



eTryOn - Virtual try-ons of garments enabling novel human fashion interactions

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Abstract	D5.1 reports on the first version of the software implementation of the i) VR system that simulates the physical try-ons for immersive experiences, ii) mobile application for the fashion consumers for use in social media, iii) AR application for virtually trying on clothes.
Keywords	VR, AR, Human Fashion Interaction, UI, Mockups, Implementation, Software, Development

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List of abbreviations and Acronyms

Abbreviation	Meaning
VR	Virtual Reality
AR	Augmented Reality
MR	Mixed Reality
HFI	Human Fashion Interaction
CTA	Call To Action
AI	Artificial Intelligence
CV	Computer Vision
FAB	Floating Action Button
MPS	MallZee Performance Score
SDK	Software Development Kit
API	Application Programming Interface
FBX	FilmBox
.bin	Binary (file)
GPU	Graphics Processing Unit
REST	Representational State Transfer
I/O	Input Output
UI	User Interface
JPG	Joint Photographic Experts Group
JS	JavaScript

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1. Executive summary

D5.1 presents the core version of the eTryOn interaction systems which include three interactive solutions outlined below:

- **VR Designer:** A Virtual Reality (VR) creative fashion application targeting fashion designers, facilitating them throughout the creative process of garment design by offering realistic fitting of the digital garments on photorealistic 3D avatars,
- **Dress Me Up:** A fashion mobile application for social media users (e.g. influencers), allowing them to virtually change their outfit in an image or video by selecting from a pool of digital garments and then uploading it to social media, and
- **Magic Mirror:** A mobile-based e-commerce Augmented Reality (AR) fashion app that enables virtual try-ons of garments during online shopping that aims to recreate the at home experience of buying clothes from a physical store.

In this document we start with an introduction about the current state of Human-Fashion-Interaction (HFI) applications, what we offer as a novel approach and the challenges that we face. We outline the application design of each eTryOn core interaction system, using mockup software to design the interface of the applications, based on the user requirements, as they were defined in D6.1. The interfaces were designed so that the user flow throughout the apps can be simple, intuitive and frictionless (i.e. to not overburden them with complex action paths). Specifically in the Magic Mirror case, a User Journey map is constructed, to better understand the actions required by a user, i.e. from marketing Call To Actions (CTAs) throughout the application and to the end goal which is to purchase a garment item.

Furthermore, we analyze the implementation choices for all interaction systems. More specifically, we investigate a range of platforms based on the requirements for each application, e.g. interactivity, photorealism and cloth simulation potential. Furthermore, for the Dress Me Up application we analyze the pros and cons of it being a mobile web application versus a mobile native one, and further compare the various options for the implementation software.

Next, we outline the process of creating an AR experience in the context of a Snapchat filter as a promotional tool to increase the visibility of the project and subsequently the eTryOn interaction systems. The Snapchat filter is a teaser application of the Magic Mirror app, offering the visualization of clothes in an AR environment but with limited capabilities in terms of accuracy and fitting. In this direction, we get into detail for all the developmental methodology steps to create this filter that offers a real-time realistic garment simulation in order to attract more users to our applications.

Finally, we outline the development choices of an administrative web application that will serve as a management tool for garments, avatars and animations for the VR Designer application.

2. Introduction

In an era of significant breakthroughs in the fields of Artificial Intelligence (AI), Computer Vision (CV) and interactive technologies (e.g. VR, AR, 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. 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 frenziness like for example Instagram.

With eTryOn, our goal is to use interactive technologies which can become mainstream in the fashion industry, focusing on three distinct applications as fashion experiences that target both fashion designers and consumers. In more detail, eTryOn aims to modernize three unique experiences of fashion; i) the creative experience in the fashion design process, ii) the social experience of fashion items by fashion lovers, iii) the shopping experience of online fashion consumers.

Creative experience: Currently, fashion designers can create digital garments in professional software like Browzwear¹, Optitex² and Clo3D³. 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. Recently only (February 2021), Browzwear announced and released the animation potential, which rather heavy in terms of the required processing power⁴. Based on the feedback we got from 20+ fashion designers (reported in D6.1), animation is an important perspective both for the design process itself, but also at later stages for presenting the garment designs to other departments (e.g. sales) and upper management, while the limited processing power is one of the main bottlenecks they mentioned.

eTryOn's first application (**VR Designer app**) aims to enhance the creative experience of fashion designers, through a VR application for immersive garment fitting. More specifically, a user-friendly VR interface will be developed using state of the art game engines (Unity) that enables designers to get a better overview of their designs, by providing them with realistic simulations on how their garments fit on their own fitting mannequins. Besides the increased realism offered by the immersive VR environment, with the advancements in the field of human-like animations that modern game engines provide, designers will be 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, state of the art virtual reality SDKs (Oculus Quest 2⁵) will be utilized for achieving the creation of the aforementioned application. Finally, in order to simplify the management of the assets that will be available in the VR application (avatars, animations, garments, etc.), a user friendly web-based back-office application will be developed.

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 even designed⁶. However, people still interact with the fashion items in the

¹ <https://browzwear.com/>

² <https://optitex.com/>

³ <https://www.clo3d.com/>

⁴ <https://browzwear.com/pr-browzwear-2021-1-edition/>

⁵ <https://www.oculus.com/quest-2/>

⁶ <https://www.olapic.com/resources/instagrams-transformation-fashion-industry-continues/>

same way, i.e. they have access to the physical clothes which they wear to shoot the photos/videos, and then post in their social media accounts. People try on clothes from their existing wardrobe or order new items that have already reached production phase. Considering that during this fashion transformation by Instagram, 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 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 (cost, materials) dictate the limits of the garment designs.

To that end the second application envisioned by eTryOn (**DressMeUp app**), aims to allow a range of users like fashion consumers, models, influencers and fashion lovers in general to upload a short video including some simple movement or a photo, choose a garment they like from a variety of digital ones and the application will return to them a synthesized media file with the digital garment simulated on their body. The end result can then be uploaded to social media networks like Instagram. 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 for their performance. For the development track, the mobile interface and backend architecture system will be designed with current state of web application frameworks (Node.js, React.js) handling a variety of tools provided for mobile application development.

Shopping experience: The consumer has the ability to buy fashion items online by browsing through a list of available options, 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 cat walking, and selecting their 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 on tried-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 a survey⁷, 77% of online shoppers return clothing because of poor fit. Other problems include poor quality (e.g. images of the products are taken at best lightning and position conditions, and may not represent the actual product accurately) and style issues (i.e. getting into the product details is almost impossible in online shopping). For the fashion industry, the impact of this is twofold. First, people still prefer to buy clothes in-store with online/in store rates being 40% vs 51% respectively⁸, 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 product⁹), which entails a cost of combating return rates as high as 50%¹⁰.

Considering the above, eTryOn's third application (**Magic Mirror app**) aims to adopt the latest advancements of AR for improving the overall experience of virtual garment fitting. The users of this AR mobile application will be able to scan themselves at home using their phone's camera and observe in real-time through the screen of their mobile device

⁷ <https://futurestartup.com/2016/07/01/three-reasons-people-dont-shop-apparel-and-footwear-online/>

⁸ <https://www.statista.com/statistics/692871/global-online-shopping-preference-by-category/>

⁹ <https://www.bbc.com/news/business-36395719>

¹⁰ <https://www.shopify.com/enterprise/ecommerce-fashion-industry>

how a particular garment fits their body. To achieve this result, AR APIs such as AR foundation¹¹ offered from Unity technologies will be the leading tool for the development both of the interface and backend architecture of the application. Moreover, to further improve the virtual try on experience, the application will use as input information on their profile (e.g. age, gender, previous purchases, etc.) and recommend a variety of garments that seem as a best fit for the consumer's profile based on the recommendation system developed in WP3.

Finally, as mentioned above, social media platforms which are very popular and even more so in the fashion domain, offer a novel AR interaction pathway with their user base in the form of filters (e.g. Instagram, Snapchat). So far, their main use was on facial filters (e.g. adding a nose on top of the user's nose, etc.). This has created a significant trend on how people use social media. Following this trend, combined with Snapchat's latest release of the first multi-platform (Android and iOS) supporting 3D body tracking¹², we have also developed a **Snapchat filter** that can be used by users to visualize themselves wearing digital garments. It is a similar approach to the magic mirror, without having any fitting information (i.e. in terms of sizing). On the other hand, it is a multi-platform solution that does not require by the users to download any additional apps and can be used for promotions and marketing as it reaches a large user base (that one of Snapchat). This filter, while it also enhances the interaction of humans with fashion, it will be mainly used as a promotion to our magic mirror app.

¹¹ <https://unity.com/unity/features/arfoundation>

¹² <https://vrscout.com/news/snapchat-3d-full-body-tracking-lenses/>

3. Application design

3.1 User Requirements

In order to define the features and the general design of the eTryOn applications, we conducted a questionnaire survey, which was part of D6.1 'The User Requirements'¹³. The statistical analysis of the results together with the domain experience of all partners served as the basis for the development of the applications.

In D6.1, we focused on two target groups of users that will use our applications, fashion designers for the VR designer app and the general public for the DressMeUp and Magic Mirror applications. Therefore, the deliverable consisted of two sections focused on each target group.

Specifically, for the VR Designer application, an interview with two designers from ODLO helped us to identify the most important questions for the questionnaire. The final questionnaire addressed questions regarding previous experiences of using a 3D software, the limitations the designers had, and the functionality that they would like to have available. The questionnaire comprised of open questions mostly and was answered by 22 fashion designers inside and outside the consortium. Given the limited sample and the open nature of the questions, an empirical and qualitative analysis was conducted in order to specify the user requirements for this application. The results showed that the visualization aspect when using 3D software is highly important for a designer. Almost all of the designers used answers like "create realistic garments", "create realistic views", etc. Therefore, during or after the creative process of garment design, creating realistic visualizations either for the design process itself or for the presentation of the garments to the upper management team, appears to be a crucial feature for the VR Designer application. It is also worth noting, that the required processing time and complexity is of high importance to the designers, as it was mentioned as a potential hazard multiple times when referring for example to animations. In this direction, the development of the eTryOn VR application will try and resolve some of the limitations and decrease the frustration that designers are facing when using the current 3D software, such as functional or workflow obstacles, in order for the VR designer application to be as appealing as possible.

The general public refers to the wider group of influencers, fashion shoppers and fashion lovers in general. This group is the target audience of the Dress Me Up and the Magic Mirror applications. The first one, a social fashion app is aimed at social media users, allowing them to virtually change their outfit in an image or video by selecting from a pool of digital garments and then upload it to social media. The second one, a mobile-based AR magic mirror that enables virtual tryons of garments during online shopping, aims to recreate at home the experience of buying clothes from a physical store. Given that the two applications have the same target group, a single questionnaire was formulated and openly distributed to Mallzee's user base, ODLO's base of influencers, as well as social media and the employees of the consortium partners. In this case, we got 143 answers, which appears to be a sufficient sample in order to conduct a statistical analysis.

The results were very informative regarding the features that consumers think are important in such applications. Specifically, the features "how the clothes looked on you" and "how the clothes fit you", when using an application which allows to virtually change outfits, appeared to be the most important for a user (with statistical difference among the other possible features such as "How quickly it created a picture", "the design of the clothes you could try" etc.). Therefore, the importance of the scanning component in these applications is clear, in order for the apps to provide an outcome as realistic and as tailored to the user as possible.

¹³ <https://etryon-h2020.eu/download/238>

Moreover, for the possibility of the Dress Me Up application being a social media platform, almost 40% of the applicants would rather use such an app but without sharing the resulting photo. Therefore, social media sharing in the Dress Me Up application will be optional.

Regarding the Magic Mirror app, the features of “Be able to rotate yourself to see how it looks all around you” and “Provide size recommendations” were statistically more significant from all other features, which led us to the decision to build this application having these two features among others, as core features.

3.2 Interface Mock-up Design

In the following subsections the design mock-ups are presented, with detailed information about the applications’ functionality and all the actions a user can perform.

The interface mock-ups have been designed using the Adobe XD¹⁴ software, which is a vector-based experience design platform that makes it easier to craft prototypes and create interactive mock-ups, so the user flows throughout the apps can be effectively communicated to designers and developers alike. More specifically, Adobe XD is widely used for whiteboarding & user flows, wireframing, user interface, animation & interaction design, prototyping and developer handoff.

3.2.1 VR Designer

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

The idea behind designing the VR environment is to emulate the way a Designer interacts with a garment in the virtual space, witnessing its physical properties, making it easier to try it on a variety of bodies and poses or animations.

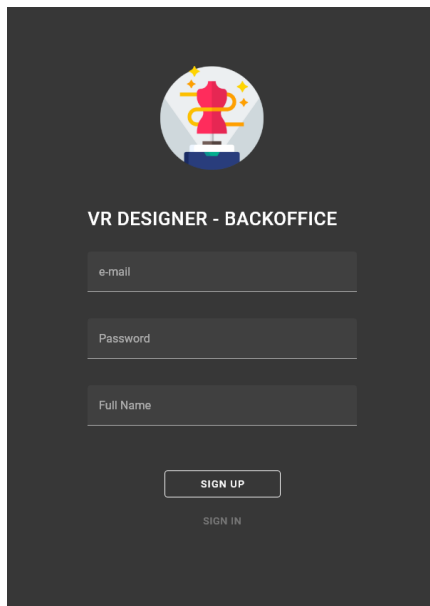


Figure 1: VR Designer: Sign Up / Login Screen

Opening the VR Desktop application, the user is greeted with a Sign Up page as illustrated in Figure 1. If the user already has a user account set up, the credentials can be used for

¹⁴ <https://adobe.com/xd>

the log in process. After successfully logging in the application, the user can interact with the VR space.

In Figure 2, Figure 2 the VR environment is shown. It emulates a room where the user can perform various actions.

In the left side of the room is a mannequin shelf, that features all the available mannequins for garment fitting. When selecting one, the Mannequin stand in the right changes to the one that is selected. The user can also cycle between available mannequins by using the two arrows at the bottom of the mannequin stand.

