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STYLESYNC:OUTFIT RECOMMENDER

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***Abstract*- Our "Style:Sync: Outfit Recommender" project is a pioneering initiative that harnesses the power of Machine Learning (ML), Deep Learning (DL), and a diverse array of advanced algorithms to revolutionize the fashion industry. By combining state-of-the-art technologies with innovative approaches, this project aims to provide users with personalized outfit recommendations tailored to their unique preferences and styles.**

Through the utilization of ML algorithms such as collaborative filtering, clustering, and decision trees, the system will analyze user data, historical fashion trends, and individual style profiles to generate accurate and relevant outfit suggestions. Deep Learning techniques, including convolutional neural networks (CNNs) and recurrent neural networks (RNNs), will be employed to extract intricate patterns from images, enabling the system to understand visual aesthetics and recommend visually appealing outfits.

Moreover, the project will explore the potential of reinforcement learning algorithms to optimize outfit recommendations over time based on user feedback and interactions. By continuously learning and adapting to user preferences, the system will enhance its recommendation capabilities and provide a more personalized and engaging experience for users.

***Index terms*- Outfit Recommender, Deep Learning, Machine Learning, Computer Vision.**

I. INTRODUCTION

In today's fast-paced world, the task of selecting the perfect outfit can often be overwhelming and time-consuming. The emergence of technology in the fashion industry has paved the way for innovative solutions to streamline this process and provide individuals with personalized outfit recommendations. One such solution is the Outfit Recommender system, a sophisticated platform that leverages advanced technologies like Machine Learning (ML), Deep Learning (DL), Computer Vision (CV) and various algorithms to revolutionize the way we approach fashion choices.

The Outfit Recommender system is designed to cater to the diverse needs and preferences of users, offering a seamless and tailored experience that transcends traditional fashion advice. By analyzing a multitude of factors, including user preferences, weather conditions, current trends, and individual style profiles, the system can generate outfit recommendations that align with the unique tastes and requirements of each user.

II. LITERATURE SURVEY

In recent years, with the advancement of technology and the rise of social media influencers, the fashion industry has seen a significant shift towards personalized outfit recommendations. This has paved the way for the development of outfit recommender systems, which utilize a combination of user preferences, stylistic guidelines, and machine learning algorithms to suggest fashion choices tailored to individual needs.

In this literature survey, we will explore existing research and implementations of outfit recommender systems, focusing on the methodologies, metrics, and user experiences associated with these systems. By analyzing the current landscape of outfit recommendation technology, we aim to identify key challenges and opportunities for further advancements in this field. Ultimately, our goal is to contribute to the development of more accurate and effective outfit recommender systems that enhance the shopping and styling experiences of users.

Sivaranjani et al. [1] focuses on the development of a fashion recommendation system using machine learning, specifically utilizing a Convolutional Neural Network (CNN) approach. The advantage of this system lies in its ability to provide personalized recommendations based on user preferences, improving the shopping experience for users. The use of CNN allows for efficient processing of large amounts of data and accurate recommendations. However, there are limitations to consider, such as the dependency on user data, which may affect the accuracy of recommendations for users with limited interactions. Additionally, the study acknowledges the limited dataset used, which may not fully capture the diversity of fashion items and styles. Despite these limitations, the paper introduces a promising approach to enhancing the fashion shopping experience through machine learning algorithms.

GUO et al. [2] explores the use of AI in fashion design, specifically in the areas of fashion detection, fashion synthesis, and fashion recommendation. In the field of fashion detection, AI models such as CNNs and R-CNNs have shown promise in accurately identifying fashion items in images and videos, aiding designers and retailers in analyzing trends and consumer preferences. However, challenges remain in detecting occluded or partially visible items, as well as fine-grained details. Fashion synthesis has seen advancements with the use of GANs and diffusion models, allowing designers to explore diverse design possibilities and generate realistic fashion items. Limitations include difficulty in controlling specific design

constraints and preserving semantic meaning. Fashion recommendation systems assist users in finding suitable products and creating complementary outfits, but face challenges in accurately capturing user preferences and recommending diverse items.

