Journal of Artificial Intelligence and Capsule Networks (ISSN: 2582-2012)
www.irojournals.com/aicn/

Smart Fashion: A Review of AI Applications in Virtual Try-On & Fashion Synthesis

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Abstract

The rapid progress of computer vision, machine learning, and artificial intelligence combined with the current growing urge for online shopping systems opened an excellent opportunity for the fashion industry. As a result, many studies worldwide are dedicated to modern fashion-related applications such as virtual try-on and fashion synthesis. However, the accelerated evolution speed of the field makes it hard to track these many research branches in a structured framework. This paper presents an overview of the matter, categorizing 110 relevant articles into multiple sub-categories and varieties of these tasks. An easy-to-use yet informative tabular format is used for this purpose. Such hierarchical application-based multi-label classification of studies increases the visibility of current research, promotes the field, provides research directions, and facilitates access to related studies.

Keywords: Smart Fashion, Virtual Try-on, Fashion Synthesis, 3D Modeling.

1. Introduction

Online apparel shopping has been growing at a surprising speed in recent years. Especially regarding the current situation with the Coronavirus, people worldwide has begun to see the potential in the fashion e-commerce industry, an evolving industry that has witnessed considerable progress but is still far from perfect. This is where science comes to assist in the form of Computer Vision (CV), Machine Learning (ML), and Artificial Intelligence (AI). These advanced technologies can affect the fashion industry now more than ever.

Fitting rooms are the heart of customary in-store apparel shopping, where the customers make the final decision about the purchase. One of the main drawbacks of online shopping is

DOI: https://doi.org/10.36548/jaicn.2021.4.002
Received: 13.10.2021, received in revised form: 29.10.2021, accepted: 14.11.2021, published: 26.11.2021

the lack of such service. Virtual try-on and fashion synthesis systems are the solutions to this problem, preventing customers from buying unsuitable and unexpected items, making sure to provide the customers with an enjoyable experience. Moreover, they can decrease the refunding rate of online stores. That is why a review is necessary of this critical subject.

The primary focus is on two categories of AI fashion applications: 1) Fashion virtual try-on and 2) Fashion synthesis. Older review studies like [1] in 2018 refer to these tasks very briefly. In 2020, [2] dedicated a section of their survey on this matter, mentioning multiple essential works through the years. Also, [3] in 2021 covered this subject and included several state-of-the-art methods, relevant datasets, and performance metrics. A limitation of past studies is that they only report several significant works in the field. They had to cover many more subjects that simply could not go into all the details of virtual try-on and synthesis tasks.

In this research, an application-based grouping of articles is followed. Figure 1 shows how articles were processed in this research. The primary focus is on articles published in 2017-2021, leading to 110 relevant studies. These articles are categorized into two main application-based groups, and multiple sub-groups. Also, different varieties of each sub-group are detected, which brings about a three-level hierarchy of application categorization. These categories are included in Figure 2.

Furthermore, this categorization is multi-label, meaning each article can show in multiple categories simultaneously. Each article is assigned to a category only if it explicitly reports relevant results for that application. This proposal is most likely the first to categorize fashion try-on and synthesis studies using this unique scheme. Such research could contribute a lot to the field by defining a structured hierarchy of fashion try-on and synthesis applications and listing related studies; it brings attention to the field and helps new researchers choose research directions while boosting the visibility of previous related studies at the same time.

The main contributions of the article are as follows:

- A survey of AI applications in virtual try-on and fashion synthesis systems is provided.
- A three-level hierarchy of related tasks is introduced and subsequently all relevant studies are listed and categorized using a multi-label scheme.

- The tabular format used in this article provides researchers with fast and easy access to relevant sources. Additionally, the introduction of a double keyword scheme eases the process of pointing to different input-output domains.

