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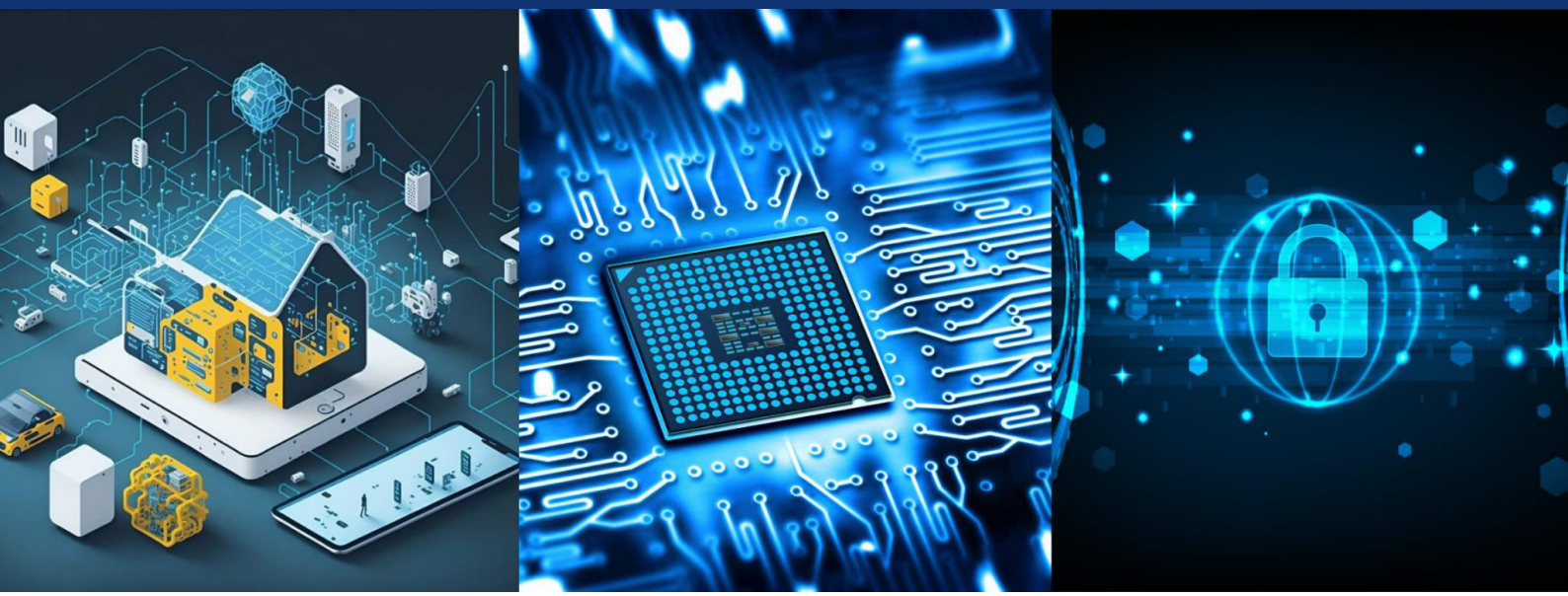