Divitiis et al. [3] delves into the fashion industry's reliance on recommendation systems in online stores, often leading to repetitive or non-diverse suggestions. The authors address this by proposing a Memory Augmented Neural Network (MANN) architecture, focusing on compatible garment recommendation by considering the co-occurrence of clothing attributes to compose outfits. The model aims to disentangle representations of fashion items and store them in external memory modules, ultimately improving recommendation performance compared to existing approaches. The model presents an approach based on the combination of color/shape feature disentanglement and the usage of external memory modules to store pairing modalities between top and bottom fashion items. The approach extends the common controller loss to train memory modules and addresses issues arising from uneven data distributions, obtaining compact and representative memories. While the model demonstrates success in achieving better performance and providing interpretable latent spaces, it faces challenges related to the convergence of certain model variants and the impact of dataset variability. These limitations underscore the need for robustness and generalizability in addressing diverse user preferences and dataset variations.

Guillermo et al. [4] proposes a content-based fashion recommender system that utilizes unsupervised learning techniques and a dataset called Fashion MNIST. The advantages of the system include its ability to handle large volumes of data, its scalability for real-world applications, and its elimination of the need for manual labeling of fashion items. However, the system's reliance on item attributes may limit its ability to capture personalized style preferences and nuanced user preferences. Additionally, the accuracy of recommendations heavily depends on the quality and richness of item attributes in the dataset and the system does not consider contextual factors or current fashion trends. The limitations of the system include its lack of collaborative filtering or other personalized approaches, its potential decline in relevance and accuracy over time without considering temporal factors, and its limited ability to handle unconventional fashion items with insufficient item attributes. Overall, the paper presents an automated and scalable solution for fashion recommendation but may benefit from further research to address these limitations and improve its accuracy and relevance.

Suvarna et al. [5] presents a comprehensive approach to fashion product recommendation using deep learning techniques, showcasing promising results and suggesting avenues for further research and improvement.The proposed deep CNN model excels in accuracy, leveraging robust feature extraction to provide precise fashion product recommendations. Its scalability and adaptability ensure effective performance in dynamic e-commerce environments, accommodating large datasets and evolving fashion trends with ease. However, the proposed deep CNN model may face limitations in interpretability due to the inherent complexity of deep learning models, potentially hindering understanding of the underlying decision-making process. Additionally, training deep CNNs requires significant computational resources and data, posing challenges in resource-constrained environments. The proposed model is compared with other existing models, demonstrating a substantial improvement in accuracy (from 66% to 89%). The results indicate that the proposed model performs well across various classes of fashion products, with some classes achieving over 90% precision and recall.

Iso et al. [6] aims to reflect an individual's preferred style by generating outfit images. The system employs techniques such as GAN architecture, deep learning for segmentation, and transfer learning with Inception-v3 for training. The advantages of the system include the ability to recommend the same outfit as different styles based on user preferences and the generation of outfit images that reflect individual styles. However, there are limitations to the accuracy of segmentation masks, limited representation of Japanese style fashion in the dataset, and the system's inability to generate certain combinations of pants and skirts. The data collection process may introduce bias and restrict the diversity of recommended styles. Overall, the evaluation experiment showed mixed results in accuracy, with some users feeling the recommended styles did not match their own preferences.

Gharaei et al. [7] explores a content-based clothing recommender system that utilizes a deep neural network (DNN) and convolutional neural network (CNN) techniques. The system offers several advantages, such as incorporating gender as a feature for recommendations, addressing the cold start problem, and demonstrating a low loss. It also leverages product gender directly, without relying on image retrieval. Moreover, the system achieves a high speed of recommendation due to its simplicity. However, the disadvantages of this approach include low accuracy and relying on only two features for recommendations. The precision of the system is reported to be 73.7%, and the average time for recommendation is 0.07%. The dataset used for this study is a subset of the Fashion Product Images dataset, consisting of 14,932 samples out of a total of 44,000.

Koshy et al. [8] introduces "Pocket Fashionista" as a personalized fashion advisor system that offers outfit and color recommendations based on the user's complexion. It incorporates various modules such as skin tone detection, outfit color recommendations, similar outfit suggestions, weather-based recommendations, and virtual trial rooms. The system aims to enhance the user experience by providing tailored fashion guidance and real-time demand satisfaction for E-commerce platforms.To extract skin tone from a given image three different color spaces(RGB, HSV, YCbR) were used.Algorithms such as the Approximate Nearest Neighbors algorithm is used for generating similar clothing recommendations and K-Means Clustering Algorithm has been used to cluster the user’s skin tone. The HoughCircles method is used for estimating the size of the clothes.Further advancements can be made by adding accessories features to complete the entire outfit. Also integrating more features such as body posture, and event type can be used to give accurate suggestions. Overall, the paper highlights the importance of personalized fashion advice and the role of technology in revolutionizing the shopping experience.