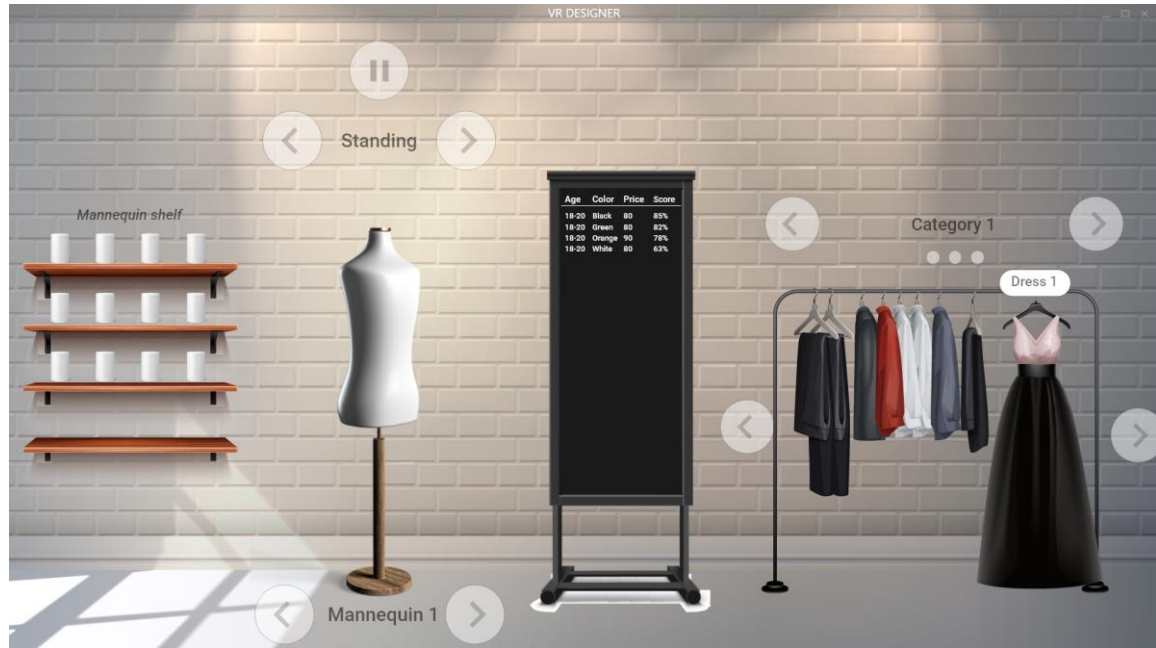


Figure 2: VR Designer environment

On top of the mannequin stand reside the animation controls. The user can cycle through available animations using the left and right arrows and play or pause the animation.

Right next to it is a panel where the user can observe the Mallzee Performance Score (MPS) for a specific garment. The score is based on the ratings similar garment items have received from users using the Mallzee¹⁵ mobile application and is the output of the trend detection algorithms of WP3. As a result, the designer can have an overview of end user sentiment about a design before it goes to production phase. Each score entry, besides from the score percentage features an age range, garment color and garment price, which are inputs for the trend detection algorithm, so that it predicts the trend potential of the garment at various market segments and with various product details.

In the right section of the wall is the garment rack. There the user can observe the available garments, load the next batch of them by using the left/right arrows and also change the category of shown available garments. By selecting a garment, it is automatically loaded and fitted on the active mannequin.

When the designer has set up a mannequin with a garment and is happy with the fitting and animations, they have the option to export the selected setup to a view-only VR standalone executable, which can be shared to interested parties (e.g. upper management) for visualization.

¹⁵ <https://mallzee.com/>

3.2.2 Dress Me Up

The Dress Me Up application is a web application adapted for mobile phones and desktop experiences alike targeting influencers, social media users and fashion lovers in general, to enhance their social media interactions. The function of this application is for the user to select a photo or video of themselves, along with a digital garment item that is provided within the application, send it to eTryOn's servers for simulating the digital garment on top of the user's image/video, visualize it inside the app after it has been rendered, and potentially share it on social media.

Upon opening the application, the user has to sign up providing an e-mail and a password and scan their body in order to proceed (**Figure 3**).

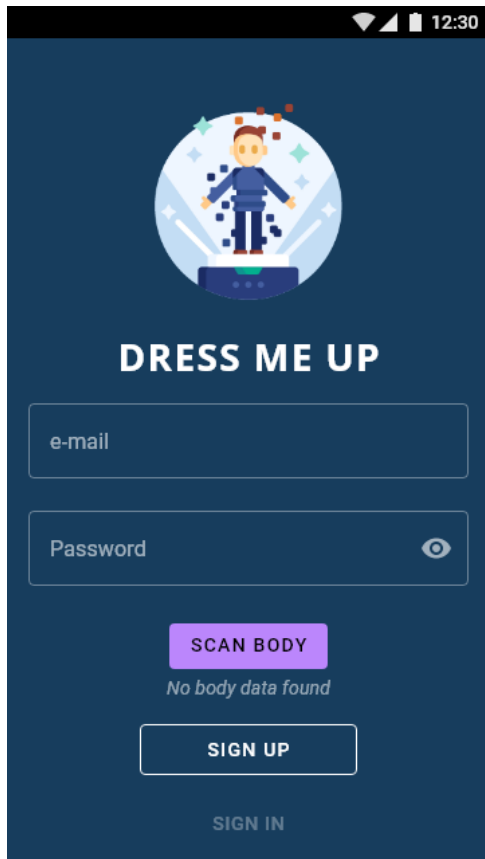


Figure 3: Dress Me Up - Sign Up Screen

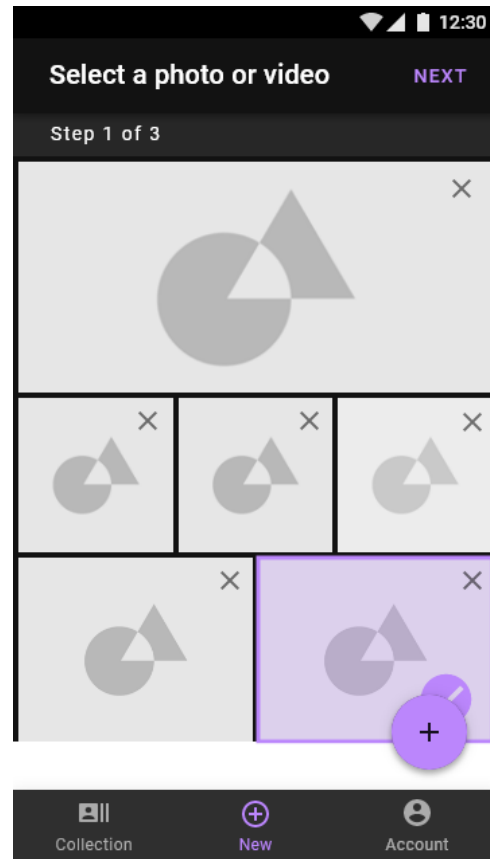


Figure 4: Dress Me Up - New Collection Item Screen (Step 1)

After successfully logging in, the user is transported to the New Collection Item screen (Figure 4). From this screen the user can initiate the creation of a new Collection Item. The first step is for the user to choose a photo or video of themselves, either by selecting an existing file from the grid list or by importing a new file to the app using the Add button.

Imported media files are shown on the grid list for easier reuse and can also be deleted. By tapping on the NEXT button situated on the top right of the screen the user is shown the next screen.

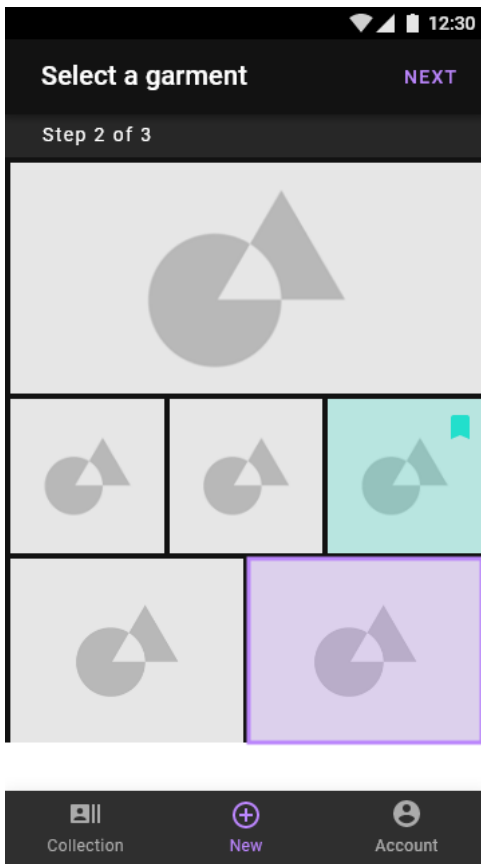


Figure 5: Dress Me Up - New Collection Item Screen (Step 2)

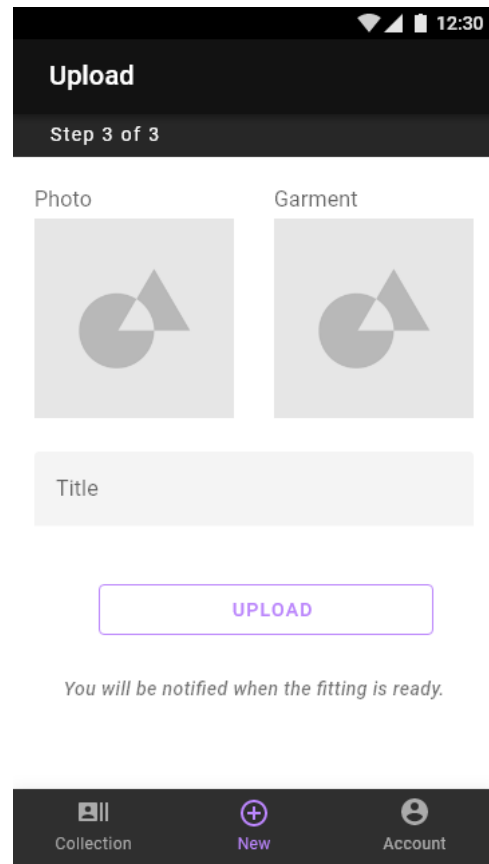


Figure 6: Dress Me Up - New Collection Item Screen (Step 3)

In Step 2 of the New Collection Item screen (Figure 5), the user has to select a garment that will be automatically fitted to the provided photo or video, from a preloaded dynamic grid list. After the selection, the user must tap on the NEXT button in the top right to proceed to the next screen.

In the last screen of the New Collection Item (Figure 6), the user can see an overview of the selected media (photo or video) and garment, and must provide a Title before tapping on the UPLOAD button to finish the process. After the upload has been successfully completed, the user is transported to the Collection screen.

The Collection screen is divided in two sections accessible through tabbed buttons. In the Pending screen (Figure 7) the user can see a list of the collection items that have been uploaded to the system and are still processing. When a Collection Item has finished processing it can be found under the Ready screen (Figure 8), where a list of the items resides. By clicking on a Ready Garment Item, the user can finally see the result. Also, on both screens the user can delete a pending or a completed Collection Item.

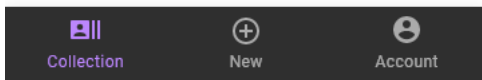
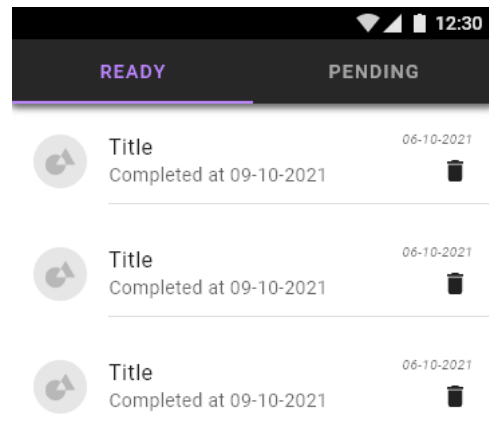
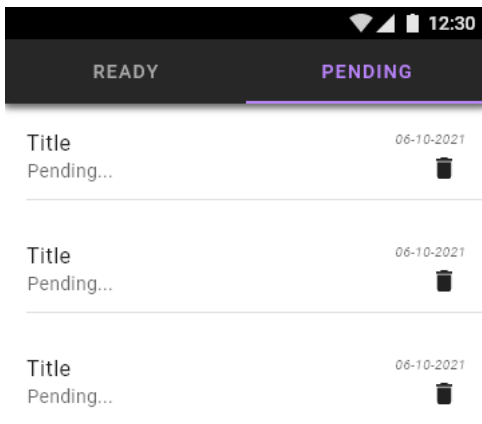


Figure 7: Dress Me Up - Collection Pending Screen

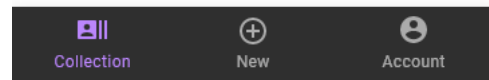


Figure 8: Dress Me Up - Collection Ready Screen



Figure 9: Dress Me Up - Collection Viewer Screen

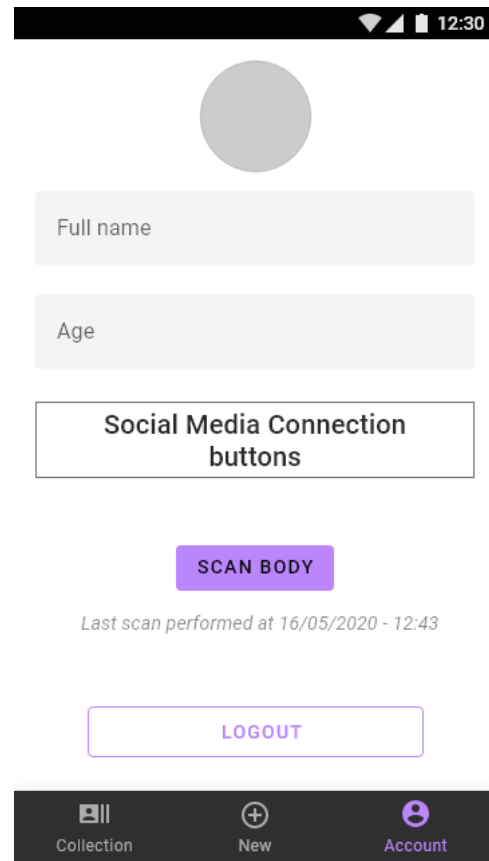


Figure 10: Dress Me Up - Account Screen

As shown in Figure 9, the user can view the resulting Collection Item, play it using the controls in the top right if the uploaded media was a video, and share it to social media.

By tapping on the right icon of the bottom navigation component the user can access the Account screen (Figure 10), where a variety of actions can be performed. These actions include, editing of user data such as Name and Age, connecting to Social Media to enable Social Media Sharing, Body scanning functionality, and logout.

3.2.3 Magic Mirror

The Magic Mirror mobile application is an AR dressing room for virtually trying on clothes at home with the capability to buy them through an interconnection to the ODLO e-shop¹⁶.

