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Enhancing Fashion Image Generation with GAN

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Abstract*—In this systematic review, we conducted a thorough examination of existing research concerning generative adversarial networks (GANs), focusing on their application in the fashion domain. Through the utilization of the Scopus database, a total of 933 publications pertaining to the use of GANs in fashion from 2017 to 2023 were identified. Ultimately, 22 relevant records were selected and examined based on the GANs' topologies, losses, inputs, and outputs. These findings formed the foundation for investigating the unique aspects of GAN methodology within the realm of fashion. Given the vast scope of fashion, a wide range of recognized methodologies have been adapted for this field. However, no approach has demonstrated clear superiority in the context of fashion. By conducting a comprehensive analysis of the literature, we identify the advancements, challenges, and research gaps in the field. Additionally, we propose potential directions for future investigations, aiming to inspire researchers to explore new horizons and drive innovation in this rapidly evolving domain.

***Keywords*— Vanilla GAN, fashion, adversarial networks**

I. Introduction

The fashion industry has witnessed a significant impact from Generative Adversarial Networks (GANs) in recent years. GANs offer unique capabilities for generating realistic and novel fashion designs, assisting in tasks such as fashion synthesis, style transfer, and virtual try-on. This manuscript presents an overview of the future potentials of GANs in the fashion domain, highlighting the advancements and opportunities for further research.

Generative Adversarial Networks (GANs) are a type of machine learning algorithm that can generate new data that looks like the data used to train the model. GANs have demonstrated their potential in automating the fashion design process by generating novel and visually appealing designs. Notable works by Ma et al. [1], Zeng et al. [2], and Liu et al. [3] showcase the application of GANs for fashion design synthesis, enabling designers to explore a vast design space and inspire creativity. The integration of GANs with augmented reality (AR) technologies has facilitated virtual try-on experiences, where users can virtually wear and visualize clothing items. GAN-based virtual try-on systems developed by Han et al. [4], Ma et al. [5], and Wang et al. [6] offer realistic and immersive try-on experiences, bridging the gap between online shopping and in-store trials. GANs have been by Li et al. [7], Zhu et al. [8], and Huang et al. [9] demonstrates the potential of GANs for personalized fashion style transfer, enabling users to customize garments and experiment with different fashion aesthetics.

GANs have shown remarkable ability in producing high-quality images in various fields, including fashion. However, to generate high-quality images, GANs require large and diverse training data. Therefore, it is crucial to have an effective way to extract relevant features from the training data to use in GAN model creation. In the fashion industry, companies often have a large and diverse product catalog. To generate high-quality fashion images using GANs, it is important to be able to extract the distinctive features of different fashion products. These features can include color, texture, shape, and pattern found in fashion products.

This research conducts a comprehensive analysis of the literature to identify the advancements, challenges, and research gaps in the field. Additionally, we propose potential directions for future investigations, aiming to inspire researchers to explore new horizons and drive innovation in this rapidly evolving domain.

II. Literature Review

Thomas et. al [10], explore the potential for personalized recommendations and style transfer, which can enhance the customer experience and increase sales. Mameli et. al., [11] highlights the potential of deep learning techniques in fashion knowledge extraction from social media and provides a valuable resource for researchers and practitioners in this field. Spatially Constrained GAN (SC- GAN) is applied in fashion image synthesis [12]. Unlike previous GANs, SC-GAN imposes spatial constraints on the generated images to ensure that they are not only realistic but also semantically meaningful. The proposed framework was evaluated on two datasets: a facial image dataset and a fashion image dataset. The experimentalresults show that SC-GAN outperforms several state-of-the-art methods in terms of visual quality, diversity, and realism. Overall, SC-GAN is a promising approach for face and fashion image synthesis that can be useful in various applications, such as virtual try-on systems and fashion design.

Multi-Task Generative Adversarial Network (MT-GAN) training technique presents a new approach to boost the performance of fashion image attributes classification using a [13]. Existing methods for fashion image classification often suffer from the limitation of insufficient data and high variance, leading to poor classification accuracy. To address this challenge, the authors propose an MT-GAN model that jointly trains a generator network for image generation and a classifier network for attribute classification. The generator network is designed to learn the underlying data distribution of the training dataset and generate new images with diverse attributes. The classifier network is trained to classify the generated images and the real images. The proposed MT-GAN model can jointly learn the representation of image features and attributes, leading to improved classification performance. The experiments show that the proposed approach outperforms the state-of-the-art methods in terms of classification accuracy, demonstrating its effectiveness for fashion image attributes classification.

