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A Review on Dress Sketch/Image Representation from 2D to 3D for Fashion Designing: Using AI

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ABSTRACT

This review investigates the growing research on automated conversion from two-dimensional (2D) to three-dimensional (3D) garments and focuses on summarizing the disjointed existing literature in the area of sketch-based 2D-to-3D garment conversion from a fashion sketch and/or a dress image. The review uses a narrative synthesis method and considers seventeen peer-reviewed and preprint studies from 2006 to 2026 that employ artificial intelligence and computational geometry to solve this problem. The key technologies the authors present include Generative Adversarial Networks (GANs) and Convolutional Neural Networks (CNNs) for feature extraction and shape estimation; Graph Long Short-Term Memory (GraphLSTM) networks for recursive feature diffusion across mesh vertices; and the Double Reverse Diffusion (DReD) framework, which integrates multi-scale image features with the unsigned-distance-field autoencoder, implemented in PyTorch and PyTorch3D. In addition, the review also discusses geometric and hybrid approaches, such as selective regularization for curve network reconstruction, unsigned-distance-field based sketch-to-mesh systems and pattern-making techniques which parameterize human body shape to produce flattenable 3D garment structures. Main findings show that existing tools excel in narrow tasks, like shape inference from a single sketch, 3D mesh generation from a single image, or reconstruction of a single garment from an image, but none of them combine the three steps of sketch interpretation, 3D mesh creation and pattern-ready output in a single end-to-end pipeline. Finally, this review suggests that future unified 2D-to-3D fashion design tools should integrate deep-learning-based shape inference, geometric pattern-making, and associative sketch-pattern linkage, and highlights the key challenges of this approach as dataset scarcity, occlusion handling, and estimation of fabric properties.

I. INTRODUCTION

Traditionally, geometric modeling techniques were used to construct and manipulate digital clothes as part of the approach created for virtual garment creation. This methodology combines concepts from simulation, computational geometry, and computer graphics.

For geometric representation, researchers explain the geometric representation of clothing using mathematical building blocks such as surfaces, curves, and volumes. Methods for modeling parts of the garment, including seams, sleeves, and collars, fall under this category.

In the simulation component, physical simulation is used to model how virtual clothing behaves under different conditions, including body movement, gravity, and wind. To compute how the clothing shape changes and moves, researchers must solve the equations of motion that govern the fabric's behaviour.

This study also covers how users interact with the system and edit virtual garments using a dedicated tool. This tool can include simple interfaces for changing the form of the clothing, adjusting settings, and modeling cloth properties.

The visualization and rendering component cover the methods researchers use to produce realistic and immersive virtual clothing. For the best visualizations and renderings, methods such as lighting simulation, shader effects, and texture mapping are used. [1]

Research Gap and Contribution: It clearly exposes progress achieved in individual parts of 2D-to-3D pipeline: geometric curve reconstruction, sketch-based mesh generation, deep-learning shape estimation, pattern making, and sketch-pattern association. Neither reviewed study nor any available commercial or research method is able to combine all of these stages to provide a seamless process with the ability to take a 2D dress sketch or image as input and generate a 3D dress model and a 2D production-ready pattern. It fills this gap by (1) summarizing all the efforts in each field so far, (2) explaining the missing technical links — i.e., how graph lstm can be extended for mesh refinement, how the unsigned distance field can be reconstructed, and how the sketch pattern can be associated using yoloV8 — to make it possible to have an integrated pipeline for 2D-to-3D, and (3) weaving all the separate efforts together in one conceptual framework and pinpointing where the field needs to invest the next development toil.