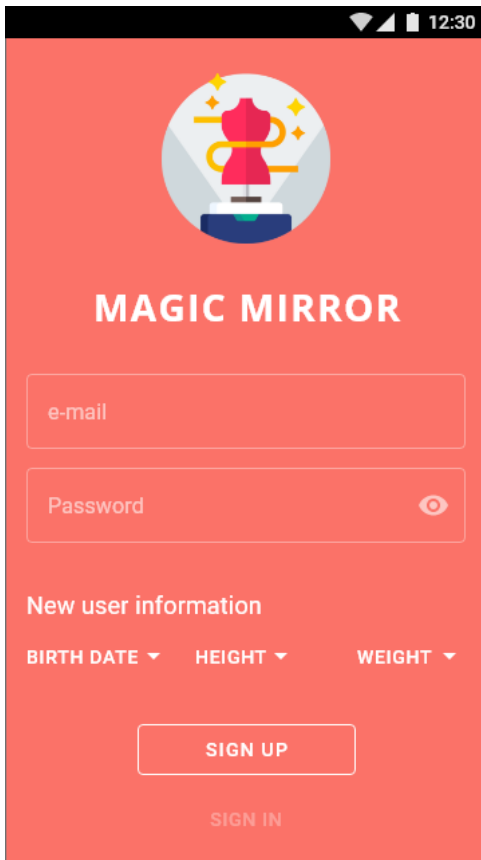


Figure 11: Magic Mirror - Sign Up Screen

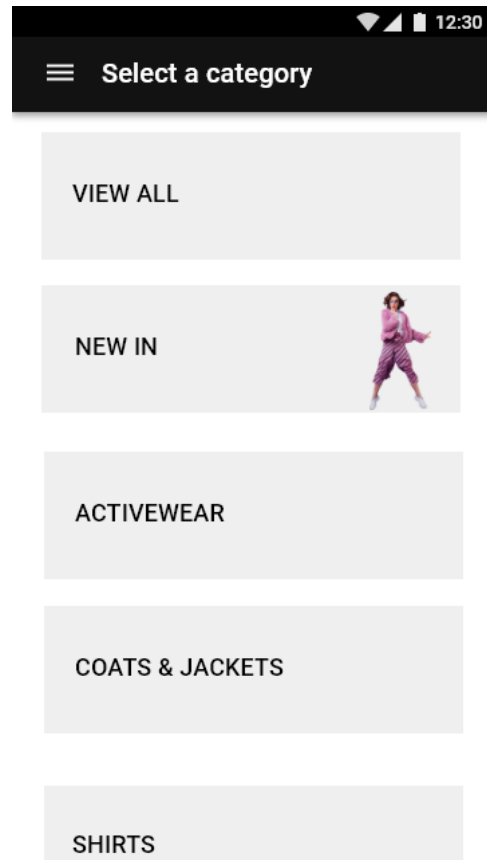


Figure 12: Magic Mirror - Select a Category Screen

The user must first create a user account providing an e-mail address, a password and some personal data like birth date, height and weight in order for the application to automatically suggest a garment size (Figure 11).

After signing in the user is shown the main view of the application where the available garment collection is separated into categories (Figure 12). By tapping on the hamburger icon situated in the top left, the user activates the Options sidebar to expand.

In the Options sidebar (Figure 13) the user can perform various tasks like, sign out, change personal information, change the units used in the application from imperial to metric and vice versa and enable or disable the garment recommendations by Mallzee. There is also the feature to scan the users' body, for more accurate garment fitting during virtual try on.

¹⁶ <https://www.odlo.com/>

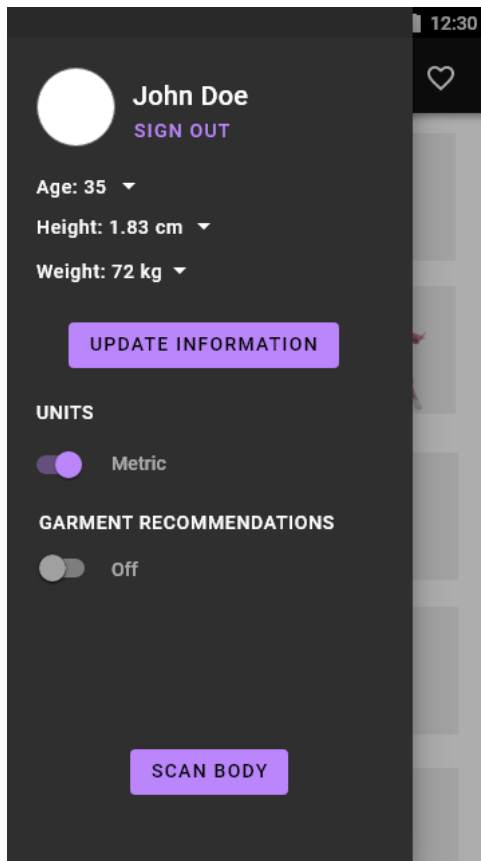


Figure 13: Magic Mirror - Options Sidebar

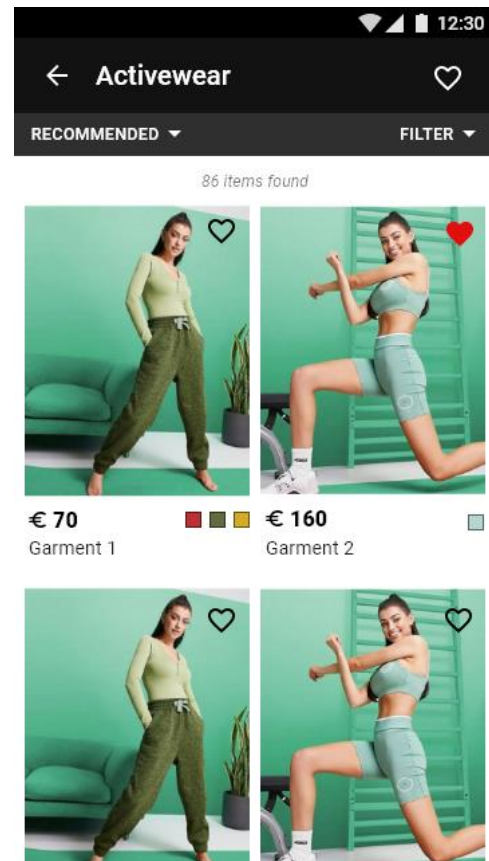


Figure 14: Magic Mirror - Garments Grid List View

Returning to the Select a Category screen, the user can tap on a category tile to view all the garments that are categorized as such. In Figure 14, the available garments are organized in a grid list view. Each grid item features a photo of the garment, a price, available colors, and the name of the item. In addition, in the top right corner on each garment item, there is a heart icon. When the user taps on this icon, the garment item is added to the Saved Items list that is tied to the users' account.

The user can access the Saved Items screen by tapping the heart icon that is located to the right of the top navigation bar. Inside this screen, as shown in Figure 15, the user can see a list of the saved garments, tap each list item to go to the garment details page or delete a garment item from the Saved Items list. By tapping on the top left arrow, the user can go back to the previous screen.

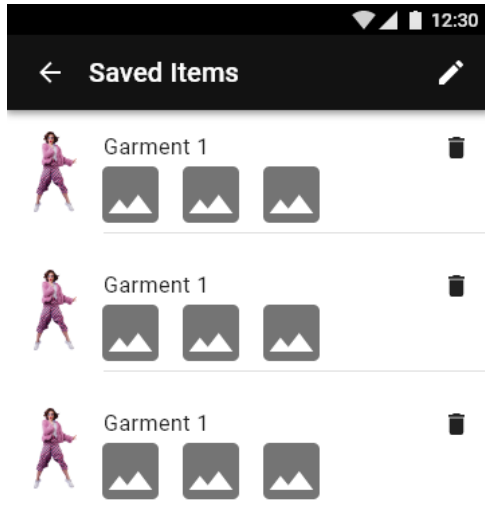


Figure 15: Magic Mirror - Saved Items Screen

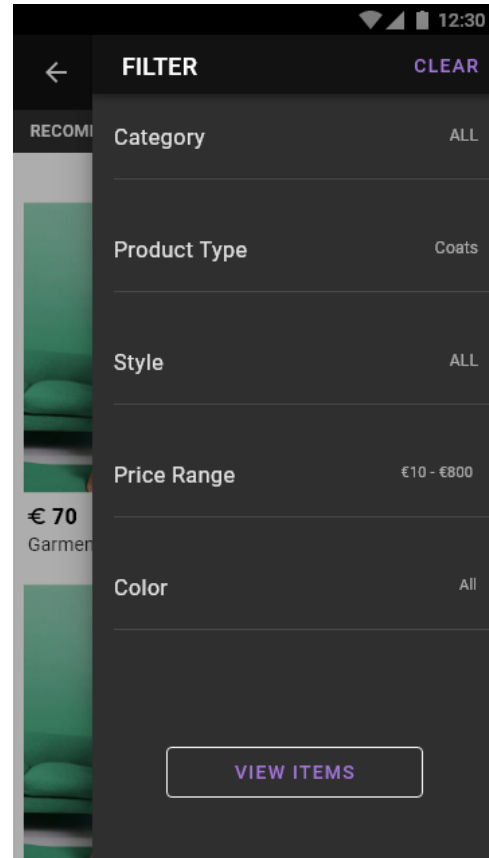


Figure 16: Magic Mirror - Filtering Panel

Returning to the garment grid list screen, the user can also sort the available garments by tapping on the left dropdown menu in the navigation sub bar, or filter the garment by tapping on the right dropdown menu in the navigation sub bar.

When tapping on the Filter dropdown, the Filtering sidebar appears from the right part of the screen (Figure 16), that features many selectable options for the user to filter the garments with. The filters are applied when tapping on the “View Items” button that is located in the bottom of the Filtering sidebar. The user can also change the category or select multiple. After the filtering is in effect, the user is shown a grid list of Garment Items similar to the one in Figure 14. By tapping on a garment item grid element, the user is shown the Garment Item Details screen.



Figure 17: Magic Mirror - Garment Item Details Screen



Figure 18: Magic Mirror - Real Time Fitting Screen

In the Garment Item Details screen (Figure 17), the user can see the details of the garment and perform specific actions. More specifically the user can:

- See all the available photos of the garment item by sliding left or right on the photo component.
- See the title and price of the garment.
- Add the garment to the list of favorites by tapping on the heart icon.
- Switch garment color if there are more garments in different color available.
- Switch size, or see which other sizes are available. There is a preselected value that is calculated automatically based on the information the user provided during registration.
- View the garment in real-time fitting on the user self, using the phones front or back camera, by tapping on the camera button.
- Preview the garment on a 3D model, by tapping on the 3D button.
- Buy the garment item by tapping on the BUY button, which transports the user to the product page in the ODLO e-shop.

By tapping on the Camera icon on the bottom left, the user is shown the Real Time Fitting screen (Figure 18). In this screen, the user is able to see the garment fitted on their body in real time using the cameras of the mobile phone and perform a range of actions. More specifically the user can:

- Add the fitted garment to the saved items list.
- Change garment size by tapping on the hanger icon.
- Capture a screenshot.
- Capture a video.

- Change cameras front to back and vice versa, in case someone else is operating the device.
- Set a timer for photo/video capture.
- Enable the tension map of the loaded garment as a colored layer with transparency on top of the garment. Tension maps during the simulation process show the impact of fabrics on garment fit, to recognize segments of the garment that might be very tight or very loose to the user.
- If the fitted garment is available in different colors, an indicator is shown to the bottom of the screen. By swiping left or right on the screen, the user can change the color of the garment.



Figure 19: Magic Mirror - 3D Preview a Garment Screen

By tapping on the back arrow icon in the top left of the screen the user is transported back to the Garment Item Details screen. There the user can tap on the '3D' icon on the bottom right to open the 3D garment previewer as shown in Figure 19.

In this screen the garment is loaded to 3D space and fitted to an avatar, in order for the user to manipulate the garment in X, Y and Z axes to check on the fitting. The user can additionally add this garment item to the saved items list, and change the garment size.

3.2.3.1 User Journey Map

We have created a user journey map to better understand what are the required actions of a consumer to be persuaded to purchase a garment from the ODLO e-Commerce website, through the Magic Mirror application. More specifically, the user journey starts from the user going through marketing CTAs, then downloading the mobile application and browsing through the garment selection to try on a garment. If the user likes a garment item and wants to buy it, then by clicking on a Buy button inside the application, they are transferred to the ODLO e-Commerce site in the specific item page where it can be purchased.

USER	SCENARIO	GOALS & EXPECTATIONS				
A consumer.	The user gets more familiar with the app through marketing CTAs, downloads the mobile application, browses through the garment selection and tries them on. If the user likes an item, then by clicking on the Buy button inside the application, is transferred to the eCommerce site in the specific item page where it can be purchased.	To purchase a garment item from the E-commerce site, using the Application first to try it on.				
		Marketing CTAs	Application Download	Application Interaction	E-commerce website interaction	Purchase Completion
		<p>Various potential CTAs need to be tested on different platforms (Facebook/Instagram/Google paid channels); the one performing the best in terms of conversion will be utilized.</p> <p>CTAs in the ads will focus on what the user looks for in such an app: e.g., post with a garment inviting user to try-on the garment virtually, variety of styles to choose from, ability to see the fit directly on oneself.</p>	<p>There are multiple ways for the user to download the Application. More specifically:</p> <p>From a link in the Odlo Facebook page.</p> <p>From a link in the Odlo Instagram account.</p> <p>From a link in the Odlo Brand Website.</p> <p>From the ODLO Questionnaire.</p> <p>Also a link to download the application could be available in the ODLO e-commerce website, in a garment details page, if the garment is available for digital try on.</p>	<p>The user opens the application and is greeted with a registration screen. There the user must also input some personal information.</p> <p>The user browses through the available garments using sorting and filtering functions.</p> <p>Selecting a garment the user observes its details.</p> <p>In the detail garment view there is an option to purchase along with the try on functionality.</p> <p>Users must scan themselves in order for the fitting to work correctly.</p> <p>The user tries on the garment or inspects it on a 3D model.</p> <p>Returning from the preview the user clicks on the 'Buy' button.</p>	<p>The user is transported to the E-commerce site product page.</p> <p>The user needs to choose the size of the garment to buy on the e-comm website and click on the "Add to Cart" button.</p> <p>The item is in the cart and the user can either continue shopping or go to the cart by pressing the cart icon on the right top.</p> <p>In the cart all the items inside feature all the product details like name, size, color, price, amount of pieces.</p> <p>As a next step the user must press on the "Checkout" button.</p>	<p>The user can buy the item using one from two methods:</p> <ol style="list-style-type: none"> 1. As a guest, by filling an email address, a Name, an Address and agree to the terms & conditions. 2. As a registered user, by creating an account or logging in to an existing one. <p>On the next page a paying method must be filled in, for example credit card number, paypal etc.</p> <p>The user clicks on the "Buy" button.</p> <p>A confirmation e-mail about the purchase is then sent to the user e-mail address.</p>

Figure 20: Magic Mirror User Journey Map

The user journey map as shown in Figure 20 is outlined below:

- **Marketing CTAs:** Various potential CTAs need to be tested on different platforms, for example Facebook, Instagram, Google paid channels; the one performing the best in terms of conversion will be utilized. CTAs in the ads will focus on what the user looks for in such an application: e.g., post with a garment inviting user to try-on the garment virtually, variety of styles to choose from, ability to see the fit directly on oneself.
- **Mobile Application Download:** There are multiple ways for the user to download the Application. More specifically from the following ODLO channels: From a link in the Facebook page, Instagram account, the brand website, or from an ODLO Questionnaire. Also a link to download the application could be available in the ODLO e-commerce website, in a garment details page, if the garment is available for digital try on.
- **Application Interaction:** The user opens the application and is greeted with a registration screen. There the user must also input some personal information. The user browses through the available garments using sorting and filtering functions. By selecting a garment the user observes its details. In the detail garment view there is an option to buy along with the try on functionality. Users must scan themselves in order for the fitting to work correctly. The user tries on the garment or inspects it on a 3D model. Returning from the preview the user clicks on the 'Buy' button.
- **E-Commerce website Interaction:** The user is transported to the e-Commerce website product page. The user needs to choose the size of the garment on the product page and click on the "Add to Cart" button. The item is in the cart and the user can either continue shopping or go to the cart by pressing the cart icon on the right top. In the cart all the items inside feature all the product details like name,

size, color, price and amount of pieces. As a next step the user must press on the “Checkout” button.