Overall, this study provides a promising direction for leveraging the power of GANs in improving the accuracy of fashion image classification and has practical applications in the fashion industry, such as product recommendation and personalization.

COutfitGAN synthesizes compatible outfits from a given set of input garments based on silhouette masks and fashion styles [14]. The proposed model utilizes a combination of two generative adversarial networks (GANs), one for generating the outfit and the other for determining the fashion styles of the input garments. Specifically, the silhouette masks are used to guide the generation of the outfit, while the fashion styles are learned from a pre-trained style classification network. The proposed method is evaluated on two datasets, and the results show that the generated outfits are visually appealing and diverse, and the fashion styles are accurately captured. Moreover, a user study is conducted to evaluate the compatibility of the generated outfits, and the results demonstrate that the proposed approach outperforms several state-of-the-art methods in terms of both visual quality and compatibility. The paper also discusses the limitations of the proposed approach, including the need for more diverse datasets and the potential biases in the style classification network.

cPoly-GAN framework synthesizes fashion items with different styles, colors, and patterns. The model was trained on a large-scale fashion dataset consisting of images with various styles and attributes [15]. cPoly-GAN model consists of two major components: a generator network and a discriminator network. The generator network is designed to generate high-quality fashion images by conditioning on the style, color, and pattern information. Meanwhile, the discriminator network is responsible for distinguishing between real and fake fashion images. The cPoly-GAN model was evaluated using different metrics, including Fréchet Inception Distance (FID) and Structural Similarity Index (SSIM), and it outperformed other state-of-the-art models. The results showed that cPoly-GAN generated high-quality images that are visually appealing to users. The proposed framework has significant potential applications in the fashion industry, such as virtual try-on and personalized fashion design.

StyleGAN is a method for generating and modifying high-resolution fashion model images using, a state-of-the- art generative model [16]. The authors proposed a pipeline that includes data collection and preprocessing, training StyleGAN on the fashion model images, and modifying the generated images using latent code manipulation. The dataset used in the study consists of over 18,000 fashion model images collected from online fashion retailers. The study showed that the latent space of StyleGAN can be manipulated to modify the generated images in various ways, including changing the pose and clothing of the model. The performance of the proposed method is evaluated using objective metrics and user studies. The results showed that the generated images are visually appealing and realistic, and the proposed method outperforms existing methods in terms of diversity and realism.

FitGAN generates realistic 3D human models that accurately fit and represent different body shapes, sizes, and poses [17]. FitGAN incorporates two major components: a shape generator that generates body shapes and sizes and a texture generator that generates high-resolution textures. The shape generator consists of two stages: a conditional generator that synthesizes a 3D point cloud given a specific body shape and a decoder that generates a mesh representation of the 3D point cloud. The texture generator synthesizes high-resolution textures that correspond to the generated mesh representation. The generated models can be used for a wide range of applications, including virtual try-on, virtual fashion design, and personalized clothing recommendations. The effectiveness of the proposed method is demonstrated through extensive experiments, which show that FitGAN outperforms existing state-of-the- art methods in terms of both visual quality and quantitative metrics.

OutfitGAN [18] is a generative fashion outfit model that generates a complete outfit by learning the compatibility of fashion items, using a GAN-based architecture. The study aims to generate outfits that match a given fashion style, while also taking into account the compatibility of the items and the variations in clothing attributes. They introduce a new evaluation metric, Fashion Compatibility Index (FCI), to measure the compatibility of the generated outfits. The proposed OutfitGAN model consists of a generator that takes as input the style code and generates an outfit, and a discriminator that evaluates the quality and compatibility of the generated outfit. The model is trained on a large dataset of fashion images, and the results show that it outperforms state-of-the-art methods in terms of FCI and visual quality. The authors also perform an ablation study to investigate the impact of different components of the model on the overall performance. The proposed OutfitGAN model has the potential to be used in various applications such as virtual try-on, personalized styling, and e-commerce.

