

# Structural fashion design elements for aesthetic garment form: visual documentation and pattern-based CLO3D simulation analysis

## Abstract

This study investigates the pivotal role of structural elements in shaping aesthetic garment form, positioning construction as the primary determinant of silhouette and visual identity. Moving beyond conventional design discourse that emphasizes surface ornamentation, the research explores how geometric and mechanical manipulation of fabric generates aesthetic form through structural logic. Seams, panels, darts, yokes, flounces, godets, pleats, gathers, pintucks and cowls are examined as mechanisms that regulate tension, volume, and movement, thereby influencing proportion, balance, and visual harmony within garments. A qualitative approach is adopted, combining literature-based analysis with digital experimentation through CLO3D for virtual pattern development and simulation. Findings indicate that aesthetic form is not solely the outcome of decorative treatments but emerges from systematic structural operations embedded in pattern architecture. Structural elements operate as a framework that governs both the spatial behavior of fabric and the perceptual qualities of the silhouette. This research advances a technical and aesthetic framework, redefining fashion design as an engineered process in which visual expression is achieved through structural precision, bridging functional construction and aesthetic design.

**Keywords:** structural elements, aesthetic fashion design, pattern engineering, garment architecture, silhouette formation, fabric mechanics, digital fashion design

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Md Ahshan Habib, Susmita Urmee Roy,  
Anamika Hossen

Department of Fashion Design & Technology (FDT), Sonargaon University (SU), Bangladesh

**Correspondence:** Md Ahshan Habib, Department of Fashion Design & Technology (FDT), Sonargaon University (SU), Dhaka, Bangladesh

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## Introduction

### Structural foundations of aesthetic garment form

Fashion is frequently perceived through the lens of surface aesthetics color, print, and trend.<sup>1</sup> However, a garment, in its truest form, is a three-dimensional object that interacts dynamically with the human body's complex geometry. Understanding fashion as a discipline of construction requires viewing the designer not merely as an artist, but as an architect.<sup>2</sup> Hegel described clothing as flowing architecture and soft sculpture, highlighting the structural nature of fashion design, where construction techniques define silhouette and aesthetic form. Architecture and clothing share a conceptual link in shaping forms, both reflecting human consciousness and cultural identity.<sup>3</sup> Geometric principles in architecture are mirrored in garment design, guiding internal and external spatial configurations to create soft, rigid, or hybrid structures. Softness emerges through careful fabric manipulation and the architectural extraction of repeated geometric patterns, which, through systematic rearrangement, are translated into textile structures. The application of different materials and processes allows a single design strategy to yield diverse experimental outcomes.<sup>4</sup> Structural elements serve as the foundation of garment design, ensuring each silhouette appears distinct, balanced, and aesthetically compelling. Comparable to character design, where structural composition enhances emotional engagement and visual clarity, fashion construction employs similar principles to achieve both functional and expressive outcomes.<sup>5</sup>

This research extends beyond conventional elements of design to examine structural components that define the physical framework of garments. The seam functions as the primary junction where two fabric planes meet, generating tension and support.<sup>6</sup> From this foundational unit, more complex interventions such as panels, pleats,

and godets manipulate fabric behavior, transforming the garment into a soft building, whose integrity depends on structural configuration. Just as architectural systems dictate a building's footprint and vertical form, structural elements in garments determine silhouette and volumetric expression.

### Defining the scope of structure: function over decoration

In contemporary fashion discourse, there is often ambiguity between decoration and structure.<sup>7</sup> A flounce is a circular or spiral-cut piece of fabric that provides ripple and flare without the bulk of gathers at the seam line. When integrated directly into pattern construction through techniques like slash-and-spread, it becomes a structural element that defines the silhouette rather than a mere decorative attachment.<sup>1</sup> Structural components are those that cannot be removed without fundamentally altering the silhouette. Garment construction is therefore a complex process involving multiple structural interventions that transform fabric into a rational and aesthetically articulated form.<sup>8</sup>

These structural elements perform three primary mechanical functions:

- Contouring:** Seams, darts, panels and yokes replicate, refine, or exaggerate the human form.
- Expansion:** Pleats, pintucks, godets, flounces, cowls and gathers introduce controlled volume and dimensionality.
- Stabilization:** Directional alignment of seams and construction lines forms a framework that prevents collapse and maintains garment integrity.

## Structural mechanics of fabric manipulation for fashion design

The central challenge of fashion engineering lies in fabric, a flexible and unstable medium that responds unpredictably to gravity, tension, and body movement.<sup>9</sup> Fabric manipulation is a three-dimensional translation of flat pattern construction, providing a systematic approach for transforming planar textiles into stable volumetric forms.<sup>1</sup> While fullness and texture techniques have historical roots, contemporary design treats them as deliberate structural interventions rather than decorative additions.

**Seams & panels:** Panels transform flat fabric into a three-dimensional garment.<sup>10</sup> Strategic placement of seams and segments regulates tension and contours the body, converting internal structural requirements into visible design lines that ensure stability and aesthetic balance. Seams and panels as primary structural elements regulating garment segmentation, tension distribution, and three-dimensional form.