- **Purchase Completion:** The user can purchase the item using one from two methods:
 - As a guest, by filling an email address, a Name, an Address and agree to the terms & conditions.
 - As a registered user, by creating an account or logging in to an existing one.

On the next page a paying method must be filled in, for example credit card number, paypal etc. The user clicks on the “Buy” button. A confirmation e-mail about the purchase is then sent to the user e-mail address.

3.2.4 VR Designer Backoffice

The VR Designer app needs an administrative tool, where a designer can upload garments, avatars and animations in order for these files to be available inside the virtual reality space of the VR Designer application.

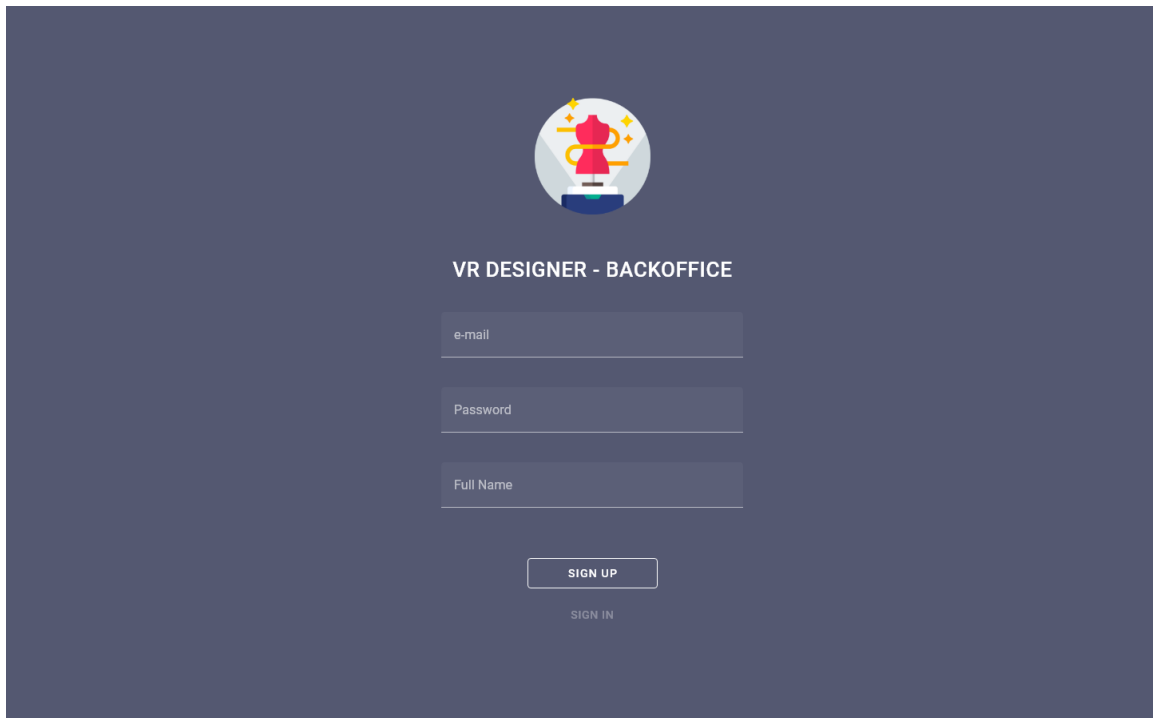


Figure 21: VR Designer Backoffice - Sign Up Screen

The VR Designer Backoffice tool is a web application, meaning that the users can access it from a browser. In order to use the app, the user must first create an account as illustrated in Figure 21, providing an e-mail address, a password and a full name.

After successfully logging in, the user is transferred to a Dashboard like interface, where it's easy to manage all garments, avatars and animations.

As shown in Figure 22 is the Garments View screen that has three columns. The first column features the navigation of the Dashboard, so the user can easily switch between the different types of items. There is also a Sign Out button.

The second column features a list of the uploaded garment items. The user can perform the following actions:

- Search for a garment item by name, using the search icon in the top right of the column.

- View all available garments in the form of a list.
- Delete a garment item using the trash icon in each list item.
- Add a new garment item by clicking on the Floating Action Button (FAB) situated in the bottom right.
- Select a garment item by clicking on it. Subsequently, the third column is populated with the editable garment item details.

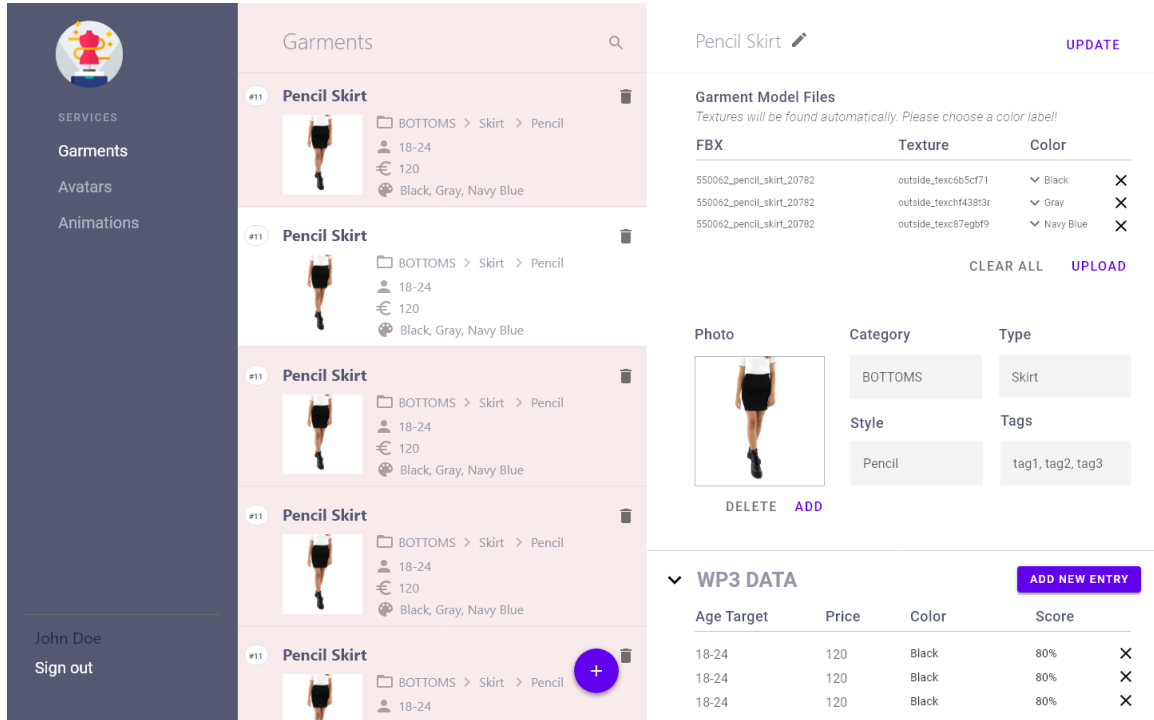


Figure 22: VR Designer Backoffice - Garments View Screen

By clicking on a garment item in the list, the third column of the dashboard is populated with the editable details of the garment item. More specifically the user can:

- Change the Title of the garment item.
- Add or remove the garment model files which include an FBX file, a .bin file, and texture files. The files must be named using a specific naming convention in order for the application to create the right entries. The user then has to select a Color label for each texture variation.
- Add an item photo.
- Select the categories of the garment item.
- Specify the tags of the garment item (if any).
- Edit WP3 Data matrix entries if available. These data entries are used in conjunction with a metric called the Mallzee Performance Score (MPS), which is essentially the prediction of the trend detection classifier developed in WP3, indicating the expected outreach of the specific garment to a market segment. This information will be displayed as a list with a percentage score in the VR Designer application, so the designer can check on the popularity of said garment across target groups, color or price ranges.

To save changes to the garment item, the user can click on the UPDATE button in the top right.


In order for the user to add a new garment, the Add a New Garment screen must be accessed by clicking the FAB button in the second column of the dashboard.

As seen in Figure 23, inside this screen the user must provide the following information in order to add a new garment:

- Garment Name (Title).
- A photo of the garment.
- Add or remove the garment model files and select a Color label for each texture variation as outlined above.
- Select the categories of the garment item.
- Specify the tags of the garment item (if any).
- Add WP3 matrix entries if available (briefly explained above).

← Add new garment ADD

Name
Pencil Skirt

Photo
 UPLOAD DELETE

Garment Model Files
Textures will be found automatically. Please choose a color label!

FBX	Texture	Color
550062_pencil_skirt_20782	outside_text005cf71	Black ×
550062_pencil_skirt_20782	outside_textcf43813r	Gray ×
550062_pencil_skirt_20782	outside_textc67egbf9	Navy Blue ×

CLEAR ALL UPLOAD

Category
BOTTOMS

Style
Pencil

Type
Skirt

Tags
tag1, tag2, tag3

WP3 DATA

Age Target: 18-24 Price: 120 Color: Choose color ▼

ADD NEW ENTRY

Sidebar: SERVICES
Garments
Avatars
Animations

John Doe
Sign out

Figure 23: VR Designer Backoffice - Add a New Garment Screen

By clicking on the ADD button that is located to the top right, the new garment item is saved to the platform.

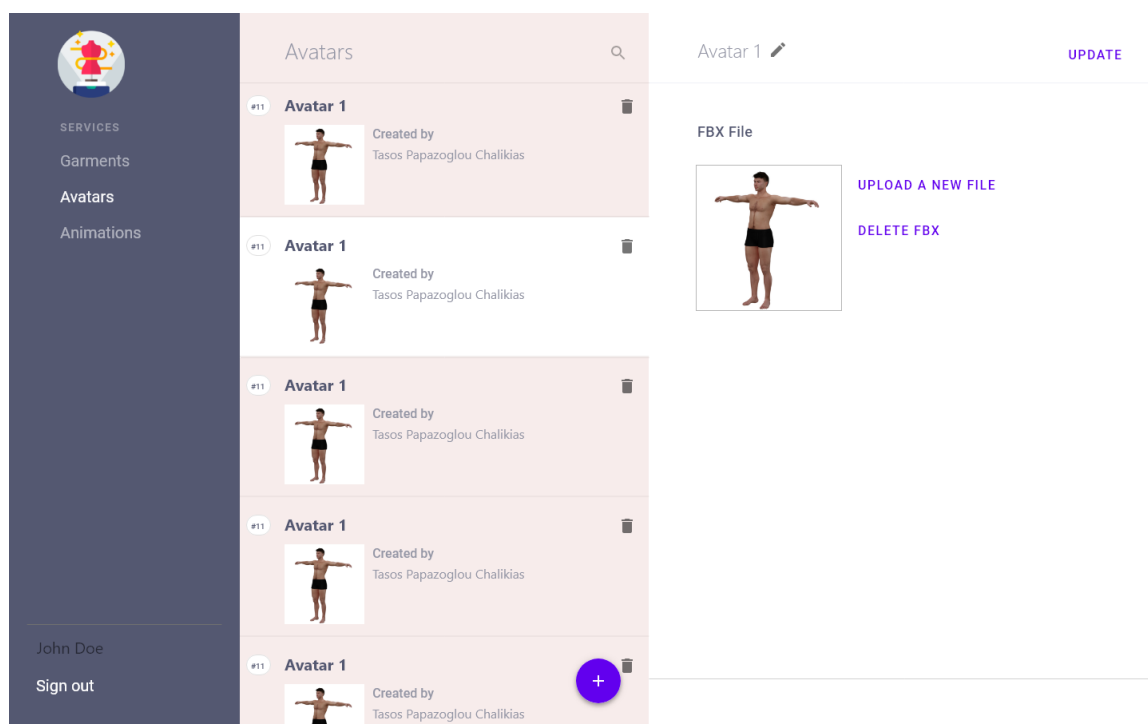


Figure 24: VR Designer Backoffice - Avatars Screen

The user can see all the uploaded avatars and perform various actions in the Avatars View as illustrated in Figure 24. This view features a list of the uploaded avatars. The user can perform the following actions:

- Search for an avatar by name, using the search icon in the top right of the column.
- View all available avatars in the form of a list.
- Delete an avatar.
- Add a new avatar by clicking on the FAB button floating in the bottom right.
- Select an avatar by clicking on it, where the third column is populated with editable avatar details.

By clicking on an avatar item in the list, the third column of the Dashboard is populated with its editable details. More specifically the user can change the avatar title and add or remove an avatar. The user can click on the SAVE button to update the avatar with the new information.

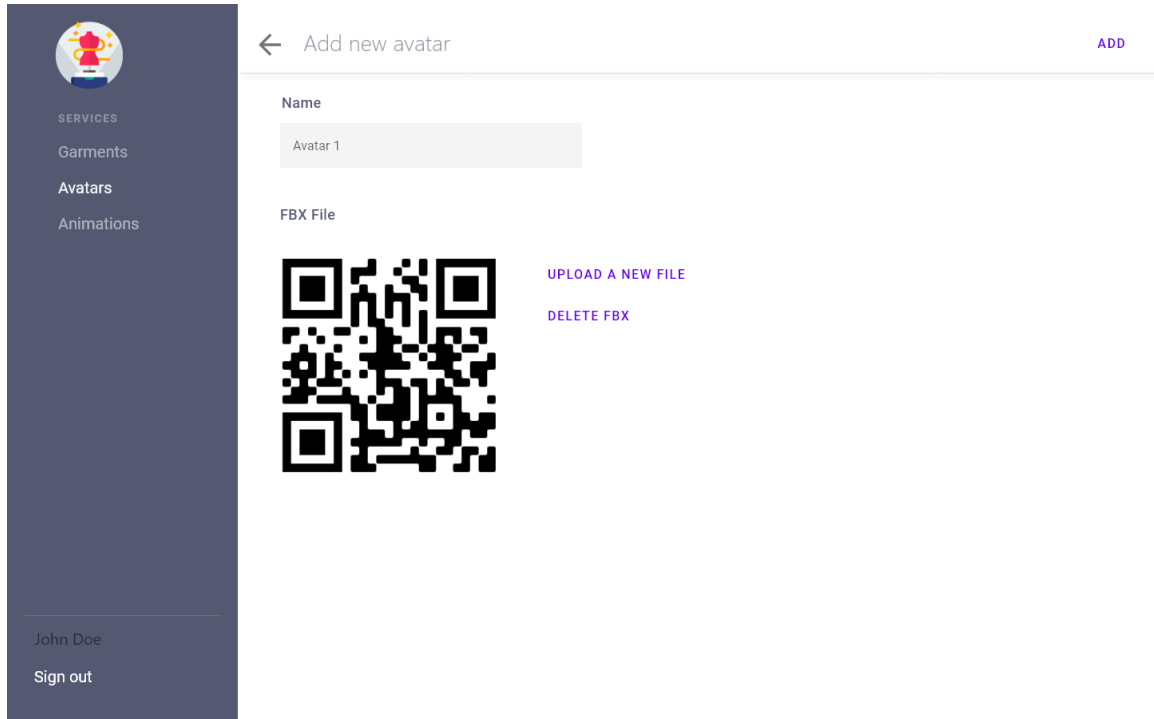


Figure 25: VR Designer Backoffice - Add a New Avatar Screen

In order for the user to add a new avatar, the Add a New Avatar screen must be accessed by clicking on the FAB button in the second column of the dashboard.