Jiang et. al. [19] introduces two frameworks namely FashionG for creating single styles and SC-FashionG for creating mix-and-match styles. Both frameworks use an end-to-end feedforward neural network consisting of generators for image transformations and discriminators for sustaining content and styles globally and locally. An optimization methodology alternating between patch- globals was also developed to minimize losses. Compared to FashionG, SC-FashionG uses additional spatial constraints to ensure each style is blended only in certain areas of the clothing image. Extensive experimentation demonstrated the effectiveness of both single and mix-and- match style creation.

ClothGAN which is based on a generative adversarial network (GAN) and style transfer algorithm is implemented to create new clothing designs, especially in the context of traditional culture, such as the ancient Chinese Dunhuang clothing culture [20]. In addition, Wu et. al. built a Dunhuang clothing dataset and conducted experiments to generate new clothing patterns and styles with Dunhuang elements. The study evaluates the works of clothing produced from different models by calculating the inception score (IS), human prefer score (HPS), and generated score (IS and HPS).

StyleTrendGAN, combines Dense Extreme Inception Network (DexiNed) for sketches extraction and Pix2Pix for transforming sketches into new handbag models [21]. StyleTrendGAN is designed to increase efficiency and accuracy in creating new fashion models compared to previous methods and human approaches. It aims to stimulate designers' creativity and visualize production

results without actually producing them. The framework was tested on a newly collected dataset called "MADAME" (iMage fAshion Dataset sociAl MEdia) containing images collected from Instagram. The experiments showed high accuracy, demonstrating the effectiveness and suitability of the proposed approach.

GarmentGAN performs image-based garment transfer using generative adversarial methods [22]. GarmentGAN can be used for virtual try-on of clothes before purchase and works for various types of apparel. The algorithm requires only two input images, a picture of the target fashion item and an image of the customer. The output is a synthetic image of the customer wearing the target apparel. The authors employ novel generative adversarial techniques to make the generated image look realistic. The proposed model also incorporates segmentation maps and body key- point information during training to improve the realism of generated imagery and solve problems related to self- occlusions. The authors provide qualitative and quantitative comparisons to several other networks to demonstrate the effectiveness of the proposed technique.

FAR-GAN allows for explicit control of color that uses a two-step encoding process to extract style information from the fashion apparel and its edge-map, which is then controlled with the target color embedding information in the decoder [23]. To control the color of the synthesized apparel image, the authors propose a color consistency loss. The network can be trained end-to-end without incorporating complex sub-units, making it easy to use. The authors conducted extensive experiments and ablation studies to demonstrate the performance of their model compared to several state-of-the-art methodologies. The results show an improvement in performance and justify the design choices made in the proposed approach.

Yang et. al. [24] proposes an emotionally intelligent design method that matches consumers' emotional needs with the design of fashion goods. The method uses modified convolutional neural network (CNN) and generative adversarial network (GAN) models to classify and generate product images that satisfy consumers' emotional needs. The method consists of two parts: a product image recognition model that calculates the loss function based on the product image score and an intelligent design generation model that combines the network architectures of DCGAN and Conditional GAN. The experimental results show that the proposed method performs well in generating fashion goods that satisfy consumers' emotional needs.

Arul et. al. [25] provides a review of the literature on fashion recommender systems that utilize deep learning techniques. The authors discuss the importance of personalized recommendations in the fashion industry and how deep learning methods can be used to improve the accuracy of such recommendations. The paper examines various deep learning techniques used in fashion recommendation systems, including Convolutional Neural Networks (CNN), Autoencoder, and Recurrent Neural Networks (RNN). The authors also discuss the challenges faced by fashion recommendation systems and propose future directions for research in the field. The review includes a detailed analysis of various research papers in the field, highlighting the strengths and weaknesses of different approaches. Overall, the paper provides a comprehensive overview of the current state of research in fashion recommender systems using deep learning techniques.

Sohn et. al. [26] focuses on examining the consumer responses to Generative Adversarial Network (GAN) technology in the fashion industry. The study uses an online survey to collect data from participants on their attitudes towards GAN technology and its impact on their purchasing behavior. The authors also review the existing literature on the use of AI in the fashion industry and discuss the potential benefits and challenges of using GAN technology. The results of the study indicate that consumers generally have a positive attitude towards GAN-generated images, but there are concerns about the accuracy and authenticity of the images. The authors conclude that while GAN technology has the potential to revolutionize the fashion industry, companies must be transparent about its use and address consumers' concerns to ensure its success.

