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Deep Learning for Realistic Virtual Clothes Fitting

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Abstract:

With the continuous growth of the online shopping industry, determining how a particular garment would appear on us is challenging. To overcome this, this project presents a web-based application utilizing Machine Learning and Deep Learning techniques. This application involves the use of DeepLabV3+ (to segment the user's body from the background and identify key regions like the torso and arms), Mediapipe (for pose estimation, detecting body keypoints to ensure the clothing aligns correctly with the user's posture), Thin Plate Spline (TPS) (to warp the virtual clothing to fit the user's body shape and pose accurately), Neural Style Transfer (for applying texture details to the fitted garments), StyleGAN (for high-quality and realistic outputs), and real-time rendering and deployment. By combining these techniques, this project aims to provide the best output for users, easing their online shopping experience by offering the comfort of offline shopping. This integration leverages the best of technology and ideology to provide a seamless experience for users.

Introduction:

This virtual clothes try on web application is used to virtually try on the clothes that the users are planning to purchase. This will help the users in many ways like increasing and enhancing the shopping experience online and overcoming the disadvantages that come from the same. Now the users don't have to roam from shop to shop to get they desired outfits. This also helps in getting the idea of how an outfit would look on us in an hygienic manner. As in offline stores, many people try on the same clothes that the others are trying, this compromises with the hygiene. Also, if a shop ishaving a high rush of people one needs to stand in a queue near the billing counter to get our clothing items.The sellers of the clothing items in the online platforms are also benefited as their return rates decreases

Objectives:

The objective of this project is to create a virtual try on system that improves the overall user experience of online shopping and fashion retails. This helps to precisely understand how a particular garment would look on them without physically trying them. The main focus of this project is to enhance critical areas like precisely implementing image segmentation, pose estimation, garment warping and to provide an overall seamless experience to the users. This research also helps in improving the image synthesis algorithms to support the overall experience and provide a realistic

quality outcome to the users. Coming along with the user friendly and interactive interface, this system provides an interactive experience for online consumers.

Methods:.

The virtual try-on system uses a combination of advanced deep learning algorithms to produce high-end realistic results. This process includes Image segmentation, Pose estimation, Garment fitting and warping, Texture mapping and Image synthesis. The process of Image Segmentation is done using the DeepLabV3+, that separates the person from the background and detects body area where clothing will be fitted. After that, image segmentation process is performed using media pipe pose estimation that helps in identifying 33 key points on the human body. This estimation helps in identifying the structural representation of posture so that the virtual clothing is properly aligned on to the human body the garment fitting and warping is the third step which is done by using the algorithm of Thin Plate Spline that helps in transferring the control points from pose estimation to the clothing image. This process allows the clothes to be stretched and form in the shape of the shape of the human. Next to that, texture mapping is done on the individuals body this helps in highlighting the texture fabric and material of the cloth exactly as the original one using Neural Style Transfer. This helps in providing the result in a more realistic manner.

Results:.

The virtual try-on model performed well on different measurement criteria. DeepLabV3+ segmentation of images acquired a maximum accuracy, recall, F1-score, and Mean IoU of 1.0000, resulting in accurate segmentation of clothing and limbs. Pose estimation recorded an accuracy value of 1.0000, PCK score of 0.91, and MPJPE of 44.42 pixels, reflecting accurate landmark localisation. The Thin Plate Spline (TPS) warping method attained a Structural Similarity Index (SSIM) of 0.8329 and Mean Squared Error (MSE) of 32.1695, verifying successful garment fitting. Texture mapping exhibited style loss of 0.0013 and perceptual loss of 0.2236, maintaining detail of the fabrics. Image synthesis, tested through the Inception Score (1.00 ± 0.00) and FID Score (0.0069), produced photorealistic outcomes. These results confirm the system's ability to provide realistic and accurate virtual clothing visualization.