Turkut et al. [9] proposes an online recommendation system for textile products using deep learning, specifically a Convolutional Neural Network (CNN). The system focuses on color compatibility and utilizes patterns as a basis for recommendations. The advantages of the proposed approach include its successful application in various fields, its personalized recommendations based on user preferences captured through an online survey, and its reasonable accuracy of 82.08%. However, limitations of the system include its narrow focus on color compatibility and patterns, the lack of comparison with other recommendation methods, and the absence of information about computational resources and

potential limitations or challenges. Overall, the paper provides valuable insights into leveraging deep learning for the recommendation of textile products, but further research is needed to address the identified limitations.

Hsiao et al. [10] presents a novel approach to clothing recommendation systems by considering five different female body types, outperforming traditional systems. Its strengths lie in its inclusivity and personalized recommendations, thanks to the model's ability to capture clothing affinity with diverse body shapes. Utilizing a unique dataset from an online shopping website adds realism to the training process. The explanation method enhances user trust by providing transparency in recommendations. However, limitations include a bias towards prevalent body shapes in the fashion industry due to online catalog data reliance and potential subjectivity in human judgment evaluations. The model's adaptability to new clothing styles and generalization to broader demographics may be hindered, as it primarily relies on visual features and learned attributes.

Hashmi et al. [11] presents a groundbreaking approach to virtual try-on technology by integrating 3D pose mapping and Neural Body Fit for custom outfit simulations. The model's use of cutting-edge technologies like GANs and NBF ensures high accuracy levels and enables the custom generation of clothing outfits through AI. This paper fills a crucial gap in the fashion industry by allowing users to virtually try on custom-selected garments on custom-chosen human models, setting a new benchmark for virtual try-on applications. However, the computational complexity of the model and its limitations in terms of dataset availability and coverage of clothing items could hinder its scalability and generalizability. Additionally, the reliance on existing datasets like DeepFashion2 and potential challenges with accuracy levels when validating with GANs generated outfits are important considerations for future research in this area.

Hidayati et al. [12] details a novel framework for learning style rules for different body types using fashion-related knowledge from social big data. By examining fashion knowledge rules, including those of stylish celebrities and recommended clothing styles for various body types, a joint embedding of clothing styles and body measurements is constructed. This approach leverages auxiliary styles to enhance fashion recommendations by propagating and selecting informative features from clothing and body measurement clusters. The methodology involves the creation of a body style map, a body shape calculator, and a benchmark dataset for style recommendation tasks. The study showcases examples of visual style and body shape clusters and the propagation and selection of informative semantic features across these clusters. Three primary datasets are utilized, including Style4BodyShape, DeepFashion, and StyleReference. The Style4BodyShape dataset comprises body measurements and images of stylish celebrities, while DeepFashion provides clothing category and location annotations. The novel addition of the StyleReference dataset enables assessment of the level of stylish sophistication, thus enhancing the compatibility between clothing styles and body shapes for comprehensive analysis. The models collectively aid in understanding, learning, and representing the detailed semantics of fashion concepts, contributing to the development of personalized style suggestions based on body shapes and clothing styles. However, the model is trained exclusively on datasets containing images of female clothes constitutes a limitation of the model.

A literature review is an objective, critical summary of published research literature relevant to a topic under consideration for research. The summary is presented here.