SketchFashion is a method for image translation from fashion sketches using Generative Adversarial Networks (GAN) [27]. The proposed method aims to generate realistic images of clothing items from hand-drawn sketches, which can help designers in the fashion industry to rapidly prototype and visualize new designs. The method involves pre-processing of the sketches to extract relevant features and then using a GAN-based approach to generate corresponding images. The paper evaluates the effectiveness of the proposed approach through a series of experiments and comparisons with other state-of-the-art image translation methods. The results indicate that the SketchFashion method can generate high-quality images that are both visually appealing and semantically meaningful. The authors conclude that the proposed approach has significant potential for practical applications in the fashion industry.

Jo et.al. [28] presents a deep learning-based fashion product retrieval and recommendation model. The proposed model employs a convolutional neural network (CNN) to extract features from product images and a recurrent neural network (RNN) to capture the sequential order of user behavior data. The user behavior data includes the user's click and purchase history, as well as their search queries. The model combines these features to generate recommendations for the user. The paper also introduces a new dataset of fashion product images and user behavior data collected from an e-commerce website. The proposed model is compared to several state-of-the-art methods using this dataset, and the experimental results show that the proposed model outperforms the other methods in terms of retrieval and recommendation accuracy..

III. METHOD

Previous researches between the years of 2017 and 2023 on the topic of GAN in fashion areas were included in this study. The search in Scopus Database was conducted using the following query: ("apparel design" OR "fashion image" OR "apparel image" OR "fashion" OR "clothing" OR "apparel") AND ("adversarial networks" OR "multi modal" OR "single modal" OR "style transfer" OR "style generation" OR "image-to-image-translation" OR "style synthesis" OR "image synthesis"). The search produced 933 results. In the preliminary screening process 466 of the reported studies must be discarded due to unrelated topics (e. g. humans, gallium nitride, human interactions) and unrelated domains (physics, health science). After undergoing second and third screening process there are 23 publications remained for further review to identify the techniques, data sources and evaluation metrics used in the

related publications. In this study, a thorough examination of the available literature was undertaken to conduct a comprehensive analysis. Through this analysis, we were able to identify the progress made, challenges faced, and areas where further research is needed within the field. Moreover, we put forth potential directions for future investigations, with the aim of stimulating researchers to delve into unexplored avenues and foster innovation in this dynamic and rapidly changing domain.

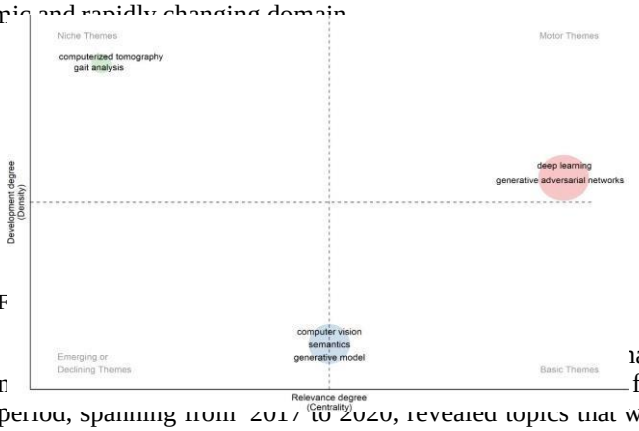
IV. Result and Conclusion

A. Result

Advancing GAN architectures to generate clothing items with enhanced realism and finer details remains a critical research area. Exploring techniques such as progressive growing GANs, attention mechanisms, and high-resolution datasets can significantly improve the fidelity of generated fashion designs. Developing GAN models that can achieve high-quality results with limited training data or adapt quickly to new fashion trends presents an exciting research direction. Few-shot learning techniques, domain adaptation, and transfer learning strategies can address the challenge of data scarcity and improve the usability of GANs in real- world fashion applications. Enabling fine-grained control and manipulation of fashion attributes within GAN frameworks is crucial for personalized fashion experiences. Research should focus on developing GAN models that allow users to modify specific attributes such as color, pattern, texture, and fit, enhancing the versatility and interactivity of virtual fashion try-on systems.