The analysis of Figure 1 validates that Seams and Panels function as the primary organizational framework for garment construction. Seams serve a dual purpose: joining fabric sections while acting as visual and structural lines that regulate tension across the body. Panels further organize this structure by distributing volume and defining the three-dimensional shell. Together, these elements establish the construction logic necessary to maintain silhouette stability and achieve precise contouring in the final garment form.



**Figure 1** Seams and Panels Illustration of seam placement and panel segmentation as foundational mechanisms for defining silhouette, contour, and structural stability, (Source: Author's compilation based on adapted references).

The seam is a fundamental component of garment construction, transforming two-dimensional fabric into three-dimensional form. Beyond its functional role as a join, a well-executed seam reflects precision, durability, and appealing refinement. Its quality is defined by both its visual finish and its ability to maintain structural integrity and the intended silhouette over time.<sup>1</sup>

**Darts:** Darts refine garment shape by controlling fabric intake, enabling precise contouring and adaptation to body curvature.<sup>11</sup> Dart is the fundamental tools used to convert a flat, two-dimensional piece of fabric into a three-dimensional form that conforms to the body's natural bulges.<sup>1</sup>

Darts as contouring devices that remove excess fabric to generate three-dimensional shaping aligned with body geometry.

The technical analysis in Figure 2 validates that Dart manipulation is the primary mechanism for converting two-dimensional fabric

into articulated three-dimensional forms. By strategically removing excess fabric and redirecting volume toward body prominences, Darts generate the necessary curvature for precise contouring. This fundamental structural intervention ensures that the garment shell conforms to the human anatomy, establishing the architectural foundation for more complex aesthetic silhouettes.



**Figure 2** Dart Manipulation Illustration of the transformation of flat fabric into fitted three-dimensional forms through Dart manipulation, highlighting their role as primary contouring elements, (Source: Author's compilation based on adapted references).

Darts are not a modern innovation but have evolved throughout fashion history, from early corsetry to twentieth-century couture tailoring. They have consistently functioned as essential devices for shaping garments and achieving desired forms.

**Yokes:** A yoke does more than just add another piece of fabric to any clothes. It has important jobs Yokes define structural subdivisions within the garment, providing support and regulating volume distribution to enhance overall silhouette. One of the primary functions of a yoke is to provide structural support to clothing.<sup>12</sup>

Figure 3 illustrates how yokes function as stabilizing frameworks that organize upper garment structure and facilitate controlled expansion below.



**Figure 3** Yokes as structural segmentation elements that divide garment zones while supporting fit and volume distribution, (Source: Author's compilation based on adapted references).

A yoke also provides shape to a garment, contributing to its overall silhouette and preventing it from looking flat or shapeless. This

directly enhances the garment's fit. The yoke contours to the body's curves at the shoulders or hips.

**Flounces:** The flounce adds playful, flowing volume to the relaxed-fit garments.<sup>4</sup>

It creates movement that makes the garment twirl beautifully. Flounces are circular or semi-circular insertions integrated into garment construction generate continuous drape and controlled edge movement, enhancing silhouette articulation without increasing seam bulk.<sup>13</sup>

Figure 4 shows how geometric construction enables flounces to create fluid volume without additional seam complexity.



**Figure 4** Flounces as circular pattern-based insertions producing continuous drape and dynamic edge movement, (Source: Author's compilation based on adapted references).

A flounce is typically derived from a circular or ring-shaped pattern, in which the inner edge is attached to a seam while the outer edge, being longer, creates fullness at the hem. This difference in edge length generates a natural flare, contributing to volume and fluid movement in the garment.

**Godets:** A godet is a triangular fabric insert incorporated into a seam or cut opening to increase the garment's hem circumference. This technique enables a fitted silhouette through the bodice and hips while generating controlled fullness at the hem, enhancing both the visual form and dynamic movement of skirts and dresses.<sup>14</sup>

Figure 5 demonstrates how godets introduce controlled volume while preserving fitted upper sections.



**Figure 5** Godets as triangular insertions enabling localized expansion and enhanced hem movement, (Source: Author's compilation based on adapted references).

Used to create fluid movement and sculptural silhouettes, this triangular fabric element has shaped garments for centuries, from historical couture to contemporary design. Its continued application highlights its role in generating dynamic form and renewed relevance in modern fashion.

**Pleats:** Pleats are a fundamental structural design element that shape garments and introduce visual interest. They consist of deliberate, structured folds that provide controlled volume, rhythm, and variation in the silhouette. Their structural and aesthetic impact depends on placement, depth, spacing, and direction, with different applications contributing to the overall form and character of the garment.

Figure 6 highlights the geometric precision of pleats in controlling expansion and reinforcing linear structure.



**Figure 6** Pleats as structured folding systems that regulate volume, direction, and spatial rhythm, (Source: Author's compilation based on adapted references).