As seen in Figure 25, inside this screen the user must provide an avatar name and the avatar files in order to upload a new avatar to the platform. By clicking on the ADD button in the top right, the new avatar is uploaded to the platform.

The user can see all the uploaded animations and perform various actions in the Animations View as seen in Figure 26. This view features a list of the uploaded animations. The user can perform the following actions:

- Search for an animation by name, using the search icon in the top right of the column.
- View all available animations in the form of a list.
- Delete an animation.
- Add a new animation by clicking on the FAB button floating in the bottom right.
- Select an animation by clicking on it, where the third column is populated with editable animation details.

By clicking on an animation item in the list, the third column of the Dashboard is populated with its editable details. More specifically the user can change the animation title and add or remove the FBX file of the animation. The animation entry is updated when the user clicks on the UPDATE button in the top right.

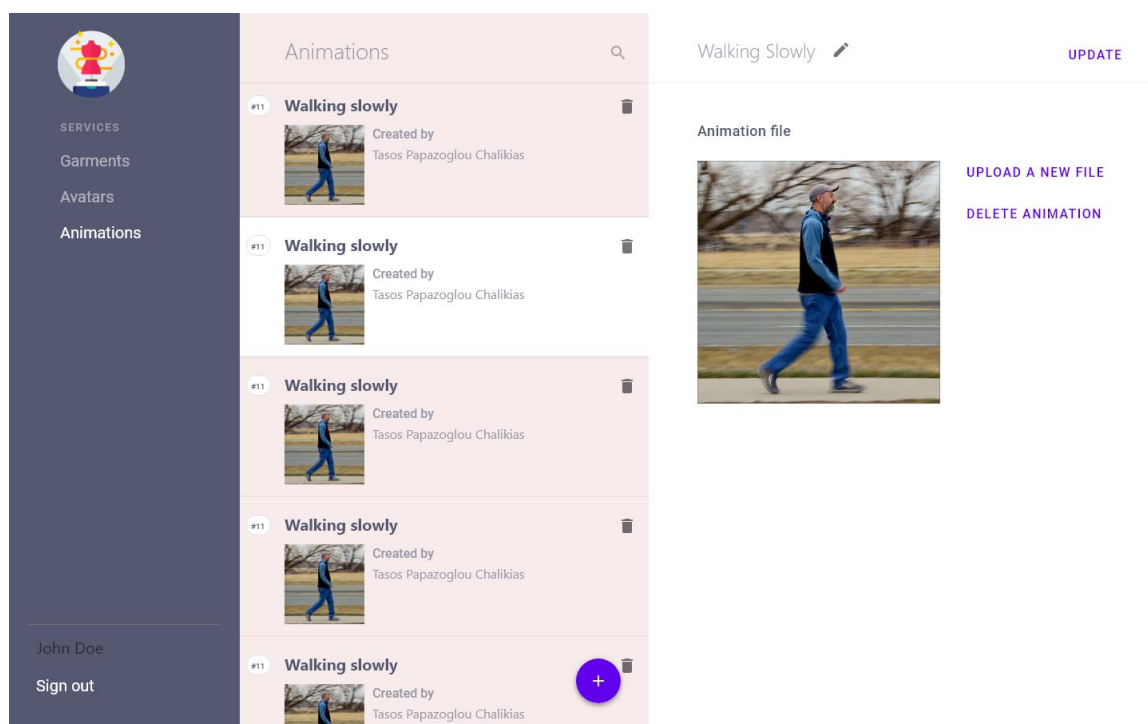


Figure 26: VR Designer Backoffice - Animations Screen

While being on the Animations View the user can click on the FAB in the bottom right of the Animations List in order to launch the Add New Animation view.

In this view (Figure 27) the user has to input the animation title and add and FBX file in order to add a new animation to the system.

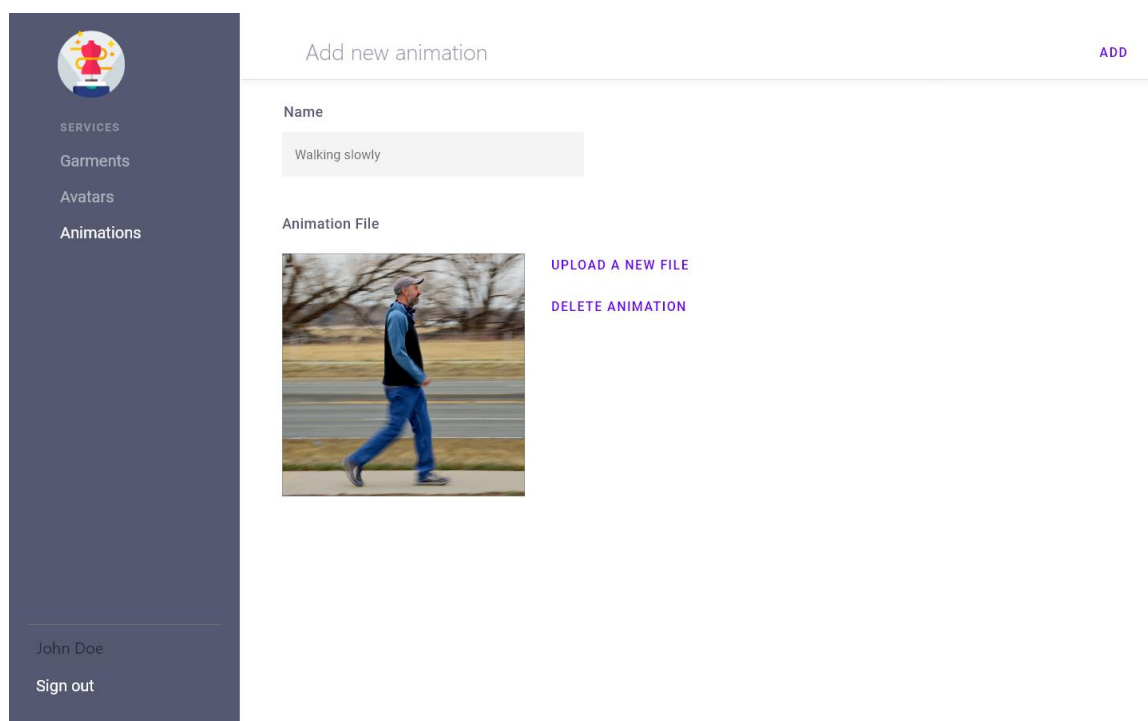


Figure 27: VR Designer Backoffice - Add a New Animation Screen

By clicking on the ADD button in the top right, the new animation is uploaded to the platform.

4. Implementation

In the following sections we describe the software implementation of all the envisioned eTryOn apps along with the development choices of any marketing or complementary applications.

4.1 VR Designer desktop application

Garment designers aiming to streamline the design process and reduce the production cost while minimizing the textile waste rely on virtual fitting and 3D design and 2D pattern making software (e.g. Browzwear, CLO3D, Optitex and Lectra). While such tools perform quite accurate fitting estimations, they are limited to using predefined avatars. Considering that fashion brands are interested in the fitting estimation on their own fit models, they parameterize the pre-defined avatars of such tools by manually adding the body measurements of their fit models. Even then, the visualization potential offered by such software is quite limited by the realism of the mannequins and the processing requirements of such software, while animations were only made available by Browzwear only recently (early 2021 release). Finally, one of the main bottlenecks of the entire workflow from designing a garment to its production, marketing and sales seems to be the need of various additional software components for visualizing the designed garment to the various teams of a fashion brand (sales, manufacturers, marketing, etc.).

Our goal implementing the VR Designer application is to overcome these limitations by creating an interactive VR environment which will enable the designers to perform virtual fitting and testing in an immersive and realistic environment. The VR environment will allow close up inspection of the garment and avatar movements and also provide some interaction tools that enable the designer with a better perspective of how the final product will look, fit and get interacted with.

Towards implementing the VR Designer app, we analyzed a range of platforms described below, to see which one offered most of the features that we needed. In general game graphics engines offer what the application requires in terms of interactivity and immersiveness. Regarding photorealism, most game engines offer similar results. Their main difference is in the quality of the cloth simulation and its capabilities.

For this goal, we explored two main approaches. The first approach focuses on Game Engines that offer cloth simulation tools, have AR and VR support and also allow a multi-platform build. The latter meaning that we would be able to build our project for different operating systems (Windows, Android, iOS) without the need to redo the whole process from the start. The above was initially, the only possible approach for our project. However, Browzwear recently launched a new software edition for their platform. This new tool offers significant improvements to Browzwear's 3D visualization and animation capabilities by enabling the designer to import and simulate different animations on created garments and export the final product in a single format, such as an alembic file.

Following the initial plan, we examined multiple Game Engines and tried to identify the key capabilities of each.

4.1.1 Game Engine showcase

4.1.1.1 Unity

Unity¹⁷ is one of the most popular graphics engines with a strong and active supporting community. As a result, there are a lot of third-party libraries available with extensive documentation. Moreover, it offers multiplatform support both for AR and VR. In the following, we will review the most prominent options for cloth simulation in the Unity engine (both built-in and third party libraries).

4.1.1.1.1 Unity Cloth

Unity has a built-in cloth simulation library that however has limited capabilities. It is suitable mostly for scene environment assets like flags and curtains. In our case, where we aim to dress up a character or avatar, there are the following options with Unity Cloth¹⁸:

- Using fully skinned garments to the avatar skeleton. This makes the garment move in accordance to the avatar based on the skinning values, however, this does not contain any cloth physics, and as a result the garment does not deform properly.
- Using unskinned meshes for the garments and utilizing colliders, i.e. objects of specific shape that do not allow the garment to penetrate the body. In this case the objective is to try to represent the avatar's body as accurate as possible with colliders. Only two kinds of colliders are supported, namely sphere and capsule colliders. It is hard to represent an exact full human body with only these two kinds of colliders. The number of allowed colliders is limited (16 capsule and 14 sphere pairs) and as a result the quality of the human representation during animation and simulation is not ideal.
- Using a mixture of skinned and non-skinned mesh parts but the aforementioned collider restrictions persist.

4.1.1.1.2 Magica Cloth

Magica Cloth¹⁹ is a Unity plugin offering faster simulation and is capable of integrating skinned and non-skinned components in a single garment file, thus lowering complexity on data input in our platform.

In terms of features, Magic Cloth works in a similar way and doesn't add any significant improvements over the built-in Unity Cloth described above.

4.1.1.1.3 Obi Cloth

Obi Cloth²⁰ is also a Unity plugin library. It is a particle-based physics library which when compared to the previous ones it offers in-depth cloth simulation customization for both skinned and non-skinned garment meshes by manipulating various skin constraints. It supports almost all kinds of colliders and additionally offers full control over multiple simulation parameters, including friction and stickiness values. It can also support inter-collision and self-collision. This means that different cloth parts are allowed to interact/collide with each other and itself (i.e. allowing collision with its own particles). Obi Cloth also offers support for mesh colliders, but the mesh collider must be static, i.e.

¹⁷ <https://unity.com/>

¹⁸ <https://docs.unity3d.com/Manual/class-Cloth.html>

¹⁹ <https://assetstore.unity.com/packages/tools/physics/magica-cloth-160144>

²⁰ <https://assetstore.unity.com/packages/tools/physics/obi-cloth-81333>

cannot be animated. Moreover, mesh colliders are computationally expensive which renders improbable any kind of real time cloth simulation.

4.1.1.2 Amazon Lumberyard

Amazon Lumberyard²¹ is a fairly new multiplatform game engine based on CryEngine²². In general, it is very similar to the Obi Cloth library in terms of how it approaches cloth simulation, offering similar features. However, the current multiplatform integration is in a beta stage, and as a result it is not as stable, documented and supported as Unity. Furthermore, one significant limitation of Amazon Lumberyard is the lack of support for AR applications.

4.1.1.3 Unreal Engine

Unreal Engine²³ offers cloth simulation support using NvCloth²⁴, which approaches clothing simulation in a similar way to Obi Cloth and Amazon Lumberyard. However, in terms of the allowed colliders, it utilizes only primitive ones like box, sphere and capsule. Additionally, Unreal Engine's cloth simulation is GPU-based and can only be built for desktop applications, which means that it does not offer multiplatform support.

4.1.1.4 Browzwear

As mentioned, Browzwear very recently expanded their platform's technologies and they have included animated simulations of garments. With its own built-in cloth simulation engine and being a dedicated fashion software, it offers high quality simulations with increased detail. However, they only offer a demo animation catwalk at the moment, and it requires significant processing power to render. In addition, Browzwear is a desktop software offering no capabilities on VR and immersive environments. On the other hand, game engines like the ones mentioned above offer immersiveness and increased realism in their visualization potentials.

Considering the above, we have also examined combining the benefits of both worlds by using Browzwear-processed detailed animated simulations as input to a game engine. In this direction, we have created the garment simulations in the Browzwear software, exported it in Alembic files and inserted them in a game engine. Alembic files are a computer graphics file format, capable of storing all the information regarding the garment and avatar meshes, textures, behavior, and movement. Alembic files can offer a highly accurate animation of the human body and the garments behavior on it but offers zero interactivity with the garment and the simulation itself.

In this case we can offer the highly detailed simulations in an immersive environment. However, it is worth noting that this kind of simulation lacks any kind of interaction in the scene apart from a simple camera rotation around the animated avatar-garment pair. On the other hand, game engine simulations offer more interactivity options (e.g. drag the garment at a specific place and see how it reacts). Moreover, with the Browzwear-based Alembic files, the user can visualise a specific movement/animation/pose of a character wearing a garment that cannot be changed after. As a result, the alembic file approach on the one hand does allow the designers to have a very clear idea of how the product will look on a real body. On the other hand, however, since the whole process is precomputed, the designer won't be able to test multiple poses or change anything on the go. A new Alembic file would be required to test any other pose. It is a big trade-off between

²¹ <https://aws.amazon.com/lumberyard/>

²² <https://www.cryengine.com/>

²³ <https://www.unrealengine.com/>

²⁴ <https://github.com/NVIDIAGameWorks/NvCloth>

animation and simulation/interactivity depending on what the designer needs on that specific time, accuracy or being able to edit on the go.

Nevertheless, the combination of Browzwear simulations with a game engine is a pathway worth of investigation. Especially if we consider the feedback from the designer questionnaires (Section 3.1), being able to easily create realistic visualizations for the presentation of the garments to the upper management team appeared to be a feature mentioned by multiple designers. In this direction, utilizing the high-quality Browzwear animations in a VR application with features for presenting garments across teams could be a better suited objective for the VR designer app. In deciding this, our plan is to prepare demonstrator apps both with Browzwear animations and game engine animations, and reaching to the end user base (designers) for trying both options and getting their feedback.