Table 1 Summary of literature survey

Paper Name	Observation
Fashion Recommendation System Using Machine Learning. Published By: 2023 4th International Conference on Smart Electronics and Communication (ICOSEC) [1]	Advantage: Using CNN, KNN, and RESNET50, the system is able to provide five recommendations based on the input image provided by the user. Disadvantage: The paper mentions that a larger and more diverse dataset is usually preferable for training models that are more accurate and generalizable to new data. The dataset used in the study may not fully capture the diversity of fashion items and styles.
AI Assisted Fashion Design: A Review. Published By: IEEE Access [2]	Advantage: Improved detection models enhance productivity for designers by reducing manual identification. Fashion parsing provides personalized styling, trend analysis, and fashion recommendations. Item retrieval incorporates personalized recommendations for efficient searching. Image-guided and sketch-guided synthesis models provide valuable guidance and inspiration to fashion designers. They enable the generation of realistic and diverse fashion items, expanding design possibilities. GANs and diffusion models revolutionize image style transfer. Task-based and input-based recommender systems assist users in finding suitable fashion items. They help create complementary outfits and offer personalized recommendations for different scenarios. Disadvantage: Fashion parsing may face challenges under unconstrained conditions with limited tags and annotations. Item retrieval methods require extensive training and optimization. Image-guided synthesis models may result in less satisfactory results when the input image texture is not prominent. Randomness in diffusion models can lead to suboptimal results. Some models may have limitations in pattern design capabilities. Fashion recommendation systems heavily rely on image recognition and metadata, which can be limited or inaccurate. Data bias can affect diversity and accuracy. User privacy and data security are concerns.
Disentangling Features for Fashion Recommendation. Published By: ACM Transactions on Multimedia	Advantage: The model can be easily adapted to both garment recommendation and outfit compatibility estimation tasks, allowing for versatile application in the fashion domain. By utilizing separate color and shape data augmentations during training, the model effectively learns disentangled features, contributing to the interpretability of its recommendations.

Computing, Communications, and Applications [3]	The proposal of an improved memory module with an adaptive controller and separate memory banks enhances the model's ability to identify pairing models for different attributes, such as shape and color. Disadvantage: The model's shape-based variant exhibited varying performance across datasets, indicating potential challenges in handling dataset variability, particularly with complex datasets. The 'Ours NoPenalty' variant faced convergence issues, highlighting limitations in the model's flexibility in certain training and the need for a more sophisticated loss function formulation.
Content-based Fashion Recommender System Using Unsupervised Learning. Published By: TENCON 2021 - 2021 IEEE Region 10 Conference (TENCON) [4]	Advantage: Focuses on the reconstruction of the input image which is used as output for the recommendation in 11 different types of classes. Disadvantage: Is not implemented using an actual e-commerce website and considers only the similarity of the product for reconstruction and recommendation.
An Efficient Fashion Recommendation System using a Deep CNN Model. Published By: 2022 the International Conference on Automation, Computing and Renewable Systems (ICACRS) [5]	Advantage: The proposed deep CNN model excels in accuracy, leveraging robust feature extraction to provide precise fashion product recommendations. Its scalability and adaptability ensure effective performance in dynamic e-commerce environments, accommodating large datasets and evolving fashion trends with ease. Disadvantage: The deep CNN model's lack of interpretability poses challenges in understanding its decision-making process, while its resource-intensive training requirements and data dependency may limit accessibility and introduce biases. Overcoming these limitations necessitates efforts to enhance interpretability, optimize resource utilization, and address data biases.
Fashion Recommendation System Reflecting Individual's Preferred Style. Published By: 2021 IEEE 10th Global Conference on Consumer Electronics (GCCE) [6]	Advantage: The fashion recommendation system can tailor the same outfit to different users based on their individual style preferences, providing personalized recommendations. By moderating the input outfit, the system can adjust the color, texture, and other factors to better suit the style preferences of users, enhancing customization. Disadvantage: The reliance on biased data, such as popular outfits and stereotype influence, may limit the diversity and inclusivity of the recommended styles, potentially perpetuating existing fashion biases. The accuracy of segmentation masks could be affected if the background is not removed.
Content-based Clothing Recommender System using Deep Neural Network. Published By: 2021 26th International Computer Conference, Computer Society of Iran (CSICC) [7]	Advantage: This paper proposes a content-based clothing recommender system that utilizes gender as a feature, effectively addressing the cold start problem and achieving low loss. Additionally, the system demonstrates high speed of recommendation due to its simplicity, as it uses product gender instead of retrieving gender from an image. Disadvantage: However, it is worth noting that the system exhibits a lower accuracy, potentially hindering its ability to provide highly precise recommendations. Furthermore, the system relies on only two features as the basis for its recommendations, limiting the depth and breadth of its recommendations.
A Complexion based Outfit color recommender using Neural Networks. Published By: 2021 International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT) [8]	Advantages: This system offers several advantages for users and E-commerce sites. Users can virtually try on suggested outfits, enhancing their shopping experience by visualizing how the outfits look on their body. The system provides weather-based seasonal recommendations, ensuring real-time customer demand is met. Additionally, it accurately recommends outfit colors based on skin tone, utilizing advanced techniques like skin segmentation and classification. Finally, the system employs the Cosine Similarity method to suggest similar kinds of outfits, making it a valuable tool for both users and E-commerce platforms.Image Warping technique is used for fitting the outfit on a 2D or 3D image.Size of clothes are estimated using HoughCircles method. Disadvantages:Outfits are categorized into 46 different types and thereby cannot capture each one of them perfectly.Other parameters like posture, hairstyle, and facial features are not considered. Resnet 18 a simple model was trained. More complex models can be used by adding more layers. It does not currently integrate accessory recommendations.
An Online Recommendation System Using Deep Learning for Textile Products. Published By: 2020 International Congress on Human-Computer Interaction, Optimization, and Robotic Applications (HORA) [9]	Advantage: The system focuses on color compatibility for textile products, which can be a valuable feature for customers who want to match their existing products. The proposed approach achieves an overall accuracy of 82.08%, indicating that it can provide reliable recommendations. Disadvantage: The system relies on patterns as the main criteria for recommendations, without considering other factors such as price, brand, or customer reviews, which could limit the relevance of the recommendations. The paper does not compare the proposed CNN-based approach with other recommendation system methods, such as collaborative filtering or content-based methods, to demonstrate its superiority.
ViBE: Dressing for Diverse	Advantages: Consideration of diverse body shapes, offering a more inclusive and personalized clothing recommendation system. Providing tailored clothing