Mechanical manipulations, specifically pleats, gathers, and pintucks, regulate fabric tension and volume. While pleats provide structured, directional expansion, gathers offer organic fluidity; both, however, transform 2D planes into 3D kinetic forms.<sup>12</sup>

**Gathers:** Gathers are created by drawing fabric together along a seam or edge, producing controlled fullness and soft three-dimensional volume. They function structurally and aesthetically by shaping contours, enhancing drape, and modifying the silhouette through localized fabric compression. Consequently, gathers contribute to garment form by introducing fluidity, visual softness, and dimensional variation.<sup>15</sup>

Figure 7 is an illustrative examples of gathering applications demonstrating their mechanical role as expansion elements. The figure showcases how gathers generate controlled volumetric expansion and dimensional depth, influencing both the spatial behavior of the fabric and the final silhouette across various garment zones such as necklines, waistlines, and bodices.

Gathers are used to shape fabric around body curves, adjust fit without complex darts, and control fullness. Commonly applied in skirts, waistlines, puffed sleeves, cuffs, and necklines, they create a romantic or voluminous aesthetic. By introducing soft, flowing texture and visual interest, gathers contrast with the rigid structure of pleats and enhance the garment's overall femininity and fluidity.

**Pintucks:** Pintucks, or narrow stitched folds, serve both structural and aesthetic functions in garment design. They introduce linear rhythm, subtle contour shaping, and controlled fullness, particularly

in the bodice. By creating raised, parallel folds, pintucks can also be employed decoratively, adding texture and visual interest to clothing.



**Figure 7** Gathers as fabric compression techniques creating soft, irregular volume and fluid drape, (Source: Author's compilation based on adapted references).

Figure 8 demonstrates how pintucks function as micro-structural elements that magnificently influence both form and visual rhythm.



**Figure 8** Pintucks as fine-scale stitched folds providing localized contouring, stabilization, and surface texture, (Source: Author's compilation based on adapted references).

Pintucks are not confined to traditional or vintage styles; contemporary fashion designers frequently incorporate them to add depth, texture, and distinctive character to modern and sustainable garments.<sup>16</sup>

**Cowls:** Cowls are draped fabric elements that create soft, voluminous forms by allowing material to fall naturally under gravity, generating fluid contours and layered depth without structured supports. Their effect depends on fabric properties such as weight, stiffness, and elasticity, with lighter fabrics producing delicate folds and heavier fabrics creating fuller volume.

Figure 9 shows how controlled excess fabric creates fluid, non-linear shaping without rigid structural intervention.

As the garment moves, cowls introduce dynamic surface motion and can serve as focal points that soften the silhouette and enhance tactile richness. Historically, the term 'cowl' referred to the loose hood of a monk's habit, but it has since evolved into a widely used design feature in both women's and men's fashion.<sup>17</sup>



**Figure 9** Cowls drapes as gravity-driven fabric configurations generating soft volumetric folds, (Source: Author's compilation based on adapted references).

Through these structural techniques, the patternmaker achieves a form of mathematical control over textile behavior, enabling fabric to maintain engineered silhouettes that turn from its natural flat state.

### Silhouette as the visual outcome of structural construction

The silhouette is the external contour of a garment, representing the three-dimensional form created when fabric is fully structured around the human body. It serves as a primary indicator of aesthetic identity, defining how the garment is perceived as a complete form. Structural and stylistic components including lines, proportional ratios, and fabric placement critically determine the final silhouette.<sup>18</sup> Panel style lines function as fundamental structural elements directly influencing construction and visual interpretation. Modifying panel configurations alters both physical structure and perceived shape, illustrating the relationship between structural engineering and aesthetic outcome.<sup>19</sup> Construction details such as seam placement and topstitching reinforce structural integrity while emphasizing design lines, transforming internal construction into visible aesthetic expression.<sup>20</sup> Despite the richness of fashion design terminology, technical vocabulary remains limited for explaining how structural components generate garment form.

### CLO3D-based structural simulation and digital analysis of garment form

To systematically examine structural principles, contemporary fashion design increasingly employs digital simulation tools. High-end structural analysis involves deconstructing garment contours and components into precise flat pattern representations, clarifying construction logic and spatial organization.<sup>21</sup> This approach translates complex three-dimensional garments into controllable two-dimensional frameworks. Advanced garments that integrate diverse structural forms, textures, and volumetric effects demand both practical expertise and knowledge of fabric behavior. Digital tools such as CLO3D and Adobe Illustrator enable designers to simulate construction, analyze fabric dynamics, and evaluate structural performance virtually. CLO3D allows real-time visualization of drape, tension, and silhouette formation, bridging pattern design and physical garment behavior. These capabilities facilitate iterative design development, reduce material dependency, and improve precision in structural decision-making.<sup>22</sup>

Through digital simulation, structural elements can be tested, modified, and optimized before physical production, allowing controlled exploration of silhouette and form. Structural design thus serves as the backbone of fashion engineering, integrating functionality, aesthetics, and experiential expression within a digitally enhanced design process.

### Research questions

This study is guided by the following research questions:

- 1) How can structural elements be categorized according to their mechanical roles in shaping garment silhouette formation?
- 2) How do selected structural elements, particularly geometric fabric insertions such as godets and flounces, affect garment movement and structural performance?
- 3) How can a technical vocabulary be developed that emphasizes structural integrity as a foundational principle in aesthetic garment design, rather than surface-level decoration?