4.1.2 Software Selection

With respect to game engines and their capabilities to support avatar-garment simulations, the combination of Unity with Obi Cloth was the best choice for our scenario. Figure 28 outlines our selection based on the availability of needed features.

	Multiplatform	Stable VR and AR support	Detailed parameters configuration
Unity Cloth	YES	YES	NO
Magica Cloth	YES	YES	NO
Amazon Lumberyard	YES	NO	YES
Unreal Engine	NO	YES	YES
Obi Cloth	YES	YES	YES

Figure 28: VR Designer Software Selection Table

The multiplatform support that Unity offers (Unity Cloth, Magica Cloth and Obi Cloth) was the key for the engine selection compared to Unreal Engine. While Amazon Lumberyard seems a good option for our case, their lack of stability and support due to being in beta version made it risky to select that pipeline over the more stable and tested Unity engine. Comparing the cloth simulation options in Unity, the Obi Cloth library is the most powerful, offering detailed parametric configurations to optimize avatar-garment simulations. In the next subsection follows a more technical analysis of the key Obi Cloth library features.

4.1.2.1 The Obi Cloth library

In this Section, we will give a brief introduction on the selected Obi Cloth library (Obi in short) and its components. Obi is a collection of particle-based physics plugins for Unity. Everything in Obi is made out of small spheres called particles. Particles can interact with each other, affect and be affected by other objects through the use of constraints. All Obi assets use the same physics framework and share the same architectural design.

4.1.2.1.1 Obi Solver

A solver is the component that performs physics simulation. Solvers expose a few global simulation parameters such as gravity, inertia scale, or velocity damping, as well as parameters for all constraints in the solver. The Obi Solver component is required to simulate an Obi object and it contains the general properties of all the Obi Cloth components. These properties include:

- Gravity: A value corresponding to how real-life gravity affects a garments movement during the simulation.
- Damping: Controls the stiffness of a cloth.

- **Shock Propagation:** High values will artificially increase the mass of particles supporting other particles, resulting in a more fluid movement.
- **World Inertia Scale (Linear/Angular):** Controls how much of the world-space linear/angular inertia is applied to the particles. For example, when manually moving or rotating the garment in the world space, how much this action will affect the rate of the movement.

4.1.2.1.2 Obi Cloth

The Obi cloth is the component added to a specified garment in order to be simulated by the Obi library. The Obi cloth component requires a cloth blueprint based on the garment's mesh and contains parameters for the specific cloth affecting the simulation by the Obi Solver.

Regarding the cloth blueprints there are the following three options: a) regular cloth (cannot be torn, cannot be used with animated meshes), b) tearable cloth (can be torn, cannot be used with animated meshes) and c) skinned cloth (designed to be used with skeletally animated meshes for character cloth, cannot be torn). It is obvious that in our case, where we need skeletally animated meshes, we will be using the skinned cloth blueprint.

Creating a blueprint allows the editing and the manipulation of the following cloth properties:

- **Skin Backstop:** Controls how much each particle is allowed to “enter” the mesh. Positive values allow entering while negative values slightly “push” particles out.
- **Skin Backstop Radius:** This parameter controls the radius of a collision sphere that keeps particles from penetrating the skinned mesh.
- **Skin Radius:** This parameter controls the radius of a sphere representing the distance that each particle can move during the simulation. A radius value of 0 will cause particles to be 100% skinned, subsequently no simulation will take place.

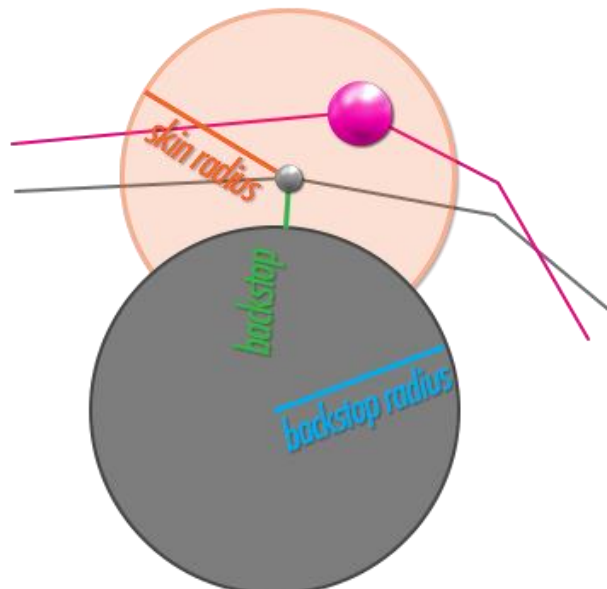


Figure 29: Skin Backstop/Backstop Radius/Skin radius properties

4.1.2.1.3 Collisions

As mentioned before, the Obi library supports all available regular colliders. Colliders allow particles to be able to collide with and react to other elements in a scene (e.g. walls, floor, crates). They can also collide with each other. These two types of collisions (against colliders and against other particles) can be controlled independently in Obi. At the beginning of each simulation step, solvers will generate collision constraints for all their particles based on what colliders are spatially close to them. Obi colliders also allow setting up their collision material and their thickness. Positive thickness values will leave a gap between the collider surface and colliding particles. Negative values will cause particles to "sink" into the collider before actually hitting its surface.

Another important feature of colliders is phases. Phases can be used to model the fact that not all particles are affected by a particular collider. For example, a sweatpants garment does not need to compute any collisions with upper body colliders. More specifically, each collider has a "Collision phase" property, and particles have a "Phase" channel that can be set using the blueprint editor. Only colliders and particles of different phases will collide. Colliders and particles of the same phase will ignore each other. By default, Obi colliders are in phase 0 and particles in phase 1, so they will collide right away. This allows manipulation of each garment's collision separately and faster, since there is no need of all the colliders to be taken into consideration.

Obi cloth supports mesh colliders as well. However, mesh renderers avatars (no humanoid rig/non skinned) cannot be animated. Additionally, mesh colliders massively reduce performance, so they are not recommended for real time simulations.

4.1.2.1.4 Proxies

Obi library supports proxies, which is a way to "glue" high quality, complex meshes to any simulated cloth mesh. Thus, a low-resolution mesh can be used to estimate the garment simulation and a high-resolution one can be rendered on top of it as illustrated in Figure 30. It is also useful when the mesh that needs to be rendered has complicated shapes that should be preserved as intact as possible in the visualization (like pockets, holes, variable thickness), while it does not hamper the performance of the garment simulation. The use of these obi proxies can provide a significant performance boost to up to 500%.

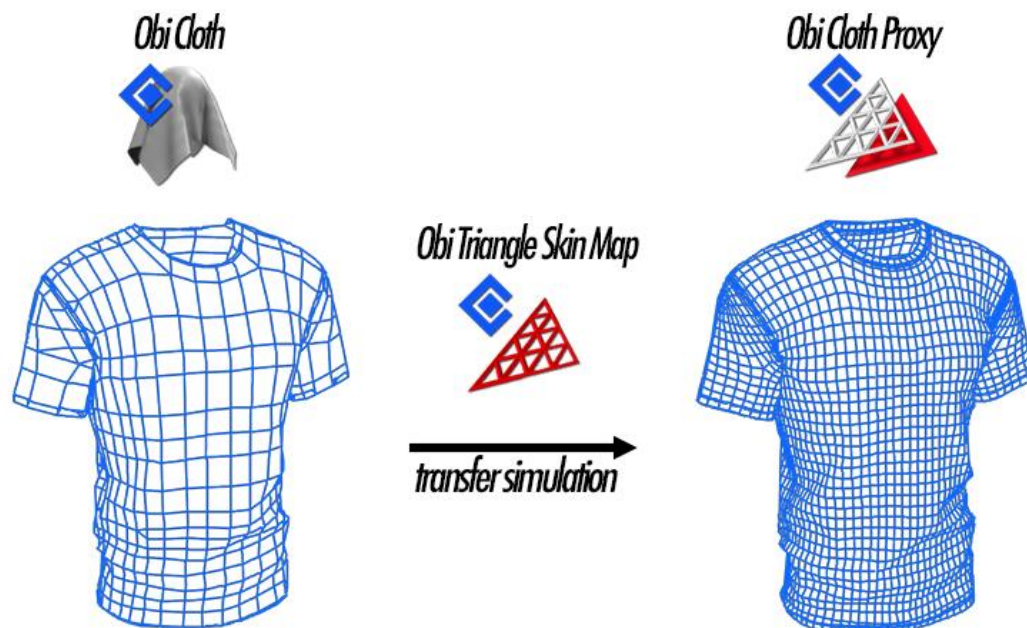


Figure 30: Cloth Proxy

4.1.2.1.5 Obi Stitcher

The Obi library allows the stitching of two obi cloth objects. It can stitch vertices from 2 independent cloth components. The stitcher component is attached to the Obi Solver object and stitches the linked edges together. Subsequently these appear as one single cloth in the simulation, but they are allowed to have different properties (cloth properties such as stiffness) as they have their own independent blueprint.

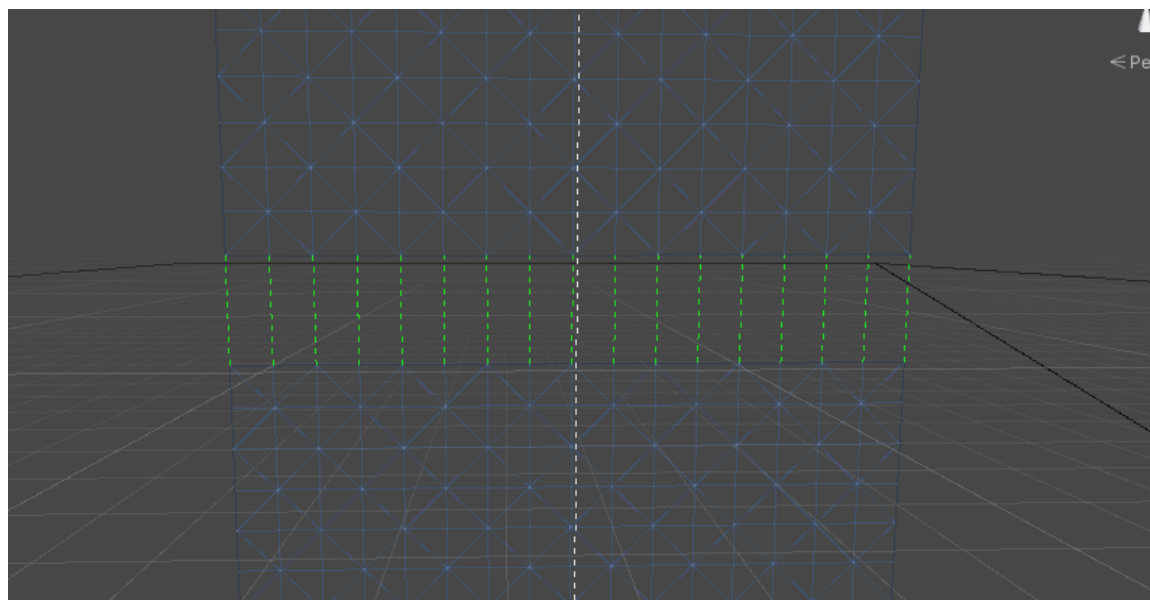


Figure 31: Obi Stitcher editor

In the context of this project, our designer partners will provide us with ready for production garments. This means that each garment, more often than not, will consist of many sub-meshes as parts of the garment, which may be of completely different materials, hence requiring different particle properties and behavior. On the other hand, they need to behave as single garments/meshes and not tear apart during simulation. As a result, the

Obi Stitcher is an important feature of the Obi library, allowing multiple cloth blueprints to stick together but have different material properties.

4.1.3 The VR Designer app implementation

To implement the VR designer app, several components have to be developed.

First, the VR scene, i.e. the terrain where the designers will be able to visualize how their designed garments fit and interact with a 3D avatar. The VR scene, besides the terrain, includes all the UI options that the app requires in order to allow the interaction between the user and the scene assets. The assets in our case include the avatars, the garments and their animations and simulations.

More specifically, the designer will have the option to select among various avatars, including both pre-defined and scanned avatars of their own fit models (using the scanning application of WP1). These avatars will be rigged so as to enable animations like cat walking, etc.

Animations is the second option the designer has in the VR environment. Plethora of animations will be available through Mixamo²⁵, while the user will be able to upload a new custom animation of their own as an FBX file from the back-office app.

The third asset is the garments, which have been designed in order to reach production through professional fashion design software (Browzwear). The transformation of a for-production-designed garment to a game engine asset that can be realistically simulated on an animated avatar is the most challenging part. Production-ready garments are designed in multiple 2D parts (patterns), which might be of different materials with different properties. These garment parts are simulated in an initial static pose of a 3D avatar in Browzwear and exported in a 3D-container file (FBX in our case), with each part as a separate mesh. These sub-meshes of the garment parts are skinned to the avatar in that pose and inserted in the Unity game engine. Afterwards, they are transformed in Obi components and the cloth parameters are added. These parameters include both the general cloth properties for each part (e.g. stiffness) and the particle weights (i.e. for each particle corresponding to a mesh triangle the backstop and radius parameters that indicate how freely is that particle allowed to move). Finally, the sub-meshes are automatically stitched using the Obi stitcher so that the garment moves as a single garment and does not tear apart.

4.1.3.1 *The VR scene*

4.1.3.1.1 Selection Panel

The VR scene is a 3D terrain that resembles a fitting room, where the users can interact with the assets of the scene. In more detail, the users (designers in our case) will be given a selection panel, through which they will be able to select from a number of existing avatars, different clothes and different animations. Using the VR headset's controller, the user will be given the choice to click on the corresponding VR buttons and change the avatar, the clothes or the animation to the combination they want to visualize. Additionally, camera movements around the visualized avatar / garment / animation pair will be enabled.

Towards giving to the users the aforementioned interactivity options, we will explore three different approaches. In the first one, the user will need to use the controller's pointer and click on floating buttons in the VR scene. This kind of interaction is quite intuitive for new

²⁵ <https://www.mixamo.com/>

users understand how to interact with the scene. However, this might bloat the scene with buttons, while clicking on floating buttons with the controllers might not be easy to manipulate. The second approach is to map all these actions to the buttons in the controller itself. This sounds as a more elegant approach, keeping the whole scene clearer so that the user can focus better on the visualizations. This resembles the interaction that people currently have with games with controller clicks, which might require learning time on how to use the controller, especially for the non-gamers. Finally, there is also the hybrid method, where selection panels emerge in the scene on demand by using the controller and then controller guided clicks are enabled as in the first option. This resembles the interaction user currently have with smartwatches but with controller-enabled laser clicks instead of haptic-enabled buttons. For the current working demo, we have relied on the first approach, but we will also explore the other two options in the future

4.1.3.1.2 Interaction with the garment

Additionally, Obi Cloth library contains a tool called “Obi Particle Dragger”. When this tool is attached to an Obi Object it allows the user to manually click and pull the garment and see how it naturally moves. For example, pull a jacket slightly and see how it moves while the avatar wears it. This interaction will also be enabled in future versions.