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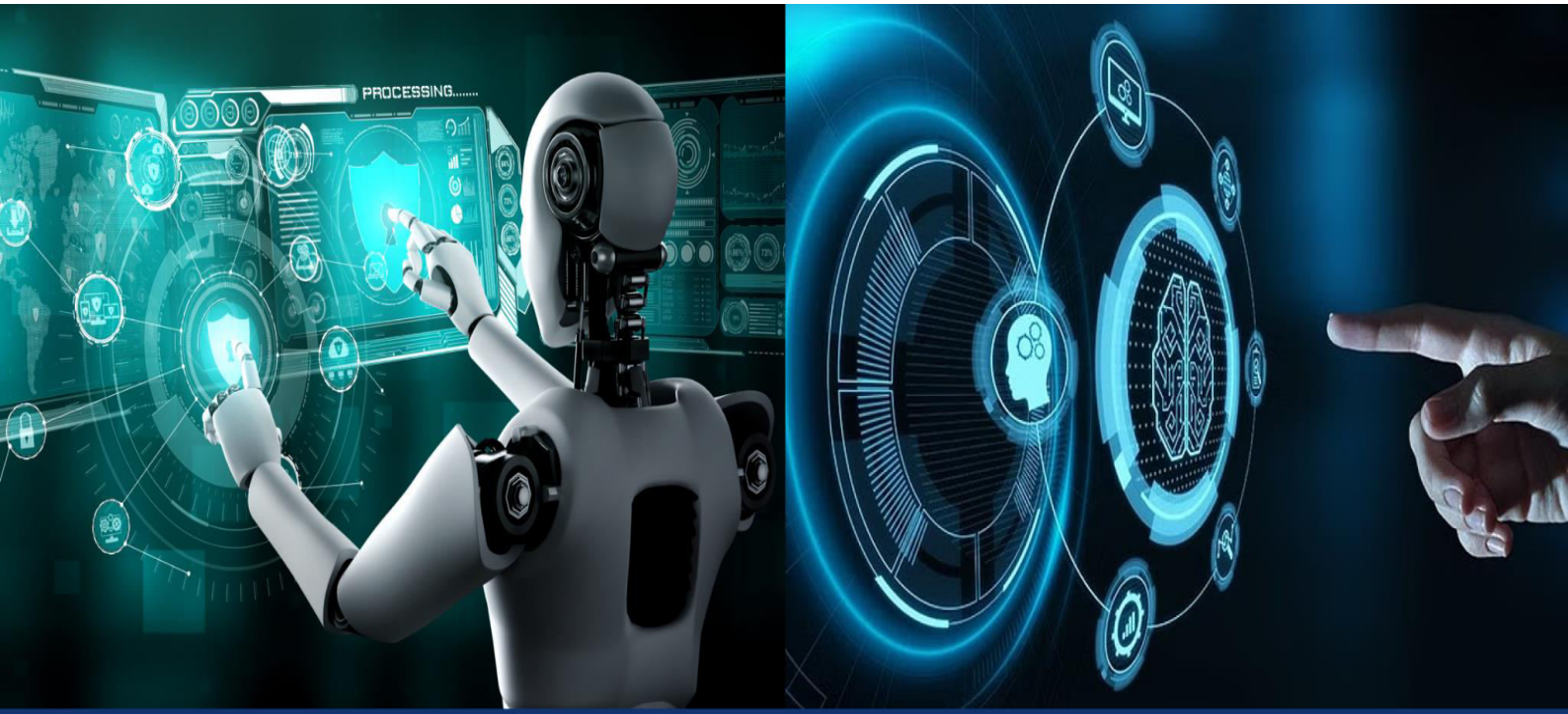

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An Enhanced Virtual Fitting Room using Deep Neural Networks

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ABSTRACT: Customer experience in traditional fitting rooms is a critical aspect of the textile industry, yet these spaces often present challenges such as long waiting lines, the inconvenience of repeatedly changing outfits, privacy concerns, and wasted time. To address these issues, we propose a Virtual Fitting Room powered by convolutional neural networks (CNNs). The system integrates a TV display, two webcams, and a computer to capture the customer's body and render a realistic visualization of them wearing selected garments. By combining deep learning with augmented reality, the application performs body detection and generates virtual clothing overlays. Using stereo vision, it extracts body measurements, while additional features analyze age, gender, facial structure, and skin tone to recommend suitable clothing styles. The system also allows customization of outfits based on user preferences and achieved 99% accuracy in style recommendations through a feedforward neural network (FFNN). Furthermore, customers can select clothing for individuals who are not physically present in the store. The output delivers highly realistic virtual try-ons, enabling efficient personalization of textile products. This innovation has the potential to significantly impact the fashion and textile industry, positioning it as a competitive solution among existing applications

KEYWORDS: Virtual Fit-on Room, Fashion, style, Convolutional Neural Network, Augmented Reality