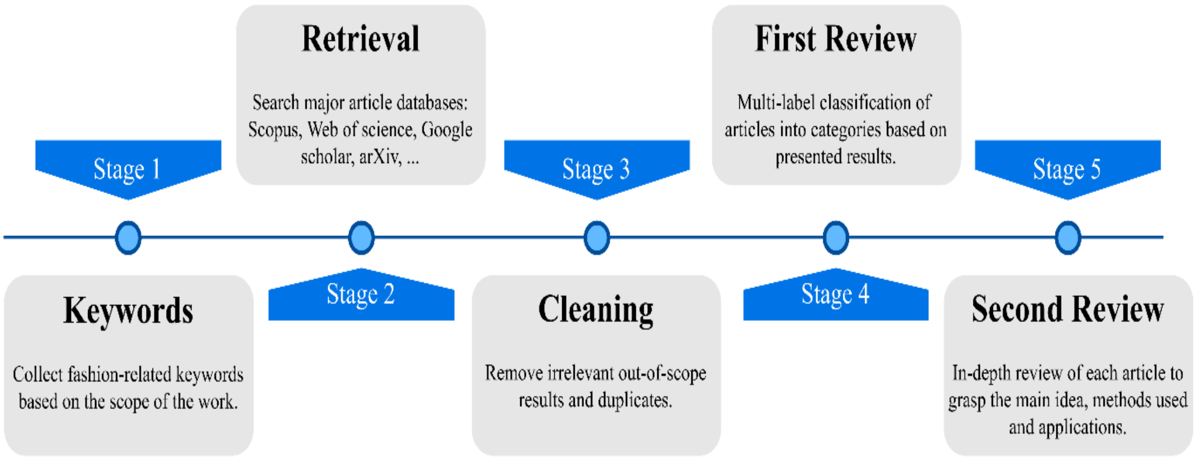

Figure 1. Workflow of preparing this review article

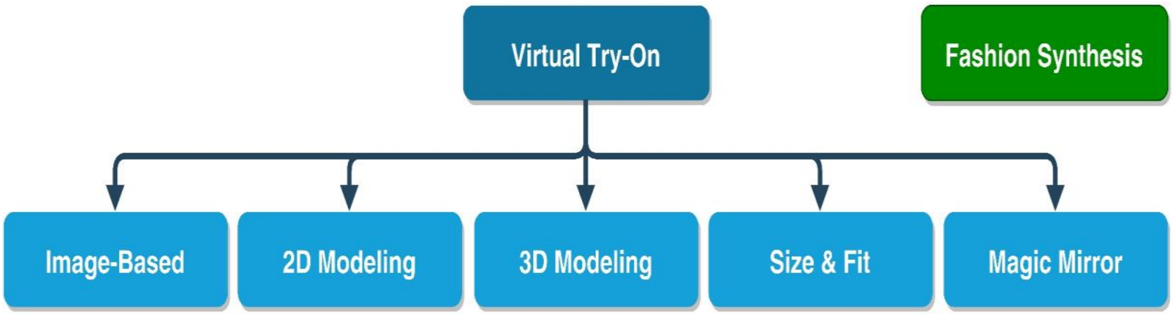

Figure 2. Fashion applications of AI discussed in this paper

2. Tables Usage and Used Terms

Related articles are categorised into two main categories (virtual try-on and fashion synthesis) and several sub-categories. Each sub-category comes with a table of listed relevant works, including information about articles, e.g., name of the first author, year, technical keywords, claimed results, and application notes. Technical keywords point out methods, algorithms, and networks used in each article. Listing these keywords and names helps researchers keep track of newly-introduced methods and networks. The “Application Notes” column in each table is also a good source of information. It shows further valuable details about the domain of each study and different task varieties of each sub-category, using keywords, dual keywords, and sentence fragments. This column is designed to be as short but informative as possible.

2.1 Image Terminology

Specific terms to refer different fashion image domains are defined; **Error! Reference source not found.** introduces some examples of these terms.

- **Item** or **Title:** These terms refer to professional catalog images. Online fashion shops mainly use such images. They illustrate only one fashion article with a white or neutral background.
- **Model:** Refers to a professional full/half-body shot of a model wearing a single or several fashion items under standard conditions.
- **Shop:** These images are mainly gathered from online fashion stores. As a result, these are professional images with a neutral background and might be "Item," "Model," or a combination of both.
- **Street:** These images are out-of-the-studio good quality pictures usually focused on one professional model. They have more sophisticated backgrounds, different lighting conditions, and minor occlusion due to various yet standard poses.
- **Wild**: Wild photos, unlike Street images, have no constraints at all. They are user-created amateur versions of Street photos, sometimes with heavy occlusion, lousy lighting, cropping, and poor overall quality.