II. Methodology

This review is done using a narrative literature review methodology as it is a technical and cross-disciplinary work, where the subject matter covers computer graphics aspects, machine learning aspects, and textile pattern engineering aspects. Targeted search of the ACM Digital Library, IEEE Xplore, ScienceDirect, SpringerLink, and arXiv was performed using the combinations of the following terms: 2D to 3D garment, sketch-based garment generation, deep learning fashion design, virtual pattern making, and associative sketch and pattern design to identify relevant studies. Studies were only considered if they proposed or evaluated an algorithm for converting 2D garments sketches or images to 3D representations or patterns, published in a peer-reviewed journal, conference proceedings or as a citable preprint or thesis, and provided enough detail in the method to be summarised and compared. Studies that did not involve garment simulation and/or draping without a 2D-to-3D conversion aspect were excluded, as were those in non-English language. The 17 studies published from 2006 to 2026 were identified and organized into four streams of research: AI-based 2D-to-3D conversion, deep learning techniques, pattern making and 3D garment generation, and associative design.

Figure 1 Generalised workflow synthesised from the reviewed 2D-to-3D garment conversion literature

III. AI-Based 2D-to-3D Conversion

This research line focuses on the fundamental problem of being able to infer the 3D geometry of a garment directly from a 2D sketch or images, relying on geometric algorithms and learned models.

Selective Regularization and Curve-Network Reconstruction

The idea of selective regularization was first introduced in 2014. It was really innovative at that time, this technique addressed a major challenge in computer graphics and 3D modelling by transforming free-hand sketches into accurate 3D curve reconstructions.

Moreover, this methodology forms the basis of True2Form technique. It identifies the difference between parts of a sketch that reflect rigid versus flexible structures. Also, it does this by preserving the shapes of the sketch as drawn while also allowing for the natural variation that occurs during hand drawn sketches.

Basically, True2Form is useful for generating a network of 3D curves that closely matches the sketch owner's original 2D sketch. These curve networks are valuable as a base framework for 3D modeling and mesh-based modelling and narrowing the gap between the initial drawing and a finished 3D model. [2]

Sketch-Based Dress Generation with Distance Fields

This body of work describes the Sketch2Cloth methodology, which uses unsigned distance fields to translate 2D apparel designs into 3D representations, combining machine learning, geometric modeling, and computer graphics technologies.

Research authors outline the procedures needed to transform hand-drawn garment sketches into digital representations, using image segmentation, edge detection, and vectorization to extract dress shapes and features.

Moreover, the concept of unsigned distance fields is useful for representing 3D shapes with implicit surfaces, covering the creation, modification, and rendering of these distance fields.

The 2D garment sketches are then converted into 3D representations using unsigned distance fields, with extrusion, deformation, and fine-tuning methods applied to achieve the desired garment shape.

Using the Sketch2Cloth system, the researchers investigate several approaches for user interaction and control, including user-friendly interfaces for real-time drawing, editing, and manipulation of clothing designs. [3]

Image- and Diffusion-Based 3D Garment Reconstruction

This body of work addresses the drawbacks of conventional techniques for direct 3D modeling of upper clothing from images, drawing on deep learning algorithms and computer vision techniques for image analysis and 3D reconstruction.

Researchers process and analyse images of upper clothing to extract important features such as shape and style, using object detection, feature extraction, and image segmentation.

3D reconstruction then follows, drawing on techniques for 3D-space draping effects, surface texturing, and cloth-geometry estimation. Model refinement, covering fine-tuning of features, surface smoothing, and fit and proportion adjustment, is applied to improve realism and accuracy. [7], [8]

Reconstructing realistic garments from images is crucial across domains including online shopping and virtual try-on systems. This paper presents the challenge of reconstructing dresses' textures and features from the images and the necessity of developing more accurate reconstruction methodologies is discussed. Then the authors also outline the image-processing stages used to analyse input images and extract essential clothing information including texture mapping, feature extraction and image segmentation. Before applying reverse diffusion: a 3D garment model is constructed from the extracted information using surface reconstruction, texture creation, and geometric modeling during model training.

The "double" part of this approach introduces the double reverse diffusion methodology, it is an iterative process for refining the reconstructed dress model through multiple passes of reverse diffusion in order to improve precision. Its evaluation combines both quantitative and qualitative indicators, assessing correctness, fidelity and visual quality against the real-world data. [9]

IV. Deep Learning Techniques

This important stream focuses on learning from data, the relationship between 2D representations of dresses and 3D shape and/or pattern outputs using deep neural networks, specifically convolutional architectures and object-detection models.