I. INTRODUCTION

The advancement of technology has significantly influenced human lifestyles, leading to widespread adoption of smart systems that simplify everyday tasks. With the rapid growth of the fashion industry, consumers are increasingly drawn to newly developed solutions. Similar to other sectors, customers expect fresh innovations, prompting retailers to explore novel approaches to meet these demands and remain competitive. At the same time, individuals who engage with technology contribute creative solutions that emerge in the marketplace. One such innovation is the concept of the Virtual Fitting Room. Several organizations have introduced this idea into the fashion industry, including FX Mirror, Magic Mirror, and KINECT Body Metrics Virtual Fit Room. However, these existing systems offer only limited functionality. They often overlook cost-effectiveness, fail to prioritize customer satisfaction, and do not adequately address consumer needs.

Most of the past researchers used expensive sensors to measure body sizes and mapping images. But this Virtual Fit- on Room is introduced by way of using two web cameras to capture the customer object, calculate the distance between 19 customer body landmarks and get real-time body measurements using the stereo vision concept. Using the landmark of the customer body, fits 3D cloth models to the customer object and when the customer moves, the cloth also moves with the customer. When the real customers do not appear physically in front of the screen, a dummy 3D avatar is used to buy the best matching outfit for another person who is not in the textile shop. Furthermore, the number of customization clothing options according to the customer's choice is available in the new VFR solution. Some sort of styles, colors, categories, and sizes are suggested according to the customer face type, face color, age, height, breadth, and gender. As a result of VFR – Virtual fit-on rooms reduce some identified problems in traditional fitting rooms. Privacy problems in the fit-on rooms, timewasting in long queues, fitting on the same clothes among number of different people (Health Matters) are some of the other issues that discourage people to go shopping and ruin their shopping experience. The motivation behind the Virtual fit-on Room is giving the best shopping experience to the customers and provides a better product to the top, middle and primary retailers in a cost- effective way.

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II. LITERATURE REVIEW

The concept of the Virtual Fitting Room has become a prominent subject of interest among researchers. Although this area of study has gained global attention, comprehensive and effective solutions are still lacking. At present, the Virtual Fitting Room remains in the experimental phase, with ongoing efforts to refine its capabilities and address existing limitations.

In [1], according to the code: Augmented Dressing Room with Tag-based Motion Tracking and Real-Time Clothes Simulation system has provided an augmented reality concept for dressing rooms. This fit on room contains a camera and a projection surface rather than a mirror. The purchasers stick some visual tags to their normal clothes and this application is giving features to provide an AR-based video stream to the customer and capture the motions of humans. After that, selected clothes are fitted to the customer's body. This system is quite the same as the New Virtual Fit-on Room system, but it limits only to camera projection. But the new VFR System provides some facilities that are not available in the former system.

In [2], A Real-Time Virtual Dressing Room Application using Kinect is one of the virtual fit-on rooms which is used to map clothes to the human object. For that, the inventors of the application have used Kinect Sensor that is provided by Microsoft, which calculates the depth using video stream.
Another factor is that the application depends on the labels provided by the Kinect sensor. It consists of mapping clothes according to the sensor and depth calculation. But an Enhanced Virtual Fitting Room uses Deep Neural Networks which is more advanced with lots of features that applications have not focused and touched before.

In [3], the Design and Implementation of Virtual Fitting Room is based on Image Blending as one of the human-friendly virtual fit-on rooms. It is quite different from the other virtual fit-on room applications and a bit like an Enhanced Virtual Fitting Room because this application provides customers to select jewellary according to their choices. The application is a mobile-based Android application, and it does not require any hardware component. Image blending techniques are used to design this system and customers can virtually wear jewellary. This system also detects human face but compared with the new VFR system, it gives advanced customer requirements than the discussed software.