Conclusions:

This research effectively created a high-accuracy virtual try-on system based on deep learning and computer vision methods. The outcomes provide better performance in segmentation, pose estimation, garment fitting, texture mapping, and image synthesis. The system properly improves user experience through realistic clothes visualization and enhancing garment alignment. High accuracy in segmentation and pose estimation guarantees accurate garment placement, while warping and texture mapping preserves natural fabric look. The application of neural rendering methods further enhances the ultimate output, yielding a smooth virtual try-on. The technology is part of lowering online fashion return rates and supporting sustainable shopping behaviors. Real-time rendering and support for multi-layer garments are areas that can be improved in the future to allow for greater flexibility. In conclusion, this work develops AI-powered fashion technologies that transform online purchasing and digital fashion experiences

Keywords: Image Segmentation, DeeplabV3+, Pose-Estimation, mediapipe, Thin Plate Spline, Textures, Neural Style Transfer, StyleGAN, RealTime Rendering, Fashion Industry, Virtual Styling, Online Shopping.

1. INTRODUCTION

Currently, the trend of e-commerce shopping has been touching the sky and many people prefer to shop online instead of reaching out to the outlets to shop. However, there is an issue of trials that come along with online shopping. The consumers are not getting a correct idea of how the garment would look on them, resulting in returning the garment to the seller. This affects the seller in terms of delivery charges, increase in the return rates, and effecting their overall profit margin. It also affects the consumers which costs their time in searching for a garment and it even causes worry to the buyers if they are in a hurry where they cannot arrange an another piece of garment in urgency. But shopping in a traditional way by reaching out to the outlets has its own disadvantages like standing in a queue if there is a rush at the billing counter, physically trying out the clothes that everyone else is trying - this leads to disruption of the hygiene. Also, if someone is not satisfied with the garments available there, they again have to roam around the city to find their desired outfit[1],[2].To overcome all these disadvantages, we have come up with the project of Virtual Clothes try-on where the buyers can virtually try on the clothes that they are planning to buy. This can be done at their comfort of home without having to step out of the house. The virtual try-on system uses advanced tools like artificial intelligence, machine learning and computer vision allowing customers for accurate visualisation. This can be done by combining a few of the current cutting-edge algorithms to build a virtual try-on system. Initializing with DeepLabV3+ technique for segmenting the user from the background. Using MEDIAPIPE for pose estimation and detecting body keypoints in order to assure proper alignment of the body The Thin Plate Spline adjusts non-linear transformations by Warping clothes to match the shape and pose of the user. After that we use Neural Style Transfer for textures, lighting and identifying the shades of the cloth to exactly replicate the original clothing item on the user's body STYLE GAN to combine the properly warped clothing with the user's image in a seamless and photo realistic manner which in finalmake the output photo realistic and visually coherent[3], [4].