In Thematic map analysis, there are various groups that can be used to understand and evaluate research results. One of them is a thematic map consisting of four quadrants: Niche Themes, Emerging or Declining Themes, Motor Themes, and Basic Themes. In the Motor Themes quadrant, there is a group labeled generative adversarial networks and deep learning that is relevant to this study about Potential Researches of GAN in Fashion Areas. This means that this study discussed the latest innovations that tend to develop rapidly and brings significant impact. Additionally, this study also discussed the basics of GAN implementation because, as seen in the bibliometrics, the adversarial networks and deep learning group slightly lean towards Basic Themes.

Research on GAN for the fashion industry has somewhat unstable popularity because the computerized tomography and gait analysis group leads to Niche Themes, meanwhile computer vision, semantic and generative model group leads to Emerging or Declining Themes. This can be interpreted that GAN for fashion may quickly become popular at one time but also quickly fade. Therefore, although the adversarial networks and deep learning group is in the Motor Themes quadrant, the position of GAN in fashion areas can change in the future. In the context of this research, it is important to understand the difference in focus between Motor Themes and Basic Themes. In the Motor Themes group, this research highlights things that are trending and developing rapidly. Meanwhile, in the Basic Themes group, this research highlights the foundational theories and concepts of the field of study. Both groups have almost the same size and are widely discussed by researchers. However, understanding the difference in focus between them is still important in the context of GAN in the fashion industry.



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first period, spanning from 2017 to 2020, revealed topics that were frequently explored by researchers during that time. In contrast, the second period, encompassing 2021 to 2023, highlighted research topics that gained prominence in recent years, suggesting shifts or advancements in frequently published areas of interest. Within the first period, there were nine topics of discussion that primarily focused on the pre-existing trends related to GANs. Conversely, in the second period, the discussions centered around current trends in GANs, with two main focal points: deep learning and generative adversarial networks.

Interestingly, the initial three topics, namely adversarial networks, image enhancement, and gait analysis, underwent a transformation and evolved into two distinct lines of research: deep learning and generative adversarial networks, during the second period. This indicates the progression and development of these three topics over time, highlighting a shift in focus. The evolution of these topics suggests an increasing number of research publications, as researchers strive to gain a deeper understanding and conduct more comprehensive analyses. These efforts aim to enhance the quality and effectiveness of research outcomes. Overall, the temporal development observed in these topics signifies an expansion of research endeavors, driven by researchers seeking to explore and analyze these areas in greater depth. This ongoing exploration and analysis are expected to contribute to the generation of more optimized and impactful research outputs.

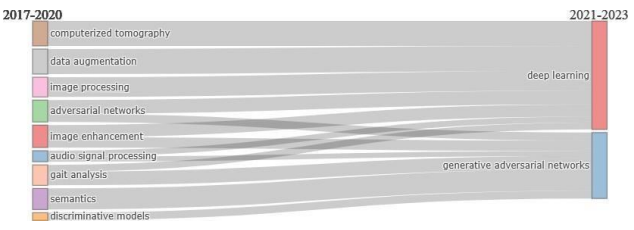

Fig. 2. Thematic Evolution

B. Conclusion

Based on the results of the analysis using thematic maps and thematic evolution from this study it can be concluded that the topic of Generative Adversarial Networks (GAN)

has become a promising method in field of fashion at this time as well as near future. In the thematic map, the GAN theme is the center of attention with currently trending topics, namely deep learning. Furthermore, according to the thematic evolution, in recent years there has been a development of topics that are increasingly specific and focused on deep learning and GAN. Expanding the application of GANs to fashion accessories (e.g., handbags, shoes, jewelry) and textile design opens new opportunities for creative expression. Future investigations should explore generative models tailored to these specific domains, enabling designers to generate innovative and unique accessory designs and textile patterns. Integrating GANs with sustainability efforts in the fashion industry can support the development of circular fashion practices. Future research should explore GAN-based methods for upcycling, reimagining garment designs, and reducing waste in the fashion supply chain. As GANs play a significant role in shaping fashion trends and styles, addressing ethical concerns, such as bias and inclusivity, is crucial. Research should focus on developing fairness-aware GAN frameworks, promoting diversity in generated fashion designs, and ensuring responsible and ethical usage of GAN-generated content. Generative Adversarial Networks (GANs) hold immense potential for revolutionizing the fashion industry. By exploring advancements, research gaps, and proposing future directions, we aim to inspire researchers to further explore the capabilities of GANs in fashion and drive innovation in this exciting field.

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