrieved June 27, 2022 from https://firebase.google.com/

[16] Heuritech. 2022. Fashion AI & Trend Forecasting. Retrieved June 28, 2022 from https://tfashion.ai/

[17] Meta. 2022. Meta Quest 2. Retrieved June 24, 2022 from https://store.facebook.com/quest/products/quest-2/

[18] The Modern Mirror. 2022. creating 3D virtual fit solutions for the luxury fashion industry. Retrieved June 28, 2022 from https://themodernmirror.com/

[19] Tekila Harley Nobile, Alice Noris, Nadzeya Kalbaska, and Lorenzo Cantoni. 2021. A review of digital fashion research: before and beyond communication and marketing. *International Journal of Fashion Design, Technology and Education* 14, 3 (2021), 293–301. https://doi.org/10.1080/17543266.2021.1931476 arXiv:https://doi.org/10.1080/17543266.2021.1931476

[20] Optitex. 2022. Optitex: Fashion Design Software. Retrieved June 24, 2022 from https://optitex.com/

[21] Ahmed A A Osman, Timo Bolkart, and Michael J. Black. 2020. STAR: A Sparse Trained Articulated Human Body Regressor. In *European Conference on Computer Vision (ECCV)*. 598–613. https://star.is.tue.mpg.de

[22] Stefanos I Papadopoulos, Christos Koutlis, Symeon Papadopoulos, and Ioannis Kompatsiaris. 2022. Multimodal Quasi-AutoRegression: Forecasting the visual popularity of new fashion products. *arXiv preprint arXiv:2204.04014* (2022).

[23] Stefanos-Iordanis Papadopoulos, Christos Koutlis, Manjunath Sudheer, Martina Pugliese, Delphine Rabiller, Symeon Papadopoulos, and Ioannis Kompatsiaris. 2022. Attentive Hierarchical Label Sharing for Enhanced Garment and Attribute Classification of Fashion Imagery. In *Recommender Systems in Fashion and Retail*. Springer, 95–115.

[24] Stefanos-Iordanis Papadopoulos, Christos Koutlis, Manjunath Sudheer, Martina Pugliese, Delphine Rabiller, Symeon Papadopoulos, and Ioannis Kompatsiaris. 2022. Attentive Hierarchical Label Sharing for Enhanced Garment and Attribute Classification of Fashion Imagery. In *Recommender Systems in Fashion and Retail*, Nima Dokoohaki, Shatha Jaradat, Humberto Jesús Corona Pampín, and Reza Shirvany (Eds.). Springer International Publishing, Cham, 95–115.

[25] Shopify. 2022. Fashion Industry: Statistics, Trends & Strategies to Use in 2022. Retrieved June 27, 2022 from https://www.shopify.com/enterprise/ecommerce-fashion-industry

[26] Sizolution. 2021. The problem of returning clothes to online stores. Retrieved June 27, 2022 from https://medium.com/sizolution/the-problem-of-returning-clothes-to-online-stores-89ddf3854f5d

[27] SneakerKit. 2022. Virtual try-on solutions. Retrieved June 28, 2022 from https://m.apkpure.com/sneakerkit/io.vyking.sneakerkit

[28] Facebook Open Source. 2022. React - A JavaScript library for building user interfaces. Retrieved June 24, 2022 from https://reactjs.org/

[29] Statista.com. 2021. Online or in-store shopping preference for selected product categories by consumers worldwide as of 2017. Retrieved June 27, 2022 from https://www.statista.com/statistics/692871/global-online-shopping-preference-by-category/
[30] Virtual Method Studio. 2022. Obi Unified particle physics for Unity. Retrieved June 27, 2022 from http://obi.virtualmethodstudio.com/
[31] T-Fashion. 2022. Fashion AI & Trend Forecasting. Retrieved June 28, 2022 from https://tfashion.ai/
[32] Unity Technologies. 2022. Unity Real-Time Development Platform. Retrieved June 24, 2022 from https://unity.com/
[33] Trendzoom. 2022. Delivering detailed fashion forecasting reports. Retrieved June 28, 2022 from https://trendzoom.com/
[34] Filareti Tsalakanidou, Symeon Papadopoulos, Vasileios Mezaris, Ioannis Kompatsiaris, Birgit Gray, Danae Tsabouraki, Maritini Kalogerini, Fulvio Negro, Maurizio Montagnuolo, Jesse de Vos, et al. 2021. The AI4Media Project: Use of Next-Generation Artificial Intelligence Technologies for Media Sector Applications. In *IFIP International Conference on Artificial Intelligence Applications and Innovations*. Springer, 81–93.
[35] TUKA3D. 2022. 3D virtual sampling software with motion simulation for fit analysis, design development, and photorealistic rendering. Retrieved June 28, 2022 from https://tukatech.com/tuka3d/
[36] Unity. 2022. AR Foundation. Retrieved June 27, 2022 from https://unity.com/unity/features/arfoundation
[37] Wanna. 2022. Virtual try-on solutions. Retrieved June 28, 2022 from https://wanna.fashion/
[38] WEARFITS. 2022. Digital disruption of the fashion industry through Augmented Reality and Machine Learning. Retrieved June 28, 2022 from https://wearfits.com/index.html
[39] WGSN. 2022. Trend Forecasting & Analytics. Retrieved June 28, 2022 from https://www.wgsn.com/en