In [4], According to this discussion it is about the real- time simulation of 3D cloths. The application uses Microsoft V2 sensor to get body parameters, fits clothes virtually to the customers by using the unity 3D game engine. Compared with the new VFR system, this system has some similarities like getting body parameters, gender detection, etc. Considering the whole product, it gives a realistic fitting experience to the customer. But the application is somewhat expensive. Due to that, it is not fulfilling the cost-effective parameter. Compared with the features, it uses different techniques for both applications and some features are available in the new VFR system rather than the discussed system in the paper.

In [5], this paper, the augmented reality platform for virtual fitting rooms is discussed. According to the author, currently so many platforms are used in multi-sensor body scanners and combined with new algorithms. But considering the applications which are presented, they are very expensive and the whole product is not affordable by middle or primary shop owners. The new virtual fit-on room provides new features with affordable cost to the customer as they are without very expensive software.

III. METHODOLOGY

The initial stage of the Virtual Fitting Room involves Human Pose Estimation and aligning garments to the customer's body.

A. Human Pose Estimation

Human Pose Estimation can be done by using a pre-trained model [6]. To deal with the pre-trained model, it implements an API using python to detect 19 landmarks on the human body. These landmarks help to create Skelton of the human body. These landmarks are facial landmarks, neck, shoulders, elbows, wrist, hips, knees, ankles [7], and background. COCO + foot as the dataset is used to detect landmarks on the human body. COCO is detecting only 18 landmarks [7]. But for efficient extraction of the human body shape from the background image, the background should get as a landmark in the new implementation.

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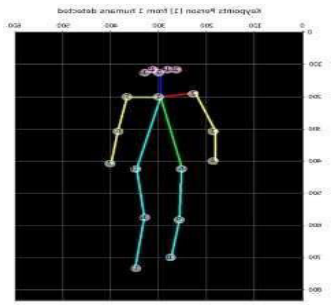


Fig. 1. Output of COCO + Background [8]

The pre-trained model which is important to landmark detection is called by OpenCV function where it is called in the implemented API. The pre-trained model which is important to landmark detection is called by OpenCV function where it is called in the implemented API. The API will get the video as the input frame by frame and those frames are interacting with the pre-trained model. After that, landmarks and a link between two landmarks are created which are named as pairs. Likewise, using a pre-trained model, the API generates a Skeleton of the human body. If the customer stays in front of the cameras, the system will generate a skeleton based on his/her body.

Fig. 2. Output of using the webcam

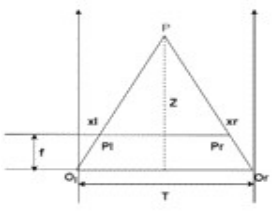
B. Fitting Clothes to Customer's Body

In this part, a dataset for a store around hundreds of 3D clothes models are created. First, the pre-trained model is done which is used to create a transparent model of cloth shapes. That model is based on different shapes of clothes. As an example, for a T-shirt, the transparent model shape should be the same as the T-shirt so that it will help to create transparent models for cloth shapes.

In a VFR system, when the customer is in front of the screen, the two webcams take the customer's view and calculates the body measurements. The stereo Vision concept is used to do this.

A. Depth Calculation

Stereo Vision consists of two webcams that allow obtaining images from two distinctive viewpoints [9]. Then the depth between the screen and the customer for the 19 landmarks of the customer is determined through finding the disparity in the images of the same 3D points [10]. According to Fig. 3. T stands for baseline, f stands for focal length, (xl – xr) stands for disparity, Px stands for P point's x value.



$$\frac{T}{Z} = \frac{T+xl-xr}{Z-f}$$

$$Z = \frac{T.f}{xr-xl}$$

$$x = \frac{f.x}{z} + Px$$

Fig. 3. Stereo Vision Depth calculation equation

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B. Camera Calibration

Camera calibration estimates the intrinsic parameters and extrinsic parameters [11] which are used to correct all kind of distortions. A lot of distortions can happen to images from the normal cameras. Since two webcams receive focal length pixel values, both cameras must be calibrated to get real values, provide sample images of the well-defined pattern (Chess Board) and find some specific points in it (Square corners). It coordinates in real-world space and image. Some mathematical problem is solved in the background to get the distortion coefficients with this data.