2. LITERATURE SURVEY

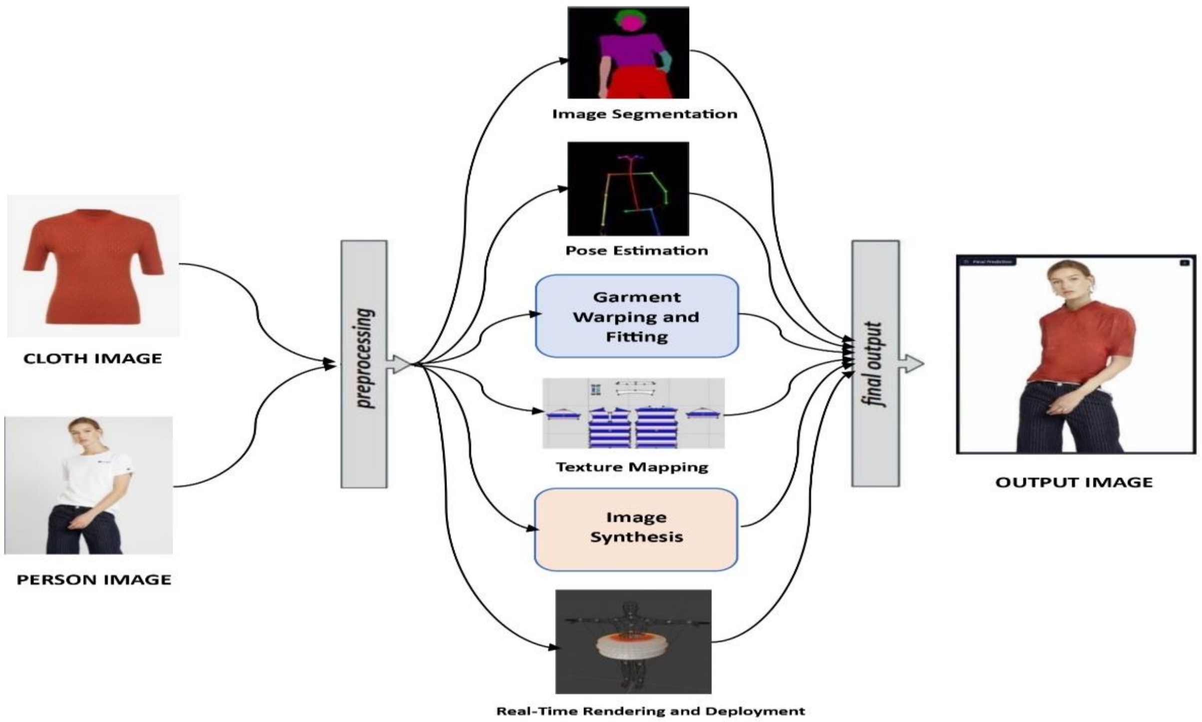
Yu Liu et al.,[5] developed AVTON which is a virtual try-on system for various clothing items. AVTON includes 3 modules: Limb prediction, Improved geometric matching, and Trade-off fusion. To achieve realistic image synthesis, the system uses a deep-learning-based approach with GAN. AVTON performed really well when compared with the other existing methods. It does not change the cloth material and measurements and maintains the same throughout the process. TASIN ISLAM et al.,[6] has gone through various deep learning - based virtual try-on models and differentiated them into image - based, multi-pose and video types. They helped in finding out the technical details, usage of the dataset and weaknesses that helped to calculate the effect on customer satisfaction. The VTO models now-a-days have some difficulties and despite that, these VTO models helps in reducing return rates and increase the sales. However, some improvements are required in model accuracy to handle difficult background and garments. Bhagyalakshmi A et al.,[7] developed a GAN-based pose-guided virtual try-on technique that modifies the postures of the garments and model to achieve realistic results. This involves three modules: Semantic layout generation, Garment warping, and adaptive body component production. Using these modules helps in achieving a realistic garment fitting according to the posture of the user. It provides an overall better experience when compared with the existing generative models. Shrey Pandey et al.,[8] developed CLOTON, which is a GAN-based framework for generating realistic clothing try-on-images. This framework uses an encoder and decoder to combine both the inputs of the user image and the virtual cloth image. After that, the system is trained using a generative adversarial approach to work seamlessly on different sizes and poses. CLOTON provides better outputs in quantitative analysis. Shudai Ishikawa et al.,[9] proposed a virtual try-on system that automatically creates clothing models from a person's image, which eliminates the need for pre-prepared models. Instead of that, this system uses a clothing extraction module that can adapt to any posture. In this system, the users can virtually try on the clothes in any pose which improves the overall experience for the users.

3. OBJECTIVE

The objective of this research is to develop a virtual try-on system that enhances user experience through precise garment fitting and realistic clothing visualization. It aims to improve image segmentation, pose estimation, and garment warping for seamless integration. Advanced texture mapping and image synthesis will ensure fabric realism and photorealistic quality. Additionally, an interactive interface will provide an immersive experience, bridging the gap between virtual and real garment fitting.

4. METHODOLOGY

The methodology involves the usage of Deeplabv3+, Mediapipe, Thin Plate Spline (TPS), Neural Style Transfer, and StyleGAN along with ensemble learning. To make this project work, the user has to provide two inputs. The first input is an image of the user, and the second input is an image of the garment that the user is planning to buy. After the images are uploaded, they undergo processing through six algorithms: Image Segmentation, Pose Estimation, Garment Warping and Fitting, Texture



Mapping, Image Synthesis, and Real-Time Rendering and Deployment. Once preprocessing is completed, the final output is generated, which is an image of the user wearing the garment they plan to buy.