Body Shapes. Published By: 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) [10]	suggestions based on individual body types, enhancing the user experience and satisfaction. Disadvantages: Firstly, the exclusion of male body types in the recommendation system restricts its applicability to only female users, limiting its potential impact on a wider audience. Additionally, the emphasis on recommending full-body clothing items over specific body part items may overlook the diverse preferences and needs of individuals with varying body shapes. Furthermore, the reliance on online catalog data may introduce biases towards certain body shapes that are prevalent in the fashion industry, potentially reinforcing existing stereotypes and norms. The subjectivity and variability of human judgment evaluations also raise concerns about the reliability and consistency of the model's recommendations. Lastly, the model's dependence on learned features and attributes may hinder its adaptability to novel or unseen clothing styles, limiting its effectiveness in capturing the evolving fashion landscape. These limitations highlight the need for further research and improvement in developing more inclusive and diverse body shape recommendation systems.
FashionFit: Analysis of Mapping 3D Pose and Neural Body Fit for Custom Virtual Try-On. Published By: IEEE Access [11]	Advantages: Presents a pioneering approach to virtual try-on systems, offering a novel and explicit model for implanting visual compatibility through fashion image inpainting and virtual try-on. Leveraging cutting-edge technologies such as Generative Adversarial Networks (GANs) and Neural Body Fit, the model achieves high accuracy levels, marking a significant advancement in the field. By enabling virtual try-on for custom-selected garments on specific individuals, the paper effectively addresses a critical gap in existing fashion designs and platforms, promising a more personalized and inclusive virtual shopping experience. Furthermore, the system's ability to disentangle the custom generation of clothing outfits using AI sets a new standard for the industry, showcasing the potential for revolutionizing virtual fashion try-on experiences. Disadvantages: Firstly, the heavyweight model used in this study can be computationally complex, potentially slowing down the processing time and requiring high computational resources. Secondly, the model is limited to classes present in the DeepFashion2 dataset, restricting the variety and selection of clothing items that can be virtually tried on. Additionally, the limited availability of certain garments in the dataset may result in a lack of coverage for all possible clothing items, limiting the applicability of the model in real-world scenarios. Moreover, the accuracy levels may be lower when validating with GANs generated outfits, indicating potential challenges in generalizing the model to new and unseen data.
Dress With Style: Learning Style From Joint Deep Embedding of Clothing Styles and Body Shapes. Published By: IEEE TRANSACTIONS ON MULTIMEDIA [12]	Advantage: The model offers personalized style recommendations based on individual body shapes and clothing preferences, catering to diverse fashion needs. By leveraging deep multimodal representation learning, the model potentially improves the user experience through tailored fashion suggestions. The use of joint deep embedding of clothing styles and body shapes demonstrates innovative approaches in fashion technology that may pave the way for more advanced recommendation systems. Disadvantage: The model's training on datasets predominantly featuring female clothing images may limit its applicability to male, or gender-neutral fashion contexts. Potential biases or limitations in the model's recommendations may impact user perception and satisfaction, particularly for those outside the scope of the model's training data.