### Research objectives

The objectives of this study are to:

- 1) Categorize structural elements based on their mechanical roles in shaping garment silhouette formation.
- 2) Analyze the relationship between selected structural elements, particularly geometric fabric insertions such as godets and flounces, and their influence on garment movement and structural performance.
- 3) Develop a technical vocabulary that prioritizes structural integrity as a foundational principle in aesthetic garment design over surface-level decoration.

## Literature review

### Structural thinking in fashion design: from surface appearance to constructed form

Fashion is frequently discussed in terms of visible surface features such as color, embellishment, textile pattern, and seasonal trend.<sup>23</sup> Yet garments are fundamentally three-dimensional objects that occupy space, interact with the body, and derive their visual identity from construction. In this sense, fashion shares conceptual ground with architecture, sculpture, and other spatial arts. Like architecture, fashion transforms abstract design intention into material form through structural decisions,<sup>3</sup> operating through volume, contour, proportion, and spatial organization. Designers must therefore think beyond surface treatment toward coherent form.

The transformation of fabric from a flat two-dimensional material into a three-dimensional body-related form is a defining operation in fashion design. Fabric itself is planar, flexible, and unstable, but once cut, shaped, and assembled around the human body, it becomes a spatial construct with distinct outline, volume, and internal logic.<sup>23</sup> Structural thinking emphasizes that aesthetic expression in fashion is embedded in the design decisions that govern silhouette, proportion, balance, and bodily relation. Structural elements including seams, panels, darts, pleats, godets, flounces, and gathers act as architectural devices that convert flat material into expressive form. Their importance extends beyond utility, because they establish the aesthetic identity of the garment and provide the foundation for subsequent pattern-based simulation and digital analysis. Although these elements may also produce decorative effects when emphasized visually, they remain

fundamentally structural because they define how the garment is built and how it functions as form.<sup>20</sup> Fashion scholars increasingly describe garments as forms of wearable architecture. Pattern cutting functions as a blueprint through which shape is engineered, while garment construction organizes line, material, and form into a coherent whole. Analyses of fashion design elements repeatedly emphasize that line, material, color, form, and construction are essential to superior design, and among these, structure is indispensable because it governs the material realization of the garment.<sup>24</sup>

### Aesthetic form, structural design, and the role of construction

Aesthetic evaluation considers beauty, visual harmony, and proportional coherence in designed works.<sup>25</sup> In fashion, aesthetic presence emerges not solely from decoration, but from how garments are structurally conceived and executed.<sup>26</sup> Construction governs both functionality and visual identity, ensuring that form and content are unified. The concept of aesthetic form in fashion encompasses harmony, rhythm, unity, and proportion, qualities strongly influenced by silhouette and outline. Silhouette often forms the first visual impression, contributing to emotional, stylistic, and symbolic interpretation. Structural elements are not neutral technical devices; they can carry expressive and symbolic significance. Exaggerated volume may suggest drama or authority, while softer lines imply fluidity or delicacy. Such theoretical perspectives justify systematic analysis using pattern-based frameworks and CLO3D simulation to investigate how construction underpins aesthetic form in garments. In this context, the silhouette becomes a primary means of expression rather than merely an outer edge, reinforcing the view that aesthetic identity is structurally generated.<sup>27</sup>

### Silhouette as the primary visual expression of garment structure

Silhouette is widely recognized as a primary visual dimension of garment design, reflecting the outline and volumetric configuration imposed by structural interventions.<sup>20</sup> Shape is frequently understood through silhouette, contour, textile, and detail, demonstrating that form cannot be isolated from construction and material behavior.<sup>28</sup> In fashion designing practice, silhouette has often been treated as a major evaluative cue. It indicates that clothing style, design details, color, and silhouette together shape consumer judgment, confirming silhouette as a central component of visual assessment.<sup>29</sup>

The term 'style' it has been defined partly through silhouette and structure, further indicating that silhouette is not an isolated visual effect but a primary organizational principle in apparel identity.<sup>29</sup> Combining qualitative and quantitative methods to improve silhouette classification and generate insight into consumer preference and trend perception. The use of aspect-based form factors suggests that silhouette can be studied not only descriptively but analytically, strengthening its relevance as a design and research category.<sup>30</sup>

### Structural elements as mechanisms of shape formation

The creation of silhouette depends on targeted construction devices that shape, suppress, distribute, or expand fabric.<sup>3</sup> Darts remain fundamental, redirecting flat material into fitted, three-dimensional forms, particularly in women's wear.<sup>31</sup> Pintucks control localized fabric distribution, providing subtle contouring and stabilization<sup>4</sup> yokes segment garments into functional zones, regulating volume and facilitating controlled expansion through pleats or gathers. Other elements produce volume, such as pleats, gathers, tucks, flounces, and cowl draping. Straight lines suggest control, while curved lines