Deep Neural Networks for Garment Shape Estimation

This study mainly highlights the disadvantages of traditional techniques and the case for a deep learning-based strategy in which training deep neural networks to infer garment geometry from 2D image inputs in order to estimate 3D dress shapes is discussed. The approach draws on convolutional neural networks (CNNs) or comparable architectures for feature extraction and regression.

For data gathering, the researchers describe compiling a dataset of clothing photos and associated 3D shape annotations, which is pre-processed and augmented to improve the network's generalisability and robustness. The study describes the deep neural network's architecture and design, including the training methods, activation functions, loss functions, and network layers used to estimate garment shape.

The training procedure, regularization and learning rate scheduling are performed for fine-tuning the network parameters to precisely estimate the shape of garments, as well as mini-batch stochastic gradient descent. Performance is evaluated using qualitative assessments of visual quality alongside quantitative metrics for recall, accuracy, precision, and F1 score. [4]

Automated Fashion Image and Sketch-Feature Generation

In a related paper, a deep learning approach enables automatic creation of dress images using different garment attributes and designs. This system uses neural-network-based image generation, learning from existing dress-image datasets to build novel fashion images without human intervention, with applications in fashion-design automation and e-commerce. [5]

Convolutional neural networks and other machine learning algorithms trained on large datasets of garment images and matching flat sketch designs are used to automatically extract image features. Researchers gather garment photos and corresponding flat-sketch design features from proprietary sources, e-commerce sites, or online fashion databases, applying scaling, normalization, and augmentation to improve model performance. The model is trained to learn the mapping between flat-sketch design features and garment images, and its performance is assessed using recall, accuracy, precision, F1 score, and computational efficiency. [6]

Integrating Sketch and Pattern via Object Detection (YOLOv8)

Artificial intelligence is also used to combine flat dress sketching and pattern-making into a smoother digital design workflow. For this purpose, a YOLOv8 model is fine-tuned on a dataset of flat garment sketches and patterns. The researchers aim to link the visual design and the corresponding pattern-making process using artificial intelligence. The proposed methodology supports the automation of garment design, improves design consistency, and helps move creative sketches directly toward pattern-ready fashion products. [10]

V. Pattern Making and 3D Garment Generation

The emphasis of this stream is to transform 3D hand-drafted, scanned and/or algorithmically developed garments into wearable and manufacturing ready 2D patterns, while also being able to modify sketch-based garments to specific body shapes or characters.

Body-Scan-Driven Pattern Fitting

This body of work discusses the importance of recreating realistic dresses from photographs for virtual fitting rooms, online shopping, and digital fashion apparel, and the challenges of capturing minute garment details and textures from images.

Researchers illustrate how 3D body-shape data is gathered using body-scanning technologies such as laser or structured-light scanning, from which personalised clothing styles that fit different body types are created. Initial clothing patterns are then created in a virtual environment using this 3D body-form data, with computational techniques accounting for body dimensions, body shape, and preferred fit (loose or fitted) to ensure a good match to the individual body shape.

Using simulation methods, this study also describes how individuals can check how well garment patterns fit 3D body models, with physical dress prototypes made and validation studies comparing virtual fitting results with human perceptions of fit and with physical garment prototypes. [11]

Parameterized Block Pattern Generation

This work describes a block-pattern-generating approach involving flattenable 3D structures and feature alignment, achieved by parameterizing human body shapes and optimizing garment patterns. It combines concepts from optimization algorithms, geometric modeling, and computer-aided design (CAD).

Human body parameterization uses anthropometric measurements and anatomical landmarks to standardise the representation of body shapes so that they can be fed into pattern-generation algorithms. Pattern optimization then creates preliminary block patterns for clothing from the derived body-form characteristics, using computational algorithms to generate flattenable 3D structures suitable for garment manufacture while ensuring feature alignment with specific body landmarks.