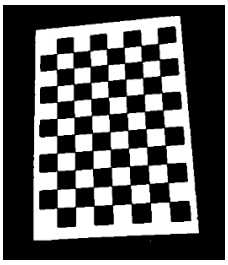

Fig. 4. Camera Calibration

C. Body Measurements

X and Y values are calculated by using the above equation and get all 3 real values (X, Y, Z) of 19 body landmarks of the customer. Using those 3D parameters, customer body measurements like height, right arm length, left arm length, waist, hip size, etc. are calculated. Customer body measurements are very important to choose clothes according to their choices.

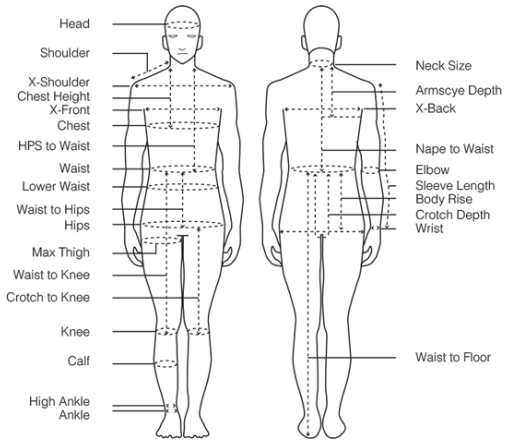

Fig. 5. Body Measurements [12]

Convolutional Neural Network architecture transforms the input layer data into an output layer through the differential layers.

A. Age & Gender Detection Model

The main purpose of this model is to detect the human age & gender through Convolutional Neural Network.

B. Proposed Architecture – Convolutional Neural Network

A classification-based approach is used to detect age and gender. In the classification-based approach, SoftMax, relu, pooling as activation functions to detect the human age and gender are used. Here, 1D convolutional layers with different size of kernels were used. Through the camera, human's height, weight, gender, and age are detected. The system provides the most suitable 3D avatar according to the detected details (age, gender, height, and weight) of a human.

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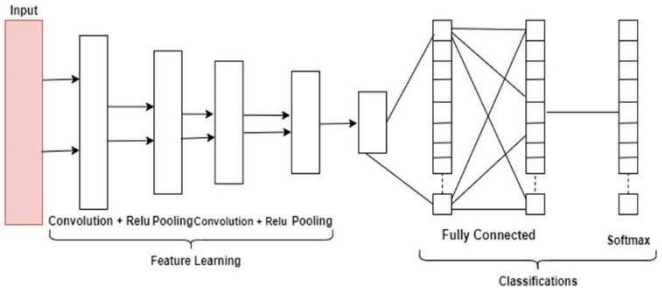

Fig. 6. The architecture of the CNN

C. 3D Avatar Model

Unity software is used to create a 3D avatar for the human body to select the most suitable clothes according to the detected details. The 3D avatar model is shown in the fig. 7.

Fig. 7. 3D Avatar Model

D. Pose net

The goal of this model is to merge the detected details of a human with the most suitable 3D avatar. Tensor Flow is the framework to train on the server by calling the Tensor Flow models/pose net library and use the JavaScript syntax to call the camera (mobile phone, computer, monitoring, etc.) of the running device and observe it on the designed monitoring screen.

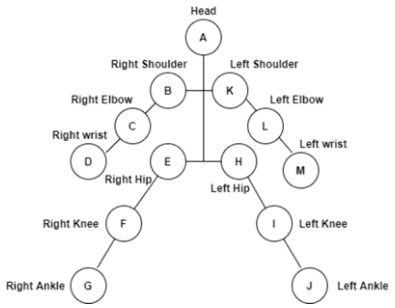

Fig. 8. Body points of the human skeleton

Next function of the VFR System is Customizing Clothing Collection.

Identify Face Land Marks

When a person buys cloth, the face is an incredibly important factor. Therefore, VFR system identifies human face first. For that, 68 Landmark detection algorithm [13] was used together with the dlib Library. K-Nearest Machine learning Algorithm is used to calculate the distance between facial landmarks [14].