2.2 Dual Keywords

Figure 3. Examples of different fashion-related images Amazon [4] and Deepfashion [5] datasets: a) Item/Title b) Full-body Model c) Half-body Model d) Street e) Wild

A dual keyword scheme is introduced and utilized mainly to refer Input-Output domains of different systems. These keywords are capitalized-cased hyphenated combinations of domain names. These unique keywords are mainly used at the beginning of the "Application

Notes" section or in image captions. The context and the capitalized case format of words on both sides of the hyphen help differentiate these keywords from ordinary hyphenated words. For example, "Title-Model" is a dual keyword, while "Pose-guided" is just a common hyphenated compound word.

2.3 Abbreviations

Due to space limitations, abbreviated words are used in tables. Firstly, familiar universal terms which are mainly known to the readers usually for reporting the results. Examples are: Acc (Accuracy), mAP (mean Average Precision), IS (Inception Score), HS (Human Studies/Score), SSIM (Structural Similarity), and FID (Frechet Inception Distance). Secondly, less familiar but easy to infer in context words. These abbreviations are in capitalized case format, and a dot always follows. A full list of these words is as follows: App. (application), Attr. (attribute), Conv. (convolution), Deform. (deformation), Est. (estimation), High-Res. (high-resolution), Lin. (linear), Modul. (modulation), Norm. (normalization), Recom. (recommendation), Rep. (representation), Seg. (segmentation), Trans. (transformation), Var. (variational).

3. Virtual Try-on

Virtual try-on is a highly active field, primarily due to its potential applications in the online fashion retail industry and also offline intelligent software packages used in clothing stores. Virtual try-on is separated into four sub-categories: 1) Image-Based Try-On, 2) 2D Modeling, 3) 3D Modeling, and 4) Size & Fit. The image-based try-on task is also 2-dimensional, but it does not change the whole input image, just the clothing items. Reference [6] is a taxonomical survey of virtual try-on systems with GAN networks, and [7] is another comprehensive survey covering image-based try-on, 2D, and 3D modeling applications.

3.1 Image-Based Try-On

Image-based try-on systems usually take one image as input and change fashion items present in the photo according to the user's need. The changes only affect specific regions of the input image, and the rest remain intact. Image-based try-on systems typically take two inputs (a reference image and a target outfit) and transfer the outfit to the reference image. In Table 1, the exact type of this transfer is reported using dual-keywords (Target-Reference) in the "Application Notes" section. These systems transfer qualities of the "Target" to the "Reference" image; for example, Model-Model designs transfer clothing from one human model image to another image with the human model present, whereas Title-Model systems need a catalog image of the desired outfit as a target.

Table 1. Articles Related to Image-Based Try-On

No	Article Reference	Year	Technical Keywords/Claimed Results	Application Notes
1	Sun [8]	2021	UCCTGAN, Color Hist., AntennaNet, 36.79 FID	Model-Model, Color transfer
2	G. Liu [9]	2021	LM-VTON, Thin-Plate Spline, U-Net, pix2pixHD, 3.04 IS	Title-Model, Details, Landmark-guided
3	Gao [10]	2021	SC-VTON, Graph attention, CNN, 62% HS	Title-Model, Shape-controllable
4	J. Zhang [11]	2021	PISE, Decoupled GAN, HPE, PGN, 13.61 FID	Model-Model, Texture transfer, Also pose
5	Lv [12]	2021	MS-VITON, CGAN, PatchGAN, 9.8 FID	(Title+Text)-Model, Multi-scene
6	Minar [13]	2021	3D deformation, CloTH-VTON+, Segmentation, 2.787 IS	Title-Model, Method comparison
7	Kips [14]	2020	Color Aware, CA-GAN, PatchGAN	Makeup transfer, Model-Model
8	K. Wang [15]	2020	Unpaired shape transformer, AdaIN, 66.42 SSIM	Title-Model, Try-on/Take-off
9	Song [16]	2020	Shape-Preserving, SP-VITON, DensePose, 2.656 IS	Title-Model
10	Neuberger [17]	2020	O-VITON, pix2pixHD, Segmentation, cGAN, 3.61 IS	Multiple Models-Model, Multi-item try-on
11	Hashmi [18]	2020	Neural Body Fit, GAN, RPN, STN, 76.62% Acc	User custom try-on
12	Jeong [19]	2020	Graphonomy, SEAN, ResBlK, SEBlK, 0.865 SSIM	Model-Model, Selective article transfer
13	W. Liu [20]	2019	Liquid warping GAN, Denoising Conv. auto-encoder	Model-Model + In-Lab images, Detailed
14	Pumarola [21]	2019	Unsupervised, Memory, GAN, Segmentation, 3.94 IS	Image-to-Video clothing transfer
15	Kikuchi [22]	2019	Spatial Transformer, ST-GAN, 32% IOU@0.75	Glasses, Title-Model
16	L. Yu [23]	2019	Inpainting-based, I-VTON, TIN, Triplet, 2.729 IS	Model-Model, Selective article transfer
17	Yildirim [24]	2019	Modified Conditional Style GAN, 9.63 FID	Model-Model, Color transfer, High-Res.
18	Chen [25]	2018	CAGAN, LIP-SSL, Transform, 90.3% HS	Title-Model, Upper body
19	Raj [26]	2018	Segmentation, Dual-path U-net, DRAGAN, SwapNet	Model-Model, Swap clothes, Pose
20	Chou [27]	2018	Pose Invariant, PIVTONS, PatchGAN, Key-points	Shoe try-on, Title-Model
21	Han [28]	2018	VITON, Multi-task Encoder-Decoder, TPS, 2.514 IS	Title-Model, Upper body, Also wild
22	Zhu [29]	2017	FashionGAN, Segmentation, Text-to-image, 82.6% mAP	Text-Model, Text-Guided, Upper body
23	Jetchev [30]	2017	Conditional Analogy GAN, PatchGAN	Title-Model, Upper body