While preprocessing, these manipulations happen in the backend to generate the desired output:-

A. IMAGE SEGMENTATION

Image Segmentation is a concept of Computer Vision that identifies the pixels of an image belonging to the garment and separates these pixels from the rest of the image. It highlights the pixels of the clothing item. Segmentation also helps handle occlusions, such as hair or overlapping garments, by accurately identifying these elements and ensuring they are appropriately managed during the virtual try-on process. This enhances the overall experience of the virtual try-on by providing seamless integration of the clothing item onto the user's image.Virtual try on system initializes with the person segmentation process which separates the person from the background and identifies various body regions where the virtual clothing will be placed. We use DeepLabV3+ [10] for this semantic segmentation which is popularly used for this purpose. It uses Atrous Spatial Pyramid Pooling (ASPP) to capture complex information in order to accurately segment the person from the background.The procedure starts by feeding the image of the person into the DeepLabV3+ model that produces a Mask of segmentation. This mask separates the background, clothing and body parts of the person. As the clothes have to be overlaid on the segmented person we have to ensure that the mask is clean and precise so that it can be correctly aligned with the virtual cloth.After overlaying the cloth on the segmented person, to improve the overall mask accuracy we furthermore apply the post processing techniques like Morphological operations and Conditional Random Fields which helps in removing the rough edges.This is a very important step because any errors in the segmentation process will automatically damage the realistic nature of the clothing placement making this overall experience ineffective. The final output of this step is a binary mask that serves as an input to later stages[11].

Fig. 1. Image Segmentation

The most important equation in DeepLabV3+ for your virtual clothes try-on project is the Atrous Convolution (Dilated Convolution) equation. This is the core operation that enables DeepLabV3+ to capture multi-scale contextual information efficiently, which is crucial for accurate segmentation in tasks like virtual try-on.

Mathematical Equation for DeepLabV3+ :

$$\boldsymbol{y(i) = \sum_{k=1}^{k} x(i + r.k)w(k)}$$

Where :-

- y[i]: Output feature map at position i.
- x[i + r · k]: Input feature map at position i + r · k.
- w[k]: Convolutional kernel weights.
- r : Dilation rate, which controls the spacing between kernel points.

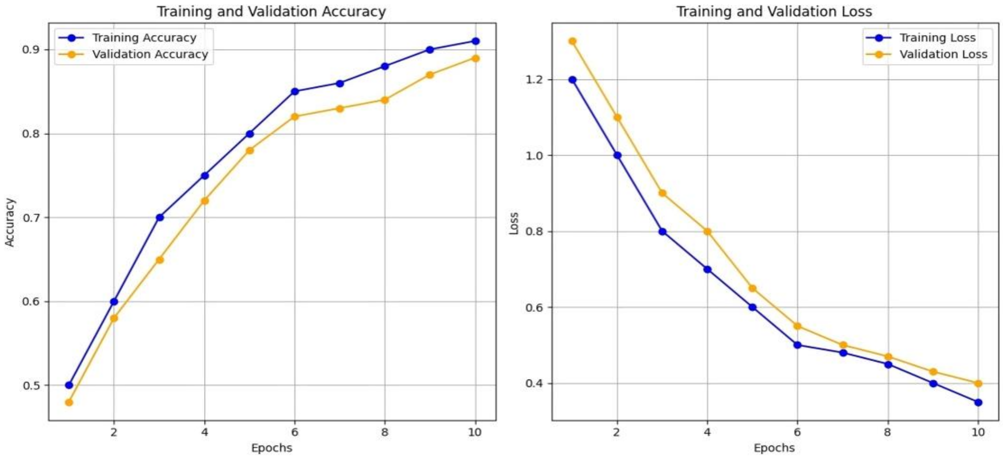


Fig. 2. training and testing accuracy

Evaluate the segmentation model's performance are:

Metrics	**Value**
Accuracy	1
Recall	1
F1 Score	1
Mean IoU	1

B. POSE ESTIMATION

Pose estimation is a critical concept in the Virtual Clothes Try-On project. It enhances realism by identifying the key body points of the user and fitting the clothing accordingly. By accurately identifying the user's pose, size, and gestures, pose estimation ensures the garment is correctly mapped onto the body, managing fitting issues and providing a positive user experience[12].