4.1.3.2 *The avatar and the animations*

In the VR scene there are three main assets, the avatars, the garments and the animations. In order to utilize a human avatar in the VR scene, it needs to be properly rigged. This means that it needs to have a complete humanoid bone structure. In order for Unity to recognize an avatar and allow animations on it, it needs to be generated as humanoid rig, i.e., a skeleton containing all the body structure information.

After the avatar and the rig are imported into the scene, an animator component is added to both of them using Unity’s animation controller. Unity’s animator editing allows to import a number of animations and create transitions between them (i.e. allowing an avatar to change from performing one animation to another one). The animation editor window allows the planning of these animation transitions. Plethora of animations for humanoid rigs are available from Mixamo and can be easily imported in the Unity VR designer app.

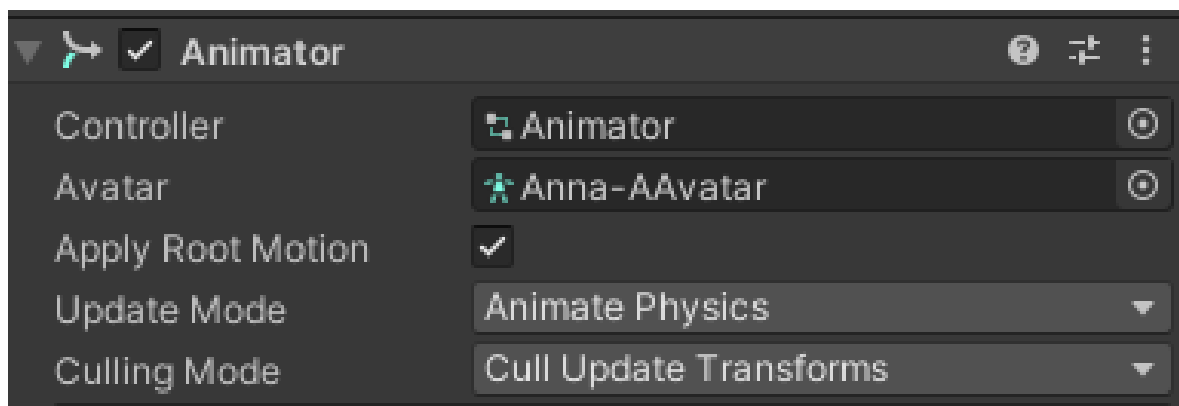


Figure 32: Animator properties

Finally, since the avatar and the garments are different objects, the animation controller should be passed to the animator component of all these objects that need to animate together. For ensuring that the avatar and garment are synced and smoothly follow the same animation in each frame, in the animator tab, both the Root Motion and the Animate Physics must be selected (Figure 32: Animator properties). Root motion enables different objects to use the same animator, while Animate Physics is required for the cloth simulation.

4.1.3.3 *The garments*

Our objective in the VR designer app is to transfer the accurate simulations of professional fashion design software to the immersive VR space offered by game engines. This means that our VR app will need to utilize garments that have been designed in order to reach production and not dedicated for game engines. These garments are typically designed in multiple 2D patterns accompanied with stitching information (i.e. which points from one garment part stitches to another) and can be simulated on an avatar in 3D. While these simulated 3D versions of the garments can be exported from the design software in a game engine readable format (e.g. FBX), there is no information on the stitching of the different parts (one part per 2D pattern is extracted as a 3D sub-mesh) or on the simulation properties. In order to achieve high quality simulations in a game engine all this information needs to be transferred and transformed. In this direction, we designed the following pipeline that will transform a production-designed garment to one that can be realistically simulated in a game engine. The pipeline includes the skinning of the garment with respect to the corresponding rig of the humanoid avatar, the transformation of the simulation information from the professional software to game engine properties and the stitching of the different sub-meshes in one, so that the parts do not fall apart.

4.1.3.3.1 Skinning and the effect of the initial pose

An important requirement for the garments is that they need to be skinned on the same humanoid bone structure of the avatar that the garment will be fitted upon. For eTryOn, we have developed an automatic skinning algorithm (details for the skinning process can be found in eTryOn's deliverable D2.1).

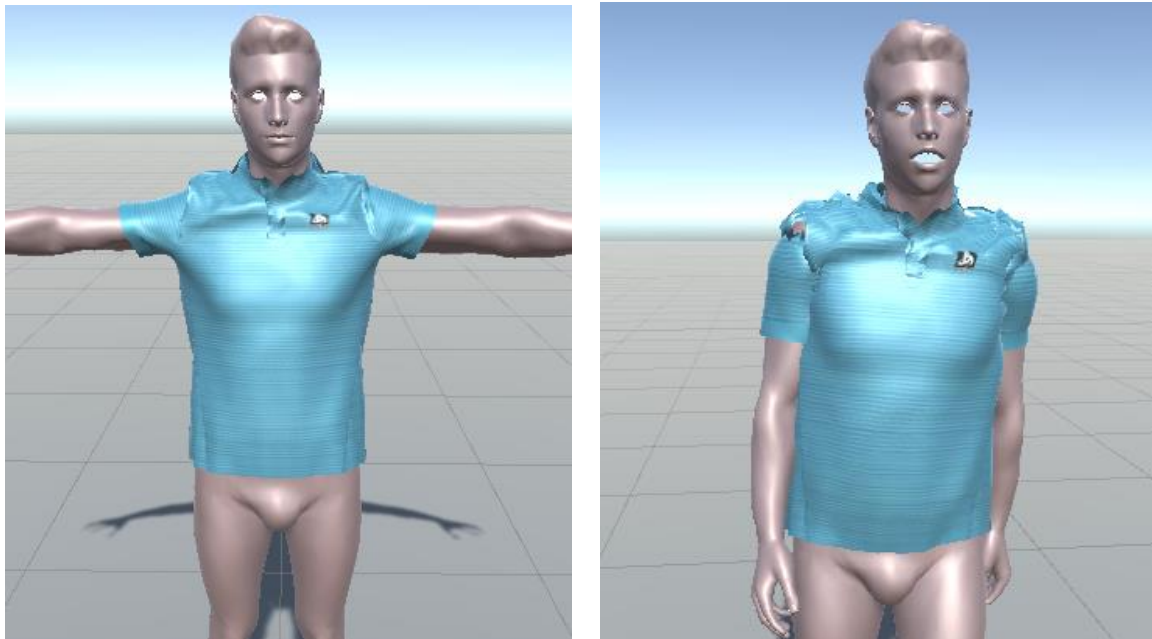


Figure 33: Left: garment skinned with T-pose in initial pose. Right: simulation of that garment during catwalk

Besides the bone structure, the initial pose of the avatar/garment pair on which the skinning was computed is an important factor affecting the simulation result. In more detail, the default pose for Unity to recognize a humanoid rig is the T-pose, which is widely used as the default pose in gaming engines. However, computing the automated skinning on a T-posed avatar, creates distortions and wrinkles in the garment and affects the Obi simulations afterwards. In tackling this issue, we selected the A-pose as the initial static pose, which is more natural in terms of how a garment drapes on an avatar and the automated skinning computes more fitting values for a more accurate simulation. In order

to visualize the aforementioned, we can see in Figure 33 the wrinkles that appear in the T-pose, which will continue to appear during the simulation as well. This is due to the fact that the game engine considers that this initial posed simulation is the garment's mesh resulting in wrong cloth simulation.

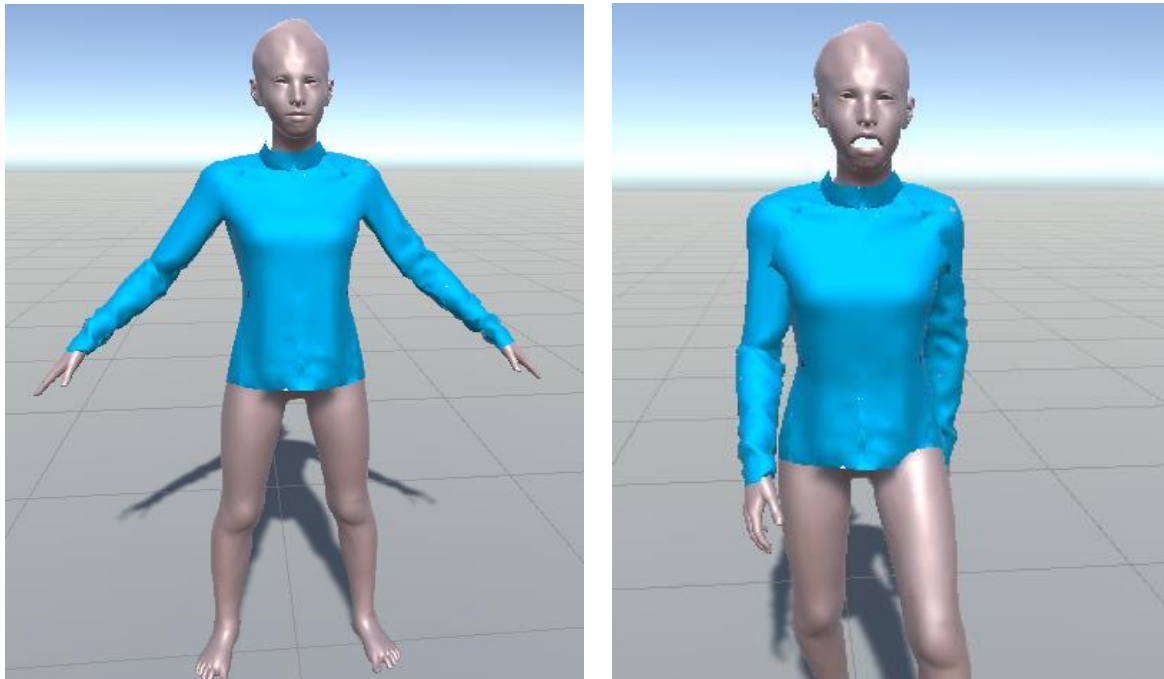


Figure 34: Left: garment skinned with A-pose in initial pose. Right: simulation of that garment during catwalk

With the use of the A-pose as the initial pose for skinning, we can see in Figure 34 that the chest wrinkles are avoided, and the garment maintains the shape it naturally has.

4.1.3.3.2 Garment properties

As mentioned before, the garments are skinned meshes based on the skeleton rig of the corresponding humanoid avatar. This means that by just adding an animator component to both the avatar and the garment, they both animate smoothly and synchronously. However, despite the character appearing to wear clothes that move according to its moves, there is no physics-based cloth simulation (e.g. draping, wrinkling). In order to add cloth simulation to the garments, the Obi library allows us to give two types of properties to the garments. First, each garment part has general properties affecting the whole sub-mesh of that part, indicating the properties of the material it is made of, e.g. stiffness, elasticity, etc. In addition, for each sub-mesh, the Obi library assigns one particle to the location of each mesh polygon. For each particle, we can set certain properties (e.g. skin backstop, radius, etc.), which affect how much is each particle allowed to move with respect to its initial position and neighbor particles. By effectively setting up all these properties, we can achieve a realistic simulation. Our objective is to develop an algorithm that will predict the values of these properties automatically using as ground truth the simulations from the Browzwear software, so that the final simulation is of equal quality.

4.1.3.3.3 Stitching

As mentioned above, production-designed garments, more often than not, consist of many parts, each of them potentially being of different materials and having different properties. As a result, each garment that can be exported from professional design software consists of various sub-meshes, correctly simulated in a specific 3D pose. In order for these sub-

meshes to move together and not fall apart once an animation is added, they need to be stitched in the game engine environment. The Obi library provides the Obi stitcher component, which can stitch two meshes together. In order to automatically stitch the whole garment, the process is the following: First, we scan all the particle positions of each sub-mesh of the garment. Then, for all possible combinations of two sub-meshes, if the particles positions of the one sub-mesh overlap (or are really close) with the particles of the second sub-mesh, the algorithm stitches these specific edges. For example, when our algorithm considers the combination of a sleeve and a main torso sub-mesh, it will identify the particles on the top of the sleeve that are in the same positions with the torso part, and then stitch these together. However, when the algorithm considers the combination of the left and right sleeve sub-meshes, no edges will be stitched since there are no overlapping particles. During simulation, this stitching algorithm manages to scan and stitch all the sub-meshes successfully without any significant delay in terms of performance.

It is worth noting that while the stitching information is provided by the designers in the professional fashion design software for the 2D patterns and we could potentially export a single mesh for the whole garment, this cannot be optimal in terms of simulation accuracy, since all the garment could have the same properties in the Unity game engine. On the other hand, stitching the sub-meshes within Unity allows us to have different properties for each sub-mesh, and as a result, each one of them can behave as a different Obi component, with different materials, properties and simulation values. Therefore, stitching in the Unity engine with the Obi stitchers allows us to:

- Have a similar visual result as if the garment was already a single mesh.
- Edit and manage each sub-mesh separately which adds more depth and accuracy to the simulation.

4.2 Dress Me Up web application

The Dress Me Up application will be developed as a web application. Statistics show that people are usually not willing to try and download new mobile apps, and when they do, they tend to forget about them rather quickly^{26 27}. Instead of the users downloading a mobile application from a store, they can just visit a web page anytime, from any device including mobile phones, tablets, laptops or desktop computers to use the Dress Me Up application.

In terms of data handling, the application performs the following actions:

- Handles login or signup requests.
- Captures photos using the Body Scanning component and sends them to the appropriate services to generate the rigged avatar of the user.
- Reads data from eTryOn APIs in order to load and show a list of garments.
- Uploads data to eTryOn APIs in the form of a text, a garment model and a photo or video for processing.
- Downloads the end result (processed image/video) from eTryOn APIs in order for the user to view it and saves it in a database.

²⁶ <https://www.zipwhip.com/resource/ebook/state-of-texting-2019>

²⁷ <https://www.comscore.com/Insights/Presentations-and-Whitepapers/2020/Global-State-of-Mobile>

- Connects the user account with social media accounts and allows them to share the end results and/or download them locally.

4.2.1 Software Selection

Software-wise the Dress Me Up web application as outlined above does not need to perform any heavy calculation of data. It communicates with eTryOn APIs to download and upload data, while visualizing photos or videos to the user. Thus, our software choice for developing the Dress Me Up application is a hybrid use of Node.js²⁸ and React.js²⁹, the former being an asynchronous, open source, cross-platform, event-driven JavaScript runtime, designed to build scalable network applications and the latter being an open-source, client-side library for delivering high-performance dynamic apps.

Node.js is a server-side JavaScript platform that runs on the Google Chrome engine - V8 and can compile JavaScript code into machine code. It's a popular platform for building web applications, hybrid applications, REST APIs, desktop programs, and even Internet of Things (IoT) solutions. It is synonymous with high speed. Having taken the asynchronous and non-blocking nature from its parent, JavaScript, it can perform minor tasks in the background without impeding the core thread. Node.js offers non-blocking I/O systems that let process concurrent requests at the same time. When the requests are lined up, they are processed efficiently and without any delays. Conversely to asynchronous request handling, which is a major benefit of Node.js, synchronous processing handles request one by one. It means that a request cannot be handled if there is another one in the process. Node.js's asynchronous processing allows handling requests without blocking the thread.