imply fluidity; these line-based decisions directly affect perceived silhouette.<sup>32</sup> Flounces, gathers, draperies, tucks, and related three-dimensional elements can act as either primary structural components or balancing devices within a design. Their placement, size, direction, and relation to other garment parts affect not only surface appearance but also volume, asymmetry, and formal balance.<sup>33</sup> Flounces in particular may be understood as manipulated fabric forms that create a wave-like effect, often through diagonal or circular cutting. Their dynamic visual quality can be inspired by organic forms such as floral silhouettes, but their design significance lies in how cut geometry translates into spatial movement and edge behavior.<sup>34</sup> Godets provide another important example of geometric insertion. Godets basically used to keep garments smooth through the waist and hips while generating fullness lower in the skirt. This technique not only increased volume but also visually lengthened the silhouette by extending the garment line downward before it opened into folds, demonstrating how structural manipulation can influence both movement and perception.<sup>35</sup> Morphological analysis in apparel design also confirms the significance of combining component elements in different ways to generate flexible yet comfortable systems of form. Research on women's suits and dresses showed how garments could integrate waist-supported and shoulder-supported structures, belts, tapes, and decorative-structural components such as flounces while maintaining adaptability and aesthetic coherence.<sup>36</sup> These traditional structural interventions provide the foundation for pattern-based and CLO3D simulation, enabling designers to visualize, test, and optimize the spatial and mechanical behavior of fabric prior to physical construction.

### Historical and cross-disciplinary perspectives on structural innovation

Historical fashion shows that structural innovation repeatedly reshapes aesthetic ideals.<sup>3</sup> Corsetry, tailoring, engineered volume, and internal supports have shaped dominant silhouettes and influenced perceptions of the ideal body. Yet many studies focus on stylistic trends or designers rather than the mechanisms through which structural interventions produce visual outcomes. Cross-disciplinary parallels in architecture and engineering reinforce the significance of structural thinking. For example, membrane structures and anticlastic/synclastic combinations illustrate how geometry can serve both functional and expressive objectives.<sup>37</sup> In contemporary fashion research, structure is increasingly treated as a visible, expressive agent, not a hidden support, and this aligns strongly with methods that combine visual documentation and digital simulation.<sup>3</sup>

### Structural design, technical representation, and analytical gaps

Advanced garment development relies on decomposing garment contours and component parts into flat technical representations for systematic analysis and correction of structural relationships.<sup>21</sup> In fashion, structural design operates as a measurable system that extends and stabilizes style.<sup>4</sup> However, existing literature emphasizes technical precision and production efficiency more than the expressive and perceptual outcomes of structural decisions. The same limitation appears in definitions of silhouette outside fashion. One source describes silhouette as a visual figure that exemplifies key features of gesture and communicative form.<sup>38</sup>

Despite extensive discussion of silhouette, form, and structural features, there is limited technical vocabulary for explaining how these components function as primary generators of aesthetic garment form. Bridging this gap motivates the present study, which applies

a pattern-based framework and CLO3D simulation to examine structural mechanics in a controlled, visual, and analytical manner.

### Synthesis and research gap

The literature establishes that fashion design is inherently structural, spatial, and three-dimensional. Garment aesthetics arise from construction devices that shape silhouette, regulate volume, articulate line, and organize bodily relation. Structural elements Seams, panels, darts, yokes, flounces, godets, pleats, gathers, pintucks and cowls function as mechanisms through which fabric becomes form. Nevertheless, existing studies often focus on aesthetics, consumer perception, technical design, or symbolism in isolation. Few integrate these perspectives to explain how structural elements generate aesthetic garment form through specific mechanical functions. This gap supports the present research, which investigates silhouette formation, structural mechanics, and the technical articulation of garment construction through visual documentation and pattern-based CLO3D simulation.

## Methodology

### Research design: A two-phase approach

This study adopts a qualitative, hybrid methodology that differentiates between empirical observation and digital validation. The research is structured into two distinct analytical phases to ensure that traditional construction logic is systematically tested through virtual experimentation.

#### A. Phase 1: Qualitative visual documentation (Observation):

This phase establishes the theoretical Structural Logic of garment construction. Through empirical observation and image-based analysis, ten foundational elements including Seams, Panels, Darts, Yokes, Pleats, Gathers, Flounces, Godets, Pintucks, and Cowls are documented to identify their influence on silhouette and proportion.

#### B. Phase 2: Digital simulation analysis (Validation):

These documented elements are translated into virtual patterns and analyzed using CLO3D software. This phase quantifies the mechanical and spatial behavior of the fabric in a controlled virtual environment, validating the observations made in Phase 1.

### Phase 1: Visual documentation and structural logic

The first stage involves a detailed visual analysis of structural interventions. To maintain technical rigor, these elements are categorized based on their mechanical function:

- a) **Contouring and Segmentation:** Analysis of Seams, Panels, and Darts to observe how grain orientation and segment placement regulate tension and define the three-dimensional shell.
- b) **Volumetric Modulation:** Documentation of Yokes, Pleats, Gathers, and Godets to analyze how fabric compression and expansion influence spatial rhythm.
- c) **Aesthetic Refinement:** Investigation of Flounces, Pintucks, and Cowls for their impact on surface texture and gravity-driven drape.