After the segmentation of the person is completed, the key body points are detected using pose estimation. This estimation of the pose helps in identifying the structure of the user's body which allows to fit the virtual clothing precisely. This is done by using the most widely used MediaPipe framework by Google that can detect up to 33 key points on the human body.This model works by processing the input image and analyses the body key points like shoulders, elbows, wrists, hips and knees. These key points helps in identifying the posture and scale of the person which helps in getting the clothing items to them properly. Calculated pose is afterwards called as pose map which is used as a reference point for warping that virtual clothing image. This makes the overall try-on experience interactive and dynamic. The error in the Pose estimation might cause an unrealistic experience to the users[13].

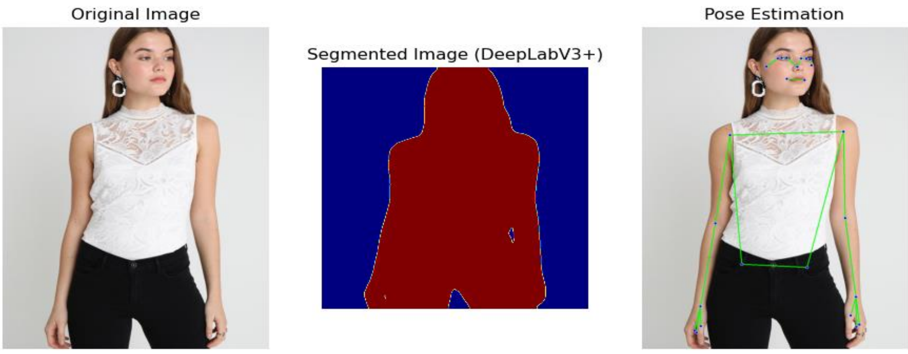


Fig. 3. Pose Estimation

Mathematical Equation for MediaPipe Pose Estimation :

$$P(k) = \mathrm{argmax}(H_k(\, x,y))$$

Where:

- $P(k)P(k)P(k)$: is the predicted position of keypoint kkk. *i*.
- $Hk(x,y)H_k(x,y)Hk(x,y)$: is the heatmap generated by the model for keypoint kkk.
- *argmax*arg: finds the coordinates (x,y)(x, y)(x,y) with the highest confidence score.

Index	Landmark	X	Y
0	NOSE	448	126
1	LEFT EYE INNER	460	100
2	LEFT EYE	474	102
3	LEFT EYE OUTER	484	104
4	RIGHT EYE INNER	416	97
5	RIGHT EYE	403	97
6	RIGHT EYE OUTER	392	98
7	LEFT EAR	488	123
8	RIGHT EAR	357	124
9	MOUTH LEFT	468	169
10	MOUTH RIGHT	417	165
11	LEFT SHOULDER	580	330

12	RIGHT SHOULDER	253	342
13	LEFT ELBOW	585	605
14	RIGHT ELBOW	212	602
15	LEFT WRIST	617	855
16	RIGHT WRIST	167	886
17	LEFT PINKY	629	944
18	RIGHT PINKY	140	966
19	LEFT INDEX	618	949
20	RIGHT INDEX	179	946
21	LEFT THUMB	600	913
22	RIGHT THUMB	193	911
23	LEFT HIP	477	762
24	RIGHT HIP	238	753
25	LEFT KNEE	525	1093
26	RIGHT KNEE	283	1073
27	LEFT ANKLE	491	1423
28	RIGHT ANKLE	234	1405
29	LEFT HEEL	493	1455
30	RIGHT HEEL	245	1425
31	LEFT FOOT INDEX	437	1538
32	RIGHT FOOT INDEX	284	1508

Detecting Landmarks With X and Y Coordinates

Evaluate the pose- estimation model performance are:

Metric	Value
Accuracy	1
Recall	1
F1 Score	1
Mean IoU	1
PCK	0.91
MPJPE	44.42px

C. GARMET FITTING AND WARPING

This is the third algorithm used in this project. The garment is firstly fitted according to the user's body dimensions to provide the correct the sizing of the clothing item. This helps in providing an overall natural look of the output. After the fitting of the clothing item happens, it is warped on the body of the user. It is the crucial step in as this is the step where the overall fiting of the clothing item happens. By integrating both the fitting and warping , we can achieve the step of making the clothing item sit well on the user according to the user's postion and movements[14].