3.2 2D Modeling

2D modeling is also image-based, with one main distinction. Here, the input image completely changes, and the output is a new 2-dimensional model of the original image. 2D modeling can be the synthesis of the same image from a different angle, pose-guided image synthesis of a person with a different pose (known as pose transformation), or even a graphical/cartoon model or an avatar of the input image. Most systems labelled as 2D modeling are pose-guided try-on systems. There also exist pose-transfer systems that might not focus on fashion; however, 2D modeling try-on systems can utilize and implement their proposed methods in fashion-related applications.

Table 2. Articles Related to 2D Modeling

No	Article Reference	Year	Technical Keywords/Claimed Results	Application Notes
1	Zhang [11]	2021	PISE, Decoupled GAN, Spatial-aware Norm., 13.61 FID	Pose transfer, also Texture, Region editing
2	Lewis [31]	2021	Pose-conditioned StyleGAN2, VOGUE, AdaIN, 32.2FID	High-resolution pose transfer
3	Chou [32]	2021	Template-free, TF-TIS, Parsing, cGAN, 3.077 IS	Pose-guided try-on, Good detail generation
4	Kuppa [33]	2021	DensePose, CP-VTON, GELU, ReLU, U-Net	Video virtual try-on
5	W. Liu [34]	2021	Liquid warping GAN, HMR, 3.419 SSIM	Pose/Outfit transfer, Motion, In-lab images
6	Gao [35]	2020	Semantic-aware attentive transfer, LGR, 3.855 IS	Recapture, Pose+Body shape+Style, Video
7	J. Liu [36]	2020	Dense local descriptors, Autoencoder, 0.959 SSIM	Human pose transfer, Try-on, Video
8	Ren [37]	2020	Differentiable global-flow local-attention, 10.573 FID	Human pose transfer
9	Men [38]	2020	Attribute-decomposed GAN, U-Net, AdaIN, 3.364 IS	Controllable person image generator, Pose
10	Tsunashima [39]	2020	Unsupervised, Disentangled representation, UVIRT	Try-on using consumer clothing images
11	Jeong [19]	2020	Graphonomy, SEAN, ResBlK, SEBlK	Try-on and also human pose transfer
12	Zhou [40]	2019	Multi-modal, LSTM, Attentional upsampling, 4.209 IS	Text-guided pose & appearance transfer
13	Sun [41]	2019	Bi-directional Conv. LSTM, U-Net, 3.006 IS	Human pose transfer
14	Dong [42]	2019	MG-VTON, Conditional parsing, Warp-GAN, 3.368 IS	Multi-pose guided virtual try-on
15	Dong [43]	2019	Flow-navigated warping, FW-GAN, CGAN, 6.57 FID	Video virtual try-on
16	Yildirim [24]	2019	Modified conditional style GAN, 9.63 FID	Try-on multiple items, Pose-guided
17	Pumarola [44]	2018	Unsupervised, Conditioned bidirectional GAN, 2.97 IS	Human pose transfer, Unsupervised
18	Si [45]	2018	Hourglass, CRF-RNN, 3D joints, 0.72 SSIM	Human pose transfer, In-lab images
19	Zanfir [46]	2018	3D pose & shape, DMHS, SMPL, HAS, Layout warping	Appearance transfer, Model-Model, Pose
20	Ma [47]	2018	Disentangled representation, U-Net, PG^2, 3.228 IS	Foreground/Background/Pose manipulation
21	Raj [26]	2018	Dual-path U-Net, DRAGAN, SwapNet, 3.04 IS	Pose-guided, Swap clothes
22	Ma [48]	2017	PG^2, U-Net-like, Conditional DCGAN, 3.090 IS	Human pose transfer