### Phase 2: Pattern-based CLO3D simulation

In the second stage, the structural parameters identified in Phase 1 are translated into digital prototypes. To ensure a standardized experimental environment, the following protocols were applied:

- a) **Baseline Establishment:** A control garment (Figure 10a) lacking structural interventions was simulated to serve as a comparative benchmark for all subsequent modifications.
- b) **Simulation Parameters:** Standard mid-weight fabric presets were utilized across all models to isolate the impact of pattern architecture from material variables. Particle distances were maintained between 5mm and 10mm to ensure high-resolution drape accuracy.
- c) **Iterative Analysis:** Patterns were refined digitally to optimize the placement and scale of Seams, Darts, and Godets, allowing for the assessment of silhouette formation without material waste.



**Figure 10a** Baseline Simulation CLO3D simulation of a garment without structural elements, exhibiting minimal contour and undefined silhouette. (Source: Author's CLO3D simulation).

### Data synthesis and integration

The integration of visual documentation and simulation data provides a robust framework for investigating garment form. By comparing traditional manual benchmarks with CLO3D virtual prototyping, the study identifies the direct correspondence between specific structural interventions and the resulting aesthetic outcomes. This comparative logic ensures that the digital simulations are grounded in established pattern-making practices.

### Limitations and future directions

While this study provides a comprehensive analysis of structural elements in shaping aesthetic garment form, several limitations must be acknowledged. The investigation focused on a specific subset of structural mechanisms namely Seams, Panels, Darts, Yokes, Pleats, Godets, Flounces, Gathers, Pintucks, and Cowls. While these are foundational, other construction elements may similarly influence silhouette and aesthetic perception but were outside the scope of this research. From a technical perspective, the CLO3D-based simulations serve as high-fidelity approximations of fabric dynamics. However, virtual prototyping cannot fully replicate the complex tactile qualities or the exact material textures experienced in physical reality. Furthermore, the assessment of “aesthetic harmony,” while informed by structural analysis, retains a degree of subjectivity, as perceptions of form vary across different cultural and professional contexts.

The scope of this investigation was primarily limited to women's bodices, skirts, and dresses. Future research should expand this framework to include the structural dynamics of outerwear, menswear, and complex multi-layered ensembles. Additionally, further studies

could incorporate physical fabric prototyping to provide direct empirical validation of digital simulations. By integrating a broader range of materials and construction methods, future scholarly work can continue to deepen the understanding of structural aesthetics in the evolving landscape of digital fashion design.

## Results and analysis of 3D simulations

**Baseline vs. Structural Integration: Seams and Panels:** Seams and panels serve as the foundational units of garment construction, determining tension distribution, contouring, and overall silhouette. Visual documentation indicates that panel segmentation, seam placement, and grain orientation directly influence body fit and volumetric expression.

The analysis begins with a baseline condition to isolate the impact of construction on garment aesthetics. As shown in Figure 10a. The absence of structural interventions such as Seams, Panels, Darts, or Yokes results in a flat, unstable form that lacks three-dimensional definition. This baseline demonstrates that without internal pattern architecture, the fabric grain cannot be manipulated to follow the geometric curves of the body or create a specific silhouette.

The analysis of Figure 10b validates that structural integration is the primary mechanism for transforming two-dimensional fabric into a defined three-dimensional silhouette. Specifically, Panels regulate curvature and maintain structural stability, while Darts and Yokes provide localized shaping and volume regulation. These interventions allow for enhanced contour and silhouette clarity, demonstrating that the garment's aesthetic form is a direct result of engineered pattern architecture.



**Figure 10b** Structural Integration CLO3D simulation demonstrating how the integration of Seams, Darts, Panels, and Yokes transforms flat patterns into articulated three-dimensional forms. (Source: Author's CLO3D simulation).

### Darts and yokes

Darts and Yokes function as localized structural components that regulate fabric compression and expansion. While Darts redirect excess fabric to align with the body's contours, Yokes provide macro-level segmentation and support volume distribution across the garment. As demonstrated in Figure 10b. These elements are essential for creating smooth silhouette transitions, enhancing fit, and ensuring balanced volumetric expression. The simulation validates that these internal interventions prevent fabric collapse and maintain the intended aesthetic form.

**Darts and yokes:** Darts and Yokes function as localized structural components that regulate fabric compression and expansion. Darts redirect excess volume to align the fabric with body contours, while Yokes provide macro-level segmentation and support stabilized volume distribution. As demonstrated in Figure 10b. These elements are essential for creating smooth silhouette transitions, enhancing fit, and ensuring balanced volumetric expression. The simulation validates that these interventions prevent fabric collapse and maintain the intended aesthetic form.

**Pleats:** Pleats create controlled volume by folding fabric in precise, repeatable patterns. They shape the silhouette, add texture, and guide the movement of the material. Depending on fabric weight, pleats can appear soft and flowing or sharp and sculptural.

The simulation in Figure 11a establishes a baseline condition to highlight the limitations of flat construction. The absence of expansion elements, such as Pleats and Gathers, results in a static form with minimal spatial variation. This baseline validates that without specific structural interventions, the garment cannot achieve the volumetric depth or dynamic drape required for complex aesthetic silhouettes.