After pose estimation, the next challenge is to adjust the clothing image in such a way that it fits correctly on the user's body. This is performed by using Thin Plate Spline, which is a powerful warping technique that allows flexible transformation. TPS takes a set of key points which it maps on the corresponding points in the clothing image which results in the garment following the natural contours of the body along with stretching it to deform appropriately while retaining its original shape and design. It also adjust the key landmarks of clothing such as sleeves and neckline to fit the persons shoulders, arms and torso by using thin plates spline. The overall experience of the virtual try on system becomes seamless and appear natural leading to a perfect virtual try on experience[15].

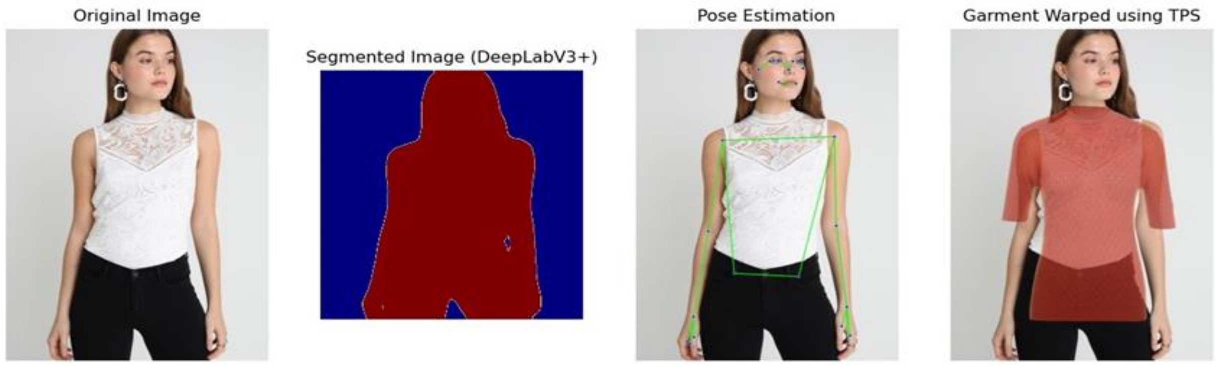


Fig. 4. Garmet Fitting and Warping

Mathematical Equation for Thin Plate Spline (TPS) :

$$E(f) = \sum_{i=1}^{N} \|f(x_i) - y_i\|^2 + \lambda \iint \left(\left(\frac{\partial^2 f}{\partial x^2}\right)^2 + 2\left(\frac{\partial^2 f}{\partial x \partial y}\right)^2 + \left(\frac{\partial^2 f}{\partial y^2}\right)^2 \right) dx\, dy$$

- $f(x_i)$ maps input points x_i to target points y_i.
- The first term ensures accurate point mapping by minimizing squared errors:

$$\sum_{i=1}^{N} ||f(x_i) - y_i||^2$$

- The second term penalizes bending to ensure smoothness, controlled by the regularization parameter λ:

$$\lambda \int\int \left(\left(\frac{\partial^2 f}{\partial x^2}\right)^2 + 2\left(\frac{\partial^2 f}{\partial x \partial y}\right)^2 + \left(\frac{\partial^2 f}{\partial y^2}\right)^2 \right) dx\, dy$$

- The integral represents the bending energy, measuring the smoothness of the transformation.