3.3 3D Modeling

3D modeling applications include try-on and also 3D garment modeling. Some studies focus on 3D body scanning and geometry or texture modeling of garments, while others focus on 3D modeling and physical simulation from a 2D input image. 3D modeling of clothed humans is a highly active field; this is not just for fashion purposes but also partly due to its applications in the huge movie and animation industry and gaming graphics. Dual keywords (Input-Output) are used in the "Application Notes" column of Table 3 to categorize systems whenever possible. For example, "Image-3D Body" shows a system that generates 3D body models from 2D images.

Table 3. Articles Related to 3D Modeling

No	Article Reference	Year	Technical Keywords	Application Notes
1	Shi [49]	2021	Style/Shape-dependent deformations, Encoder-decoder	3D garment transfer on 3D models
2	Tiwari [50]	2021	DeepDraper, SMPL, VGG19, Multi-view perceptual loss	3D Clothing draping on 3D models
3	M. Zhang [51]	2021	Gram matrix, PatchGAN, Conditional instance Norm.	3D Fine-scaled geometry, Details, Wrinkles
4	Hu [52]	2021	3DBodyNet, SMPL, PointNet, DGCNN	Animatable 3D body from images, Clothing
5	Minar [13]	2021	CloTH-VTON+, SMPL, TPS, Shape-context matching	Item image-3D garment, Image-based try-on
6	Saito [53]	2020	Multi-level, Trainable, PIFu, CNN, MLP, pix2pixHD	Image-Detailed High-Res. 3D model
7	Jiang [54]	2020	Layered garment Rep., SMPL, PCA, ResNet-18, GAT	Image-3D clothed body
8	Li [55]	2020	Morphing salient points, MPII, Garment mapping	In-home 3D try-on App.
9	Ali [56]	2020	FoldMatch, Physics-based, Wrinkle-vector field	Garment fitting onto 3D scans, Accurate
10	Patel [57]	2020	TailorNet, MLP, SMPL, PCA, Narrow bandwidth kernel	3D clothed body, Pose/Shape/Style, Detailed
11	Vidaurre [58]	2020	Parametric 3D mesh, SMPL, Graph CNN, U-Net	Parametric try-on, Garment/Body/Material
12	Jin [59]	2020	CNN, Pixel-based framework, PCA, Deformations	Pose-3D garment, Pose-guided 3D clothing
13	W. Liu [20]	2019	SMPL, HMR, NMR, Liquid warping GAN	In-lab image-3D Mesh, Motion transfer
14	Shin [60]	2019	Deep image matting, DCNN, Recursive Conv. Net.	Realistic garment rendering for 3D try-on
15	Santesteban [61]	2019	Learning-based, Physics-based, RNN, MLP, PSD	3D try-on clothing animation, Wrinkles, Fit
16	Alldieck [62]	2018	Pose reconstruction, Unposed canonical frame	Video-3D clothed body
17	Lähner [63]	2018	cGAN, DeepWrinkles, Pose Est., PCA, LSTM	4D scans-3D garment, Accurate, Realistic
18	T. Wang [64]	2018	Shared shape space, PCA, Siamese network	Sketch-3D garment, Design, Retarget

No	Article Reference	Year	Technical Keywords	Application Notes
19	Daanen [65]	2018	Measures, Devices, Processing, Virtual fit	An overview on 3D body scanning
20	Hong [66]	2018	3D Scanning, Rule-based model, Sensory descriptors	3D-to-2D garment design, Scoliosis
21	Daněřek [67]	2017	Mocap sequence, CNN, 3D vertex displacement	Image-3D garment, Single image
22	Pons-Moll [68]	2017	ClothCap, Multi-part 3D model, Segmentation	4D Clothing capture & retargeting, Motion
23	S. Yang [69]	2016	Physics-based, Parameter Est., Semantic parsing, Shape	Image-3D garment, Single image
24	Guan [70]	2016	Review, A section on 3D Try-on, Various methods	Apparel virtual try-on with CAD system