React.js provides server-side and front-end support, with reusable code components, faster debugging, easy UI test cases and support for both Android and iOS devices. It is a great fit for projects with many components, like changing states often, user login, and access permissions.

The current architecture plan relies on React.js for the development of the application in a way that the same user experience is retained on all users accessing it from different kind of devices and screens. However, we might also consider a hybrid approach during development, if it is required. This hybrid approach of implementing the Dress Me Up web application will benefit performance positively, meaning that many users can connect to our application at once and use it with no user experience interruptions and without our server encountering performance issues. The amount of usage for both frameworks outlined will be finalized according to architecture needs and the interconnection of the Dress Me Up web application with other eTryOn APIs or components.

4.3 Magic Mirror mobile application

The Magic Mirror application will be developed as a mobile application and will be available on mobile app stores for download. The users will be able to navigate a collection of garments, and virtually try them on using the app's AR features. While, as mentioned above, it is known that users are not in favour of downloading apps, in this case, in order to offer all the required functionalities of the Magic mirror app (real time garment simulations and fitting) the use of a game engine is imperative in this scenario and, as a result, the Magic Mirror app has to be encapsulated in a standalone mobile app.

²⁸ <https://nodejs.org/>

²⁹ <https://reactjs.org/>

4.3.1 Software Selection

Based on the review of the game engines in Section 4.1.2, Unity is selected for the development of the Magic Mirror application as well, due to its stability and multi-platform support: In addition, it offers AR Foundation, an AR framework that includes developer tools that enable fast and easy implementation of mobile applications for AR use cases. AR Foundation enables development in Unity and builds directly on native code. AR Foundation is the wrapper library of Unity that integrates the AR capabilities of various AR platforms (ARKit for iOS and ARCore for Android). With respect to garment simulations, we will be using the Obi Cloth library like in the VR Designer app, which offers extensive parameterization options for the garments. The Obi Cloth components will drive the physics of the garment and will render it in a natural way. Finally, for in-app navigation and UI implementation, we will use Unity's UI framework, an asset library that contains customizable UI widgets.

Unfortunately, the 3D body tracking features of the AR libraries, which are imperative for our application, are currently available only in the ARKit³⁰ subsystem which enables builds exclusively on iOS devices. As a result, at the moment the Magic Mirror app will only support iOS devices, but in the future, once ARCore supports 3D body tracking the application will become available for Android as well. We have also explored the use of external libraries to enable body tracking in Android devices³¹. However, their quality is limited by the fact that the depth sensor of the most modern devices is not taken into account during processing. In addition, relying on external libraries can create stability and long-term support issues, since they are not an integral part of ARCore/AR Foundation.

Finally, Snapchat lately released the first multi-platform (Android and iOS) support of 3D body tracking³². In order to cover all mobile users and also capitalize on the user base of such popular social media, we have also developed a Snapchat filter that can be used by users to visualize themselves wearing digital garments. It is a similar yet simpler approach to the magic mirror (i.e. without having any fitting information in terms of sizing). On the other hand, it is a multi-platform solution that does not require by the users to download any additional apps and can be used for promotions and marketing as it reaches a large user base (that one of Snapchat). This filter, while it also enhances the interaction of humans with fashion, it will be mainly used as a promotion to our Magic Mirror app.

4.4 Snapchat Lens filter

4.4.1 Social media and the filters trend

To increase visibility of the eTryOn project and the produced applications we considered the development of an AR experience in the context of a Snapchat³³ effect as a promotional tool for the fashion sector. Users will be able to overlay a selection of garments on themselves using their phone's camera, as well as interact with these garments by moving around in space and changing their colour. Such an AR experience would provide interactivity and vividness in the display of the products, which has been shown to lead to immersion and ultimately to media usefulness and enjoyment.

Developments in AR and its availability to a variety of devices have brought up numerous examples of innovation in its use, particularly in mobile, handheld environments. In addition to mobile phones becoming powerful enough to withhold the intense

³⁰ <https://developer.apple.com/augmented-reality/>

³¹ <https://ai.googleblog.com/2020/08/on-device-real-time-body-pose-tracking.html>

³² <https://vrscout.com/news/snapchat-3d-full-body-tracking-lenses/>

³³ <https://www.snapchat.com/>

computational needs of AR applications, we are seeing new frameworks being built on top of processors or even existing applications that utilize this power efficiently. As a result, the newest user experiences with AR have been seamless and have been captivating the attention of their audience at a fast-growing pace.

In particular, an area where AR currently thrives is one of the social media. Already existing applications such as Snapchat and Instagram are exposing their users to the magic of AR via filters. AR filters are computer-generated effects layered over the real-life image displayed by a mobile camera. Pictures or videos captured can then be shared via stories, posts or direct messages.

AR experiences have been identified as a marketing technique with a major impact on consumer behavior as they provide an immediate interaction between the prospective client and the product or service that is being advertised.

Snap Inc. has developed Lens Studio, a tool which allows users to create, publish, and share experiences, also known as Lenses with millions of Snapchat users across the globe. The interactions inside the AR experiences are being tracked and are available to the creator of the filter to view and analyze through an insights dashboard to assess the performance and effectiveness of the filter over the audience. These interactions include:

- **Opens:** The number of times people have opened an effect through the application cameras.
- **Captures:** The number of times someone took a photo or video that featured these effects in application cameras.
- **Saves:** The number of times people took a photo or video while using an effect and saved it to their device.
- **Shares:** The number of times someone took a photo or video featuring an effect and shared it. Shares are counted in stories, posts, and messages.

4.4.2 Development Methodology

The pipeline for the development of our Snapchat Lens is described in Figure 35 below.

The majority of work is centered around the rigging and skinning process, as those are that enable the 3D model to deform (rotate/twist/bend/etc.) according to the movements performed by the user. Rigging refers to the process of creating the bone structure of a 3D model. This bone structure is used to manipulate the 3D object with a series of deformations, like a puppet for animation. Hence, the rig is a series of connected joints used to describe an animation. Skinning, also known as vertex blending, enveloping, or skeleton-subspace deformation, is the process of transforming a mesh's vertices according to the rig that was created earlier. More specifically, we expand on the diagram steps in the following subsections.

Garment Preparation

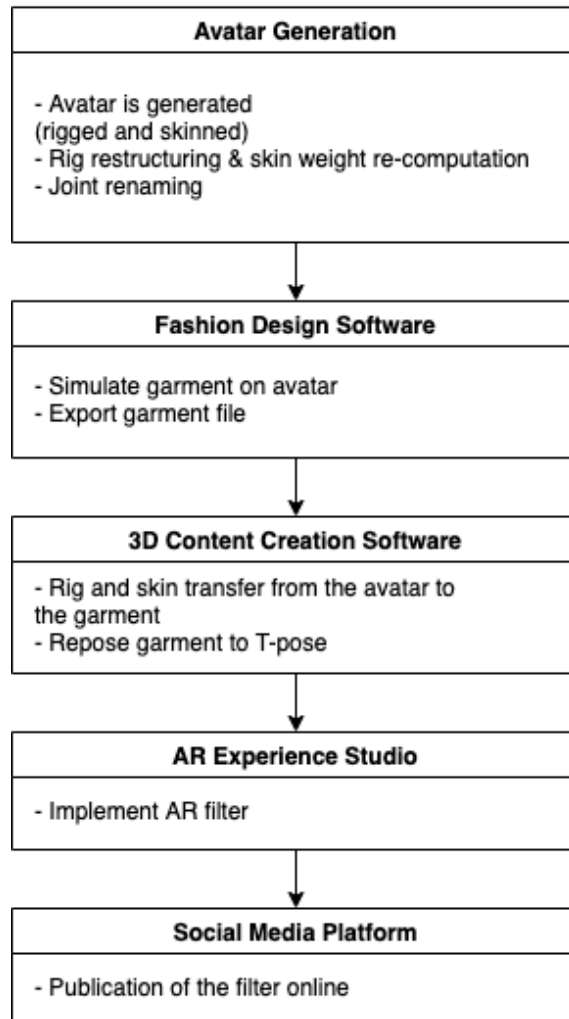


Figure 35: Magic Mirror development methodology

4.4.2.1 Avatar Generation and Modifications

The Genesis 8.1 system, which is offered by Daz3D studio³⁴, was used for avatar generation. The FBX SDK³⁵ was additionally used to modify the avatar's skeleton to match the Snapchat Lens Studio requirements.

4.4.2.2 Garment simulation in Fashion Design Software

There is a variety of options regarding the choice of a fashion design software. For the design of our garments, we have used VStitcher 3D Apparel Design Software³⁶ by

³⁴ <https://www.daz3d.com/genesis-8-1>

³⁵ <https://www.autodesk.com/developer-network/platform-technologies/fbx-sdk-2020-0>

³⁶ <https://browzwear.com/products/v-stitcher/>

Browzwear. We assume a garment has already been designed in VStitcher by the fashion company's designers and pattern makers. The garment is then simulated on the avatar we created, using VStitcher. Last, the simulated garment's mesh along with its textures and material properties are exported to an FBX file.

4.4.2.3 Processing in 3D Content Creation Software

In order for the garment to be able to move along with the user's bone structure and follow their body pose, it needs to be rigged and skinned. Since the simulation avatar has the correct bone structure, it will be used to rig the garment. The current best industry standards for 3D content creation software are Autodesk® Maya®, and its open-source counterpart Blender®. Blender offers a scripting API in Python and, hence, it was used to automate this process.

Both the avatar and the garment are imported in Blender. The avatar's rig is then copied over to the garment's mesh. The skinning weights for the garment's vertices are assigned based on the avatar's vertices that are nearest—this is using a nearest neighbor algorithm. For every garment vertex, we find the vertices that are closest to the avatar, then average their weights' values, and lastly assign them as the vertex's skinning weights. The result is a garment with the correct skeleton structure that can deform properly according to the avatar/skeleton movements.

The last step is to set the garment to a T-pose, which means arms should be horizontally outstretched. This needs to happen since the 3D body tracking component takes into account the initial rotations of the model's joints and adds the person's movements into those initial values.

The garment is now ready to export for use in the AR experience studio, where the Snapchat filter will be set up.

4.4.2.4 Development of the filter in AR Experience Studio

The Snapchat filter that is developed for eTryOn, features two main components: i) the user's body tracking component and the rendering of the garment onto the user's body through the use of a phone camera, and ii) a user interface component that enables the user to interact with the garment by changing its color and style.

4.4.2.4.1 Body Tracking

A 3D Object Tracking component is used to attach the garment to the body features found in the camera. Then, the garment is imported into Lens Studio as an FBX file, and the skeleton structure is visible in the file overview. With the use of the body tracking asset, the list of available tracked points is presented in the inspector panel, and the joints of the skeleton are connected to the respective fields. This can be done manually by dragging and dropping the different joints into the tracked points value fields, or automatically by choosing the Match Hierarchy option. In order for the latter method to work, a specific naming convention should be applied to the joints when the skeleton is created in the 3D content creation software.

The last important step is to set the material texture of the mesh. This is a JPG file that is provided by the Fashion Design Software and should be added to the lens's resources and then linked to the mesh's material. Both a base texture and a normal texture is applied.

This process is repeated for all the garments that are going to be a part of the lens. The next step is to setup the UI, so that the user is able to interact with the garments.

4.4.2.4.2 User Interface

Snapchat Lens Studio provides developers with a UI component asset through their Asset Library. In this project, the color picker and the toggle component have been used. A piece of JavaScript code attached onto the color picker component connects the component with the garment shown at the time and sets the garment material's Base Color property to the value of the color picker. The toggle component has been modified –again, through a JS script– to switch between two garments. The UI interface's position is then adjusted to the side of the screen, so that they can be easily accessed by the user without obstructing the view from the main attraction of the garment.

4.4.2.5 Upload to Social Media Platform

Snapchat Lens Studio is directly connected to the developer's Snapchat account, so the filter can be easily published from the Experience Studio. A title, icon and a preview video for the filter must be specified. These will all be visible to the end users via the Snapchat app while in the capture screen of the mobile application. After the filter is uploaded, it is reviewed by Snapchat to ensure it follows their submission guidelines.

4.5 VR Designer Backoffice Web application

The VR Designer Unity desktop application does not feature a mechanism to import new assets, namely garments, avatars or animations. Also, it would probably increase tremendously in size as a standalone application if it featured all available assets, demanding a big chunk of hard drive space from the designers' computer. There also needs to be a mechanism to upload and manage all these assets and tie them to each designer individually, so each designer can load their own assets in the VR Designer application.

Thus, the VR Backoffice web application is created to offer designers a way to manage their assets and to provide them for the VR Designer Unity desktop application. More specifically the application handles logins or signup requests, reads and saves data using an eTryOn API about garments, avatars, and animations, and finally, presents them to the user in a clear and manageable manner.

4.5.1 Software Selection

For the implementation of this application, React.js was selected as a software framework because of all the features that are offered (Section 4.2.1). In the application, users can perform all the actions needed to manage their assets, read & write of data to storage and databases using the interface components provided by React.js.

The ability to create self-contained, reusable components means we can keep code smaller and more organized. If components are set up well enough, they can be dropped in where necessary with no additional development required at all.

Just like the Dress Me Up application though, we might consider a hybrid approach during development, if it is required, using both React.js and Node.js. The amount of usage for both frameworks outlined will be finalized according to architecture.

5. Conclusions

The success of the eTryOn project depends on many factors that we try to address through the design and development of the eTryOn interaction systems.

A significant one is to produce realistic and stylistic tryons of garments on the avatars online and in real time. Existing designer software provide high quality artistic simulations, but they require both human intervention and significant time to process. On the other hand, gaming physics engines perform the simulation efficiently, but they do not incorporate stylistic elements, nor they provide the necessary information on how a garment fits. The eTryOn applications bring the best of these two approaches together by using the high-quality artistic simulations to empower the game engines so as to provide stylistic simulations automatically in close to real-time.

Combining the best of two worlds, our aim is to create three applications in the fashion industry. More specifically, a VR designer app that will assist the designers in the fashion design process. By generating high quality avatars and extracting exact body measurements using a mobile phone camera is a significant challenge that the eTryOn platform aims to take on with the implementation of both of Dress Me Up and Magic Mirror interaction systems. Our users will be able to try on new garments using their mobile phones or laptops and share a media file to social media, either by using the Dress Me Up application or the Snapchat Lens filter. This will bring exposure to the eTryOn project and drive more users to our apps. Finally, by emulating an e-commerce website and adding the feature to virtually try on the garments before purchasing, the magic mirror application will set a new paradigm for online shopping experiences.

Ultimately, user adoption would be key to measure our success that is also dependent on user experience factors like the ease of use of the envisioned applications, so users can have a pleasant experience while using them and continue to do so in the future. Our selections in the deliverable for the software and the way the apps will be implemented were made with a primary focus on easing the user experience and minimizing the frictions. Our next steps will be to finalize the first prototypes of these applications, which are currently under development and try them out with real users for feedback in an iterative process until the pilots.