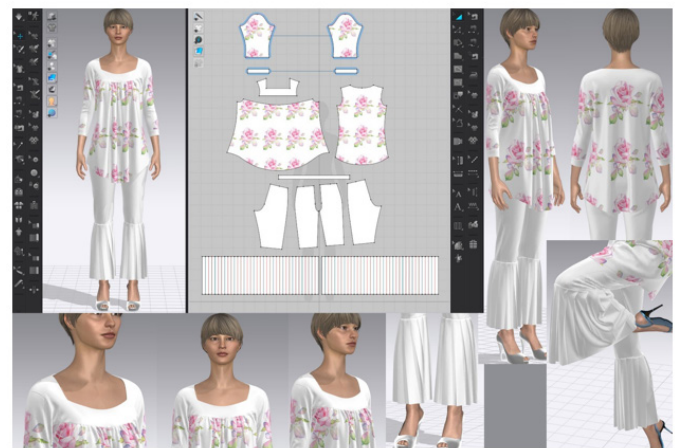


**Figure 11a** Baseline Simulation CLO3D simulation of a garment without expansion elements (Pleats or Gathers), exhibiting restricted volume and a static form, (Source: Author's CLO3D simulation).

The simulation in Figure 11b validates that Pleats and Gathers are primary mechanisms for regulating expansion and spatial rhythm. By manipulating pleat depth and directional orientation, the structural architecture produces predictable three-dimensional behavior and silhouette dynamics. The CLO3D analysis further confirms that specific placement of these elements influences fabric tension and drape, transforming the static baseline into an articulated form with organic volume and aesthetic depth.

**Gathers:** Gathers create soft volumetric fullness by drawing fabric along seams or edges to regulate contour and drape. As demonstrated in the simulation analysis (Figure 11b), Gathers provide localized three-dimensionality by manipulating fabric density. The CLO3D results reveal that tension distribution along these points of expansion directly affects silhouette curvature and spatial fluidity, reproducing the intended aesthetic effect with high precision.

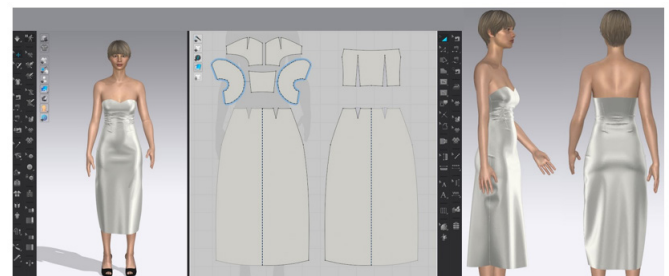
Figure 11b gather Simulation CLO3D simulation illustrating how expansion mechanisms contribute to controlled volume, drape behavior, and silhouette complexity. (Source: Author's CLO3D simulation).



**Figure 11b** Expansion Simulation CLO3D simulation demonstrating how Pleats and Gathers introduce controlled volume, enhancing movement and three-dimensional depth. (Source: Author's CLO3D simulation).

**Flounces:** Flounces, whether circular or semi-circular, generate dynamic movement and continuous edge modulation.

The baseline analysis in Figure 12a highlights the limitations of structurally simplified designs regarding kinetic movement. The absence of rhythmic edge articulation results in a static silhouette with limited visual depth. This comparative benchmark validates that without specific geometric insertions like Flounces, the garment edge remains functionally and aesthetically inert, failing to generate the dynamic spatial variation observed in more complex structural configurations.



**Figure 12a** Baseline Simulation CLO3D simulation of a garment without Flounce integration, exhibiting minimal edge movement and reduced visual dynamism, (Source: Author's CLO3D simulation).

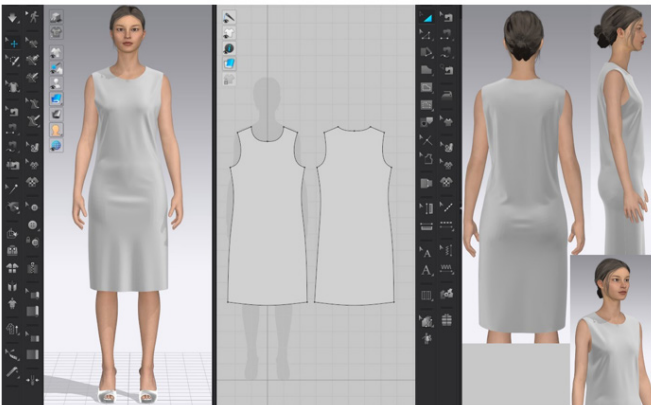
The simulation in Figure 12b validates the role of geometric construction in enhancing motion and silhouette fluidity. The results demonstrate that Flounce geometry maintains intended edge behavior while enhancing silhouette curvature without increasing seam bulk. By strategically utilizing geometric cutting and placement, the structural architecture produces a consistent visual rhythm and volumetric articulation, confirming the predictable behavior of these expansion elements in a virtual environment.

**Godets:** Godets are triangular inserts engineered to expand localized areas of the garment, particularly at hems.

The baseline analysis in Figure 13a demonstrates the structural rigidity of designs lacking localized expansion elements. Without the geometric insertion of Godets, the hemline remains constrained, offering limited kinetic movement and reduced silhouette variation. This comparative benchmark serves to isolate the mechanical function of Godet interventions in transforming a static hem into a dynamic, expanded form.