3.4 Size & Fit

Choosing the right clothing size and the best fit is one of the main reasons fitting rooms exist in the real world. Technology needs to provide solution to this problem in online apparel shops. One main approach is 3D body scanning. Digitization technologies can measure specific body parts or even generate full body measurements in seconds. Thus, various 3D modelling methods are considered and discussed in sec 3.3 for this application.

Table 4. Articles Related to Size & Fit

No	Article Reference	Year	Technical Keywords/Claimed Results	Application Notes
1	Foysal [71]	2021	SURF, Box filter, Bag-of-features, k-NN, CNN, 87% Acc	Body shape detection, Smartphone App.
2	Wolff [72]	2021	Structure sensor, Isometric bending, Var. surface cutting	3D Custom fit garment design, Pose
3	Hu [73]	2020	Body PointNet, MLP, OBB Norm., Symmetric chamfer	Body shape under clothing from a 3D scan
4	Li [55]	2020	3D scanner, MPII, Salient anthropometric points	In-home 3D fitting room App.
5	Yang [74]	2020	Multi-view, Semantic Seg., PSPNet, Clustering, Matching	Girth measurement, Stereo images, Design
6	Hsiao [75]	2020	Visual body-aware embedding, 3D mesh, SMPL, HMD	Fashion Recom. for personal body shape
7	Yan [76]	2020	SMPL, Non-rigid iterative closest point, Non-Lin. SVR	Measurements from 3D body scans
8	Dong [77]	2019	PCW-DC, Bayesian personalized ranking, MLP	Personalized capsule wardrobe, Body shape
9	Sattar [78]	2019	SMPL, 3D model, Multi-photo optimization	Clothing preference based on body shape
10	Du [79]	2019	Agglomerative clustering, Character-LSTM, QP	Automatic size normalization
11	Sheikh [80]	2019	Content-collaborative, SFNet, Siamese, 76.0% Acc	Size & fit prediction, E-commerce
12	Guigourès [81]	2018	Hierarchical Bayesian model, Mean-field approximation	Size recommendation
13	Daanen [65]	2018	Measures, Devices, Processing, Sizing	An overview on 3D body scanning

No	Article Reference	Year	Technical Keywords/Claimed Results	Application Notes
14	Hidayati [82]	2018	BoVW, Auxiliary visual words, Affinity propagation	Fashion Recom. for personal body shape
15	Abdulla [83]	2017	Gradient boosting classification, Word2vec, 81.28% Acc	Size recommendation, E-commerce

4. Fashion Synthesis

Fashion synthesis emphasizes synthesizing new fashion item images and designs from scratch. Try-on applications also synthesize images but with a different purpose. In try-on applications, the focus is on the human present in the photo, while in fashion synthesis, the main focus is on creating novel and unseen fashion items. Reference [84] provides comprehensive research on consumer responses to GAN-generated fashion images. Various approaches exist, and different inputs are used to guide the system to generate the final output. Each system's output is reported in the "Application Notes" column of Table 5 or use dual keywords (Input-Output) wherever possible. For example, "Model-Item" shows that the system takes one fashion image with a human model and generates the fashion article's catalogue image. Image synthesis is not the final goal of all synthesis systems, and some try to generate designs and ideas leading to the physical production of fashion items.