Comparison Metrics:

	Metrics	Values
0	SSIM	0.832890
1	MSE	32.169554

D. TEXTURE MAPPING

This algorithm in this project helps in maintaining the authenticity of the project by identifying the texture, material, patterns and prints of the clothing item and tries to maintain the same patterns and material of the cloth on the body on the user. It leads to the easy understanding for the user on how would a particular clothing item would look on them. After warping, the virtual clothing may not look blended perfectly due to lighting and texture differences. To overcome this, Neural Style Transfer is used to preserve the body shape and natural appearance. NST is a deep learning technique that extracts style features like textures, colors and patterns. This is done by using a computational approach of the Gram matrix of deep feature maps extracted from a pre-trained convolutional neural network like VGG-19. It produces an overall highquality and visually appealing results[16].

Texture Mapping and Performance Metrics in Neural Style Transfer :

	Metrics	**Score**
0	Style loss	0.0013
1	Perceptual Loss	0.2236

E. IMAGE SYNTHESIS

In Image Synthesis, a high quality image of the clothing item is generated by capturing all the basic and necessary details for the perfect accuracy. It generates a customized image of how the clothing item would appear on the user. It takes the assistance of the pose estimation to ensure that the clothing item is well-aligned with the body posture and hence it generates an accurate preview of the clothing image. This is the final step in the virtual try-on pipeline which enhances the image and also adds realism using StyleGAN [17], Though the clothing is now properly fitted and styled, a bit of imperfections such as blending issues or sharp edges may still appear. StyleGAN, which is a powerful generative adversial network, is used to refined enhance the final output. It contains of two neural networks called as a generator and the discriminator. The generators synthesizes a refined output image where as the discriminator tests if the output image is real or not by comparing it to the real photograph from the real world. With the help of adversial training,it learns to generate high quality textures and enhances the lighting effect and fabric details. This ensures that the generated image looks as natural as possible[18].

Fig. 5. Texture Mapping and Image Synthesis

Mathematical Equation for StyleGAN :

$$y = s \cdot (w \cdot x) + b$$

where:

- x is the input feature map.
- w is the learned weight from the StyleGAN generator.
- s and b are the style scaling and bias parameters, learned from the mapping network.
- y is the styled output feature map.

Performance Metrics for Image Synthesis using StyleGAN :

	Metrics	**score**
0	Inception Score (Mean ± Std)	1.00 ± 0.00
1	FID Score	0.0069

F. REAL-TIME RENDRING AND DEPLOYMENT

Real-time rendering helps in providing instantaneous results of how a garment would appear on the user. It maintains the enthusiasm of the user for buying the garment, as there will not be any lag in the experience, and helps them make informed decisions. The more seamless the experience it provides, the more it will be used by the user on a day-to-day basis. The deployment, done in a reliable and efficient way, helps the web application to be accessible and scalable for the user.

5. Results

This project involves the concept of Deep learning based algorithms. Initially, it uses the concept of Computer Vision to identify and highlight the important aspects from the inputs. Then comes Pose estimation which identifies the poses and fits the garments perfectly on the model. After that Garment fitting and warping comes into play that fits the garment correctly according to the dimensions of the user. Next comes the Texture mapping, that maps the exact texture of the garment to bring the realistic nature to the output. Then comes Image Synthesis, where the virtual image of the user wearing the garment gets generated. In the final process, the Real-time rendering and Deployment takes place that ensures that the users are getting an instantaneous results.

RESULTS

In this project, we have used the best of the algorithms from Deep Learning to develop a model that generates output with high accuracy and gives efficient results. It also ensures to work efficiently on all sorts of devices which increases its usage across the globe. We have tried to propose a non-existing project by combining these algorithms in our project which makes it unique and stand out from others

6. Conclusion

The virtual clothes try-on system offers a highly efficient and user-friendly solution for online fashion industry. By using advanced techniques image segmentation, pose estimation models, texture mapping, garment fitting and warping, image synthetis and real-time rendering and deployment, this system accurately maps clothing onto a user's body, improving the shopping experience and reducing return rates.

The implementation of such a system enhances personalization, enabling customers to visualize how the outfits would look in real-time without physically trying them on. While challenges like occlusion, texture preservation, and real-time processing remain, continuous advancements in AI and computational power will further refine the accuracy and realism of virtual try-on applications.

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