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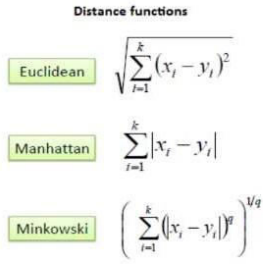

Fig. 9. K- Nearest Neighbors Functions [15]

Each 68 points have the (x, y) coordinates. Those 68 Landmarks are mapped to facial structures on the face. Detecting Human faces and correctly recognizing faces are the main tasks in this virtual Fit-on Room. This technique helps to detect the key facial structures on the human face, and it involves localizing the face in the image. Eyebrows, Nose, Mouth, Jaws, and eyes are representing notable regions on a human face.

Fig. 10. Face Landmarks

A. Predicting Face Type

Six standard face types are identified. Diamond, Oval, Oblong, Round, Triangle, Square are the types included in the dataset. Those are identified as labels. Then a new facial data set is created. To train the data set, six labels that are identified as types and the six distances are used. Those are identified in face landmark detection. That's to get six distances in a human face. Those six distances are features of the testing and training dataset. After we train features and labels together, the face type is extracted.

D1 = D2/D1
D2 = D3/D1
D3 = D4/D1
D4 = D5/D1
D5 = D6/D1

Features (D1,D2,D3,D4,D5)

B. Recognizing Skin Color

Recognizing face color is another useful factor. New VFR System uses 68 landmarks and gets a color code of the customer's face. When taking face color, it gets data of a particular place in the face. To recognize face color, some necessary skin tones are taken. Then hex values and decimal values of those skin tones are identified. After that, ranges of that skin tone are taken and are categorized. For this task, live human facial tones that were collected from people are used. Finally common ranges of skin colors are selected. Fig. 11. illustrates the selected skin tone categories for the VFR Application. The purpose of taking face color is to suggest proper clothing colors according to customer's skin tone.

Category	Color Tone	Hex Value	Decimal Value	Color Code
1	Pink dark	#e4bdad	14990765	
2	Pale Dark	#e6c8b0	15124656	
3	Fare Dark	#e7b38d	15184781	
4	Tan Dark	#be794a	12482890	
5	Dark Dark	#733e26	7552550	

Fig. 11. Identified Skin color category ranges

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C. Suggest Styles

For Style Category Prediction, Feed Forward Neural Network is used. The proposed architecture uses 3 layers such as the Input layer, Hidden Layer and the Output Layer. The hidden layer consists of dense cells to develop the FFNN to Predict Style category. Purpose of predicting style category is to provide best matching and best fitted output to the customer. The activation layer's activation function is softmax. The proposed FFNN Architecture of the Style category selection is shown in the Table I.

TABLE I. THE PROPOSED FFNN ARCHITECTURE OF THE STYLE CATEGORY SELECTION

Layer	Neurons
Dense Layer 1	64
Dropout (Probability 0.5)	N/A
Dense Layer 2	128
Dropout (Probability 0.5)	N/A
Dense Layer 3	64
Dropout (Probability 0.5)	N/A
Dense Layer	10

IV. RESULTS & DISCUSSIONS

The results demonstrated in this chapter match the state- of-the-art methods. For the human pose estimation, the skeleton of the customer's body using body landmarks is created. Based on the skeleton, the clothes which are chosen by customers are dressed. For that, we use a created dataset to store 100 of the clothes. Clothes that were used to dress the transparent model are like cloth shapes. After that, the dressed model can be fixed to the human skeleton. Now the customer can see their body through a screen with the dressed cloth which is chosen by them. It is shown from the screen as a live video. That screen behaves like a mirror. But this video will slow or lag because the pre-train model which detects landmarks requires a high-performance GPU like GTX 1080Ti. But the system GPU is GT 130MX. If we use high- performance GPU, we can get high accuracy output.