Table 5. Articles Related to Fashion Synthesis

No	Article Reference	Year	Technical Keywords/Claimed Results	Application Notes
1	J. Lin [85]	2021	PaintNet, CGAN, InceptionV4, Gram matrices, 1.561 IS	Street photo-Item, Take-off, Shape constraint
2	Jiang [86]	2021	FashionG, Spatial constraint, VGG-19, MDAN	Item image, Style transfer, Spatial constraint
3	Liu [87]	2021	CMRGAN, Multi-modal embedding, Inception-V3, VGG	Item-Compatible Item, Top/Bottom
4	Wolff [72]	2021	3D Scans, Pose, Design out of standard size garments	3D Custom fit garment design
5	Zhan [88]	2020	Appearance-preserved, PNAPGAN, U-Net, Triplet loss	Street photo-Item, Street2shop generation
6	Gu [89]	2020	Multi-modal, GAN, PatchGAN, 3.124 IS	(Pose+Text)-Model, Fashion translation
7	Ak [90]	2020	e-AttnGAN, LSTM, FiLM-ed ResBlock, 4.98 IS	Text-Model, Semantically consistent
8	Dong [91]	2020	Adversarial parsing learning, FE-GAN, U-net, 0.93 SSIM	Fashion editing, Sketch, Inpainting
9	Li [92]	2020	Bi-colored edge Rep., Residual Conv., cGAN, 4.076 IS	(Sketch+Texture)-Item, Interactive
10	K. Wang [15]	2020	Unpaired shape transformer, AdaIN, 61.19 SSIM	Model-Item, Clothing take-off
11	Tango [93]	2020	GAN, pix2pix, Minimax game, U-Net, 30.38 FID	Anime character image-Real item, Cosplay
12	Kınlı [94]	2020	Dilated partial Conv., U-Net-like, Self-attention, CNN	Inpainting, Irregular holes, Benchmark

No	Article Reference	Year	Technical Keywords/Claimed Results	Application Notes
13	Chen [95]	2020	TailorGAN, Encoder-decoder, Self-attention mask	(Ref. item+Attr. item)-Item, Attr. editing
14	Ak [96]	2019	CNN, AMGAN, Class activation mapping, 79.48% mAcc	Attribute manipulation
15	C. Yu [97]	2019	Personalization, VGG-16, LSGAN, Siamese, 4.262 IS	(Item+User preference)-Compatible item
16	Albahar [98]	2019	Bi-directional feature transformation, 3.22 IS	(Sketch+Texture)-Item, Image translation
17	Ravi [99]	2019	VGG-19, Style transfer CNN, Super Resolution SRCNN	(Silhouette+Pattern)-Item, Style transfer
18	Y. Lin [100]	2019	Co-supervision, FARM, Variational transformer, DCNN	(Item+Text)-Compatible item, Recom.
19	Yildirim [24]	2019	Modified conditional style GAN, 9.63 FID	Multiple items-Clothed Model, High-Res.
20	Kumar [101]	2019	Conditional distribution, c+GAN, DCT, Faster R-CNN	Upper body image-Compatible bottom
21	Hsiao [102]	2019	Fashion++, Semantic segmentation, cGAN, VAE	Minimal edits for outfit improvement
22	Xian [103]	2018	TextureGAN, VGG-19, Scribbler, Texture patch	(Sketch+Texture)-Image, Bag, Shoe, Clothes
23	Günel [104]	2018	Feature-wise linear modulation, GAN, fastText, 2.58 IS	(Text+Model)-Model, Attr. manipulation
24	Yang [105]	2018	Siamese, BPR, GAN, SE-Net, Inception-V3, 6.823 IS	Generates fashion collocations, Item image
25	Rostamzadeh [106]	2018	Progressive GAN, StackGAN-v1/v2, 7.91 IS	Text-Model, Fashion-Gen, Challenge
26	J. Zhu [107]	2018	CNN, Nonnegative matrix factorization, VAE	Popular items-New items, Design
27	Lassner [108]	2017	ClothNet, VAE, CVAE, Image-to- image Trans.	Seg. body map-Person image, Pose, Color
28	A. Yu [109]	2017	Semantic Jitter, Attribute2Image, CVAE, MLP	Synthesize varying Attr. Images, Shoes
29	Date [110]	2017	Segmentation, VGG-19, SVM, LBFGS	Multiple items-Item, Style transfer

5. Conclusion

Recent advancements in machine learning and artificial intelligence are helping ease the fashion industry's transition from customary stores into modern online shops equipped with high-tech features such as virtual try-on and fashion synthesis systems. This article sheds some light on different applications related to these systems, tracked the research progress through the years, and illustrated the field’s rapid growth. Although scientists have achieved significant milestones, still many unsolved matters remain. One main issue is the systems’ performance compared to human abilities; another important factor is the applicability of methods regarding computational effort and energy efficiency. Another critical problem is the definition of a well-structured and uniform objective metric to assess the results. To conclude, this area of research is highly active and any research in this fast-growing field, whether improving one of the branches discussed here or introducing new applications, will be precious and potentially profitable for fashion e-commerce.

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