The approach also addresses matching clothing details such as pleats, darts, and seams to corresponding anatomical features, and investigates techniques for flattening 3D garment structures into 2D pattern pieces to streamline cutting and sewing operations. [12]

Scale-Preserving 3D-to-2D Pattern Editing

The system described in this paper enables fashion designers to modify 3D dress models directly while automatically updating the underlying 2D patterns and preserving scale of garment patterns. It was a significant advancement in technology, since conventional dress creation traditionally began with 2D patterns and that were subsequently sewn together into 3D clothing.

PerfectTailor makes significant progress in preserving 2D pattern scale while incorporating 3D garment-model modifications, ensuring that changes made to the design in three dimensions can be precisely represented in physical patterns and substantially streamlining the process from design to production. The system gives designers an easy-to-use interface to alter the 3D garment model's size, shape, or fit directly, with the 2D patterns instantly reflecting these changes. [13]

Comparative Evaluation of Traditional and 3D Pattern Making

This study is most likely to be comparative research, comparing the traditional pattern-creation methods with 3D virtual pattern creation, and rating them based on several criteria such as environmental impact, adaptability, operational efficiency, cost-effectiveness, accuracy and ease of use.

The comparative study's results allow the researchers to highlight the advantages and disadvantages of each strategy, offering guidance to fashion educators, garment-industry practitioners, and fashion-industry policymakers on the acceptance and use of 3D methods in garment design and production workflows. [14]

Sketch-to-3D Garment Generation for Virtual Characters

The approach discussed in this paper closes the gap between digital character modeling and traditional fashion designing while creating new opportunities for designers and animators. This technique involves figuring out a sketch's lines and curves as garment patterns and understanding the ideal fit and drape on a 3D model/form.

Moreover, one of the main challenges the authors discussed is analysing stylized sketches that do not necessarily follow realistic proportions or physics of garments. Advanced algorithms are useful for converting those sketches into actual dresses in 3D space while accounting for characteristics like body proportions and properties of fabric. [15]

There is a related process focuses on creating dresses influenced by simple sketches that are also tailored to the 3D shapes of characters. It is a combination that represents an innovation in the production of digital garments. Its main contribution is freeing designers from the need for understanding difficult 3D modeling knowledge by having the ability to generate 3D garment models from basic 2D dress sketches. Unlike any older technique that requires manual adjustment of garments to fit into different 3D models, this procedure automatically adjusts sketches to the precise body proportions and posture of a 3D avatar or character, justifying he avatar’s curves and positioning during shape adaptation. [16]

VI. Associative Design

This work explains the approach used to create an associative relationship between fashion sketches and garment patterns, using machine learning, computer graphics, and computer-aided design (CAD) tools to understand connections between sketches and geometric patterns.

The authors describe the procedure for deriving relevant design elements, such as silhouette, seams, and drape, from fashion sketches, using semantic analysis, feature extraction, and image-processing techniques. Appropriate garment patterns are then created automatically from these design features, using geometric modeling to convert 2D sketch parts into 3D pattern components.

An associative relationship between design sketches and clothing patterns is created using algorithms for matching design elements, propagating alterations between drawings and patterns, and synchronising real-time modifications. To facilitate this associative design process, the researchers investigate user interaction strategies, including interfaces for sketching, editing, and visualising design changes between drawings and patterns. [17]

VII. Comparative Analysis of Key Techniques

Table 1 summarizes the basic method, principal strength, and principal limitation of the research studies reviewed above that were most technically distinct, for direct comparison across the three research streams.

Technique / Study	Core Method	Key Strength	Key Limitation
True2Form [2]	Selective regularization of 2D curve networks	Preserves sketch fidelity while inferring 3D curves	Limited to curve-network output, not a full textured mesh
Sketch2Cloth [3]	Unsigned distance fields from sketch input	Enables interactive editing of the generated mesh	Struggles with complex, layered, or overlapping garment parts
DeepGarment [4]	CNN-based shape regression from a single image	Learns directly from image data without manual rules	Requires large, annotated 3D shape datasets to train
DReD [9]	Double reverse diffusion with GraphLSTM and UDF autoencoder	High-fidelity reconstruction from a single photograph	Lambertian garment surfaces and single-direction lighting
YOLOv8 sketch-pattern linkage [10]	Object detection fine-tuned on flat sketch and pattern datasets	Links design sketches directly to pattern-ready output	Dependent on the coverage and quality of the sketch/pattern training set
PerfectTailor [13]	Scale-preserving 3D-to-2D pattern adjustment	Keeps 2D patterns synchronised with 3D edits automatically	Focused on pattern adjustment rather than sketch-to-3D generation
Block pattern generation [12]	Body parameterisation and pattern optimisation	Produces flattenable, manufacture-ready pattern pieces	Relies on accurate anthropometric input data
Associative design [17]	ML/CAD-linked sketch-to-pattern association	Synchronises real-time changes between sketch and pattern	Requires tight integration between sketching and CAD interfaces