The two webcams take a customer's object view and get the depth between the screen and the customer. The stereo vision concept is used to calculate the depth. By using the depth values of all the 19 body landmarks, the X and Y coordinates are calculated. Finally, the customer's body measurements are calculated from the X, Y, and Z, real 3D parameters and using that, the customer can then choose clothes according to his/her choices.

The system provides the most suitable 3D avatar according to the detected age and gender details of the customer. Pose net merges the detected details with the most suitable 3D avatar. With those detected details, the customer can fit on clothes according to his/her choices. To predict the accuracy of Age and gender detection dataset, Support vector machines (SVMs) that are a set of supervised learning methods used for classification, Regression, and outlier detection are utilized. In this case, SVC with a linear kernel is used. Accuracy values consider Precision, Recall, support, and F1-score. Precision (P) is defined as several true positives over the number of true positives plus the number of false positives. To calculate Precision values, this equation can be used.

P = Precision
T_P = True Positive
T_F = True False

$$\mathbf{P = T_P / T_P + T_F}$$

TABLE II. ACCURACY OF THE AVATAR MODEL SELECTION USING

F1-score	Precision	Recall	Accuracy
0.98	0.98	0.98	0.97

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According to Table II, 97% accuracy was achieved successfully. This model was developed with the SVM and Kernel was linear.

As a result of customizing clothing according to the client's requirements, the landmarks of the human face have to be identified successfully. Identification of the human face type due to detecting face landmarks of the human face and the distance between nodes have to be done essentially only after that. The identification of the human face type is helping to give the best matching cloth style to the customer. Here, to identify the face type, first we use a data set with the 60 images of the six face types and one face type has only 10 images. At that time when results were taken, accuracy was not high. After that, expanding dataset and checking with a different type of face has helped to increase accuracy. In the face, the color detection method provides accurate results and code of the color. But due to lighting conditions, sometimes the result may vary. Necessary solutions have to be taken after creating a dataset with face type, face color, height, width, age, gender, and style category. Using proposed FFNN Architecture, VFR suggests different kinds of clothing options to the customer. A Feed forward neural network is an artificial neural network where in the connections between the nodes, they do not form a cycle. Proceeding style prediction using proposed FFNN module expects to suggest best matching outfit to the customer.

TABLE III. ACCURACY OF THE STYLE CATEGORY SELECTION USING FFNN.

Train Accuracy	Validation Accuracy	Loss	Validation Loss
0.992	0.99	0.12	0.02

TABLE IV. ACCURACY OF THE STYLE CATEGORY SELECTION USING FFNN.

Precision	Recall	F-1 Score	Accuracy
0.992	0.99	0.12	0.02

Fig. 12. Displays accuracy of the proposed style category selection model.

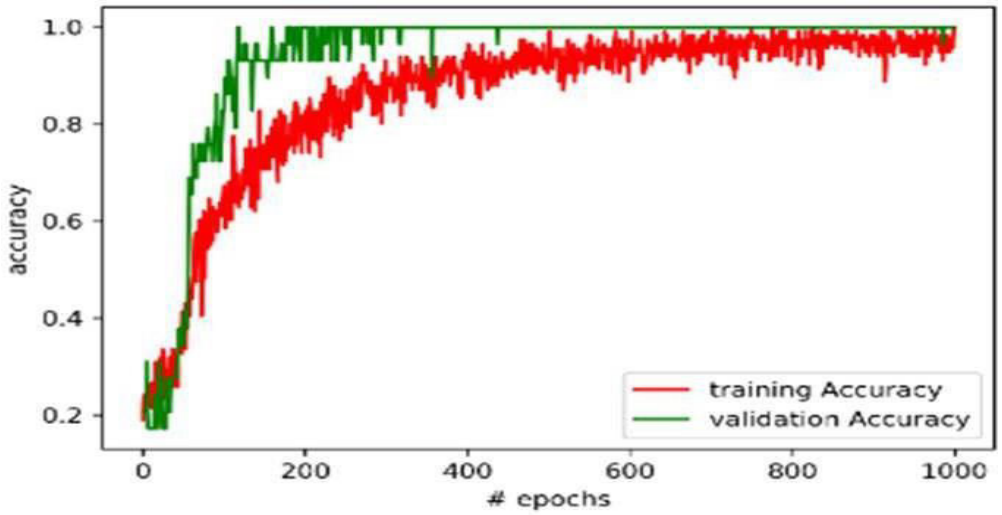

Fig. 12. Training Accuracy and Validation Accuracy of proposed FFNN Model

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Achieved Validation Loss and the training loss is also shown in Fig. 13.