III. PROPOSED SYSTEM

The Outfit Recommender System is designed to provide users with personalized outfit suggestions based on their preferences, style, and the occasion. This system aims to simplify the process of selecting an outfit by leveraging machine learning algorithms to analyze user input and recommend suitable clothing combinations. By incorporating user feedback and continuously learning from user interactions, the system will refine its recommendations over time, ensuring a more tailored and accurate outfit selection for each user.

Existing System Architecture

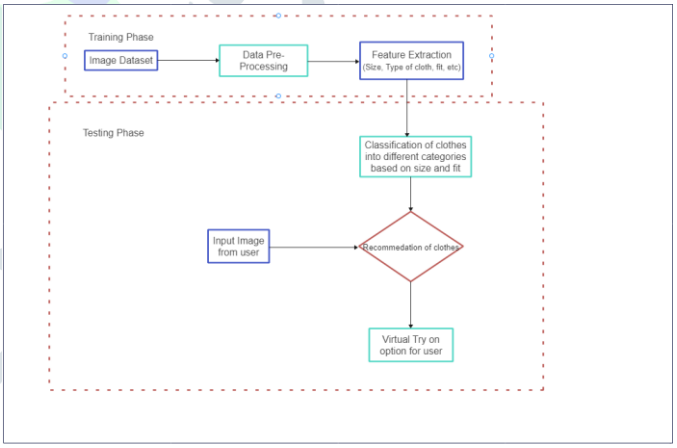

Figure 1 Existing system architecture [10]

The existing system [10] does the feature extraction using ResNet-50 for clothing images and 3D body estimation for body shapes. Based on the extracted feature the system classifies the clothes into five categories based on the body type of the fashion models using CNN. The fashion model only consists of adult female models and no male models or models of different demographics. The clothes are also classified according to two categories i.e full body clothes and specific body cloth. Upon user input which is an image of the user, the system recommends the clothes which are suitable for their body type. The recommendation of specific body cloth has low accuracy hence it is not further used by the system and the system is able to recommend full body clothes with a mean AUC of 0.611. The user is also given an option to try on the recommended cloth in a virtual environment.

Proposed System Architecture

The proposed system consists of the following elements:
Dataset: The proposed system consists of various datasets such as dataset for skin complexion, dataset for body type, dataset for clothes and so on. The system uses the DeepFashion dataset.
Feature Extraction: The features are extracted from the datasets as well as the input image and text from the user.
Classification of Clothes: The clothes are classified according to body type, fit, occasion and similar characteristics.
Feature Database: The feature database contains the features that were extracted from the dataset. The database contains a list of features extracted from images and texts.
Query Features: The query features are derived from the features input query and preserved. Color, shape, texture, and keywords are the extracted features.
Similarity Measurement: Query image features are compared with dataset features. A set of relevant images is retrieved then arranged in descending order of similarity.
Virtual Try-On: The virtual environment for users to try different recommended clothes on themselves.

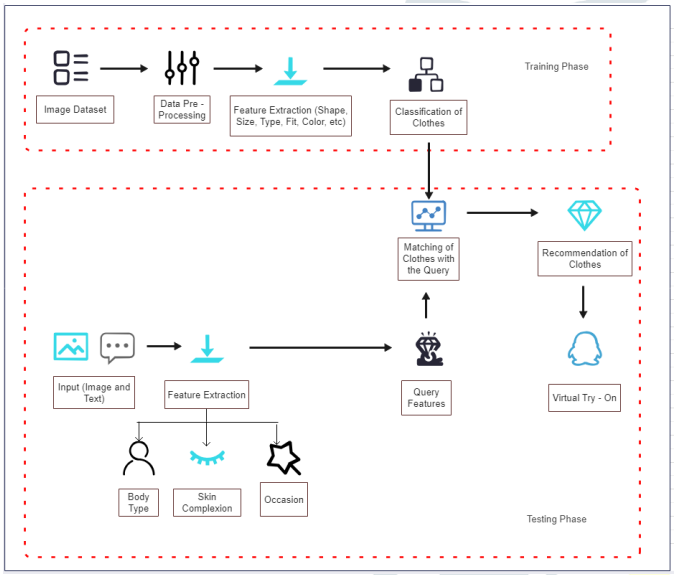

Figure 2 Proposed system architecture

Dataset

Table 2 Dataset Details

Dataset Used	No. of Images	Types of Images	No. of Categories
DeepFashion	800,000	Dresses, shirts, pants, shoes, etc.	50

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