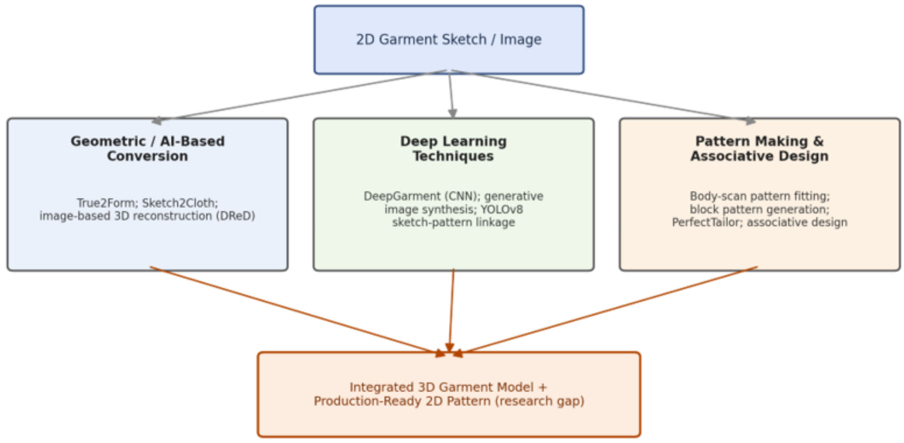

Figure 2 Comparative architecture of the three converging research streams identified in this review

VIII. Conclusion

The seventeen studies reviewed show four main results. On one hand, being able to infer a plausible 3D garment shape from a single 2D sketch or image with reasonable fidelity, when the image is fully visible and well-lit, thanks to the geometric and diffusion-based approaches (True2Form, Sketch2Cloth, DReD). Second, deep-learning methods, such as DeepGarment, generative image synthesis and YOLOv8-based linkage of the sketch-patterns, have been shown to be superior to purely geometric methods in tasks where large amounts of annotated data are available, but there are no large-scale annotated datasets of garments available. Third, pattern making research has reached a stage where it is possible to generate 2D patterns from a 3D model, which preserve the scale and are ready to manufacture, but most often outside the scope of sketch-to-3D conversion as a separate process (e.g., body-scan fitting, block-pattern generation, PerfectTailor). Fourth, associative-design methods have shown that sketches and patterns can be kept synchronized in real-time for only systems designed to carry out this task.

The common issues that are frequently addressed in the literature are occlusion and self-intersection in complex or layered clothing, Lambertian (non-reflective) cloth surface and one-directional light, unbalanced training data sets (sketch-3D shape pairs) and generalization to highly stylized or non-proportional sketches. No one of the tools reviewed covers the entire 3D garment process from the original sketch to the pattern-ready garment, as these constraints show.

Based on this review, the future research directions are as follows: (1) larger paired datasets of 2D garment sketches, 3D shapes, and corresponding 2D patterns to enable end-to-end model training, (2) extending 2D to 3D reconstruction methods, which was mainly based on GraphLSTMs and diffusion models, to occluded, multi-layered and non-Lambertian garments, (3) and introducing and combining YOLOv8-like sketch pattern object detection with scale preserving pattern editing system like PerfectTailor to achieve a truly unified 2D-to-3D-to-pattern pipeline. Knowing that this integration would shift the field from today's suite of specialized, task-specific tools to the single general-purpose conversion tool that the fashion design industry needs

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