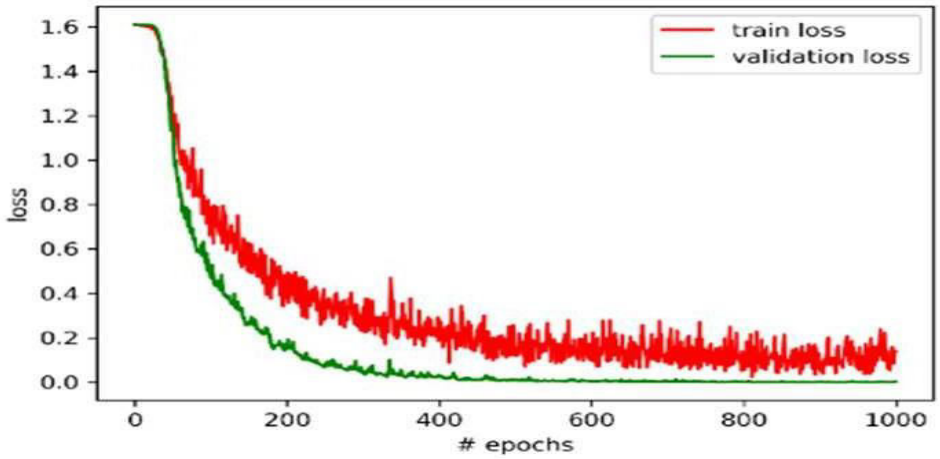

Fig. 13. Training Loss and Validation Loss of proposed FFNN Model

According to the Achieved Results, Virtual Fit-on Room System successfully achieves target outcomes and it will address customer's difficulties soon.

V. CONCLUSION

In this research of the Virtual Fit-on Room product, we mainly focused on the approach which we used to develop this system. CNN in deep learning is the approach that we have chosen as our approach. Two web cameras are used to capture the customer body. The system calculates the distance between the 19 body landmarks and get customer body measurements according to the real time x, y, z values. The stereo vision concept is used as a task to accomplish taking body measurements. Using this product, customer can fit clothes virtually and select those clothes. If customer choose clothes among the dataset, the image which is related to chosen clothes appears on the customer's object in screen. The image is a two-dimensional image and that moves according to customer's movements. Also, customer can customize clothes as they wish, but are under some limitations. Already there are ten styles of categories created for clothes. Using those styles, customers can do their customizations for chosen clothes. Also customers can select clothes for another person who is not present at the moment and disable people too will be able to choose clothes. For that purpose 3D models are created and pre-trained module files are used for predictions. Deep learning is the most popular and latest trending approach which is highly demanded in the IT industry [16] currently. Graphic designing also is a brilliant part of the IT industry since it is the best way of communicating with people [17]. These days some software like Unity are trending IDs for graphic designing. In this project, we target to introduce a product that is combined with deep learning and Unity. That discovery is very useful for movie making, gaming industry, advertisement industry, etc. VFR is a serious concept [18] of the IT industry and it also directly links with the fashion industry. Presently these two industries are highly profitable in the world. Using that advantage, this Virtual Fit-on Room is produced for targeting the global market. From a small textile shop to a large shopping mall, this product can be utilized to buy and use more easily than other products since having a simple device structure, having low cost devices, and low system requirements to run this program. The live dressing of this product brings a new experience to people and may increase to attract them to this product. Therefore, retailers may be interested in buying this product to engage in new experiences in their shops. Therefore, this product will be the next turning point of the IT and Fashion industries.

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