**Figure 12b** Flounce Simulation CLO3D simulation demonstrating how geometric Flounce application generates continuous drape, edge flow, and volumetric articulation, (Source: Author's CLO3D simulation).



**Figure 13a** Baseline Simulation CLO3D simulation of a garment without Godet integration, exhibiting constrained hem expansion and limited movement, (Source: Author's CLO3D simulation).

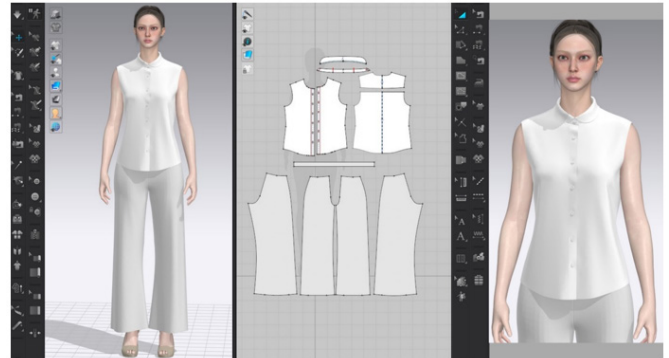
The simulation analysis in Figure 13b demonstrates how inserted panels transform silhouette dynamics and spatial behavior. The results validate that Godets facilitate gradual volumetric expansion and silhouette elongation while ensuring controlled movement. The CLO3D data reflects a harmonious integration of these expansion elements with the primary garment structure, confirming that Godet geometry allows for increased hemline flow without compromising structural integrity.



**Figure 13b** Godet Simulation CLO3D simulation demonstrating how Godet integration enables controlled expansion and increased hemline movement, (Source: Author's CLO3D simulation).

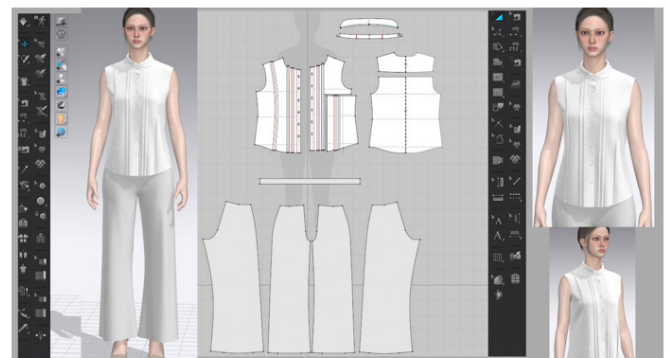
**Pintucks:** Pintucks are narrow stitched folds that regulate fabric distribution at a micro-scale, creating subtle contour shaping and linear rhythm.

The baseline analysis in Figure 14a highlights the limitations of garments lacking micro-structural control. The absence of Pintucks results in a uniform surface area with minimal form definition or rhythmic articulation. This comparative benchmark validates that without these localized structural reinforcements, the fabric maintains a static, undifferentiated appearance, failing to achieve the precise shaping and surface complexity found in manipulated textiles.



**Figure 14a** Baseline Simulation CLO3D simulation of a garment without Pintuck integration, exhibiting a uniform surface and minimal structural detailing, (Source: Author's CLO3D simulation).

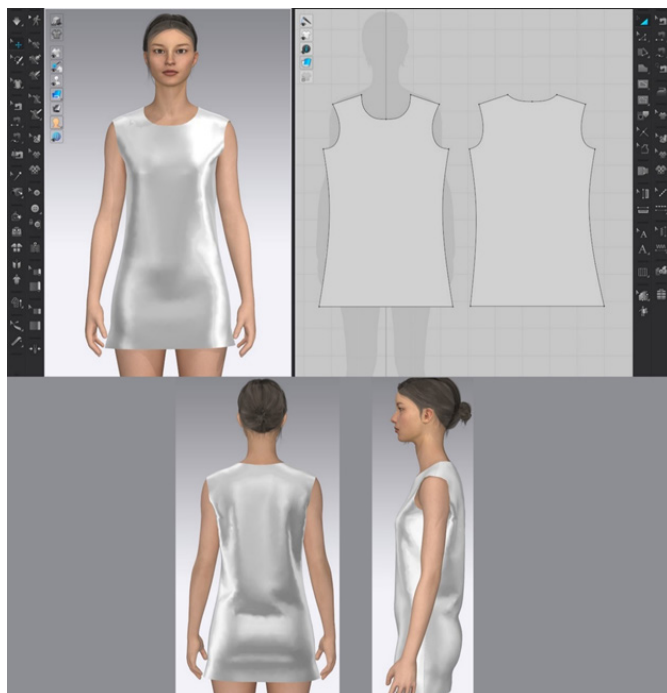
The simulation in Figure 14b validates that Pintuck detailing enhances both structural stability and visual complexity. The results demonstrate that variations in placement and density directly influence localized fabric tension and volumetric control. The CLO3D analysis confirms that these micro-structural elements serve a dual purpose: reinforcing the garment's architecture while providing rhythmic surface texture in both bodice and skirt configurations.



**Figure 14b** Pintuck Simulation CLO3D simulation demonstrating how Pintuck detailing introduces linear rhythm, surface texture, and localized contour control, (Source: Author's CLO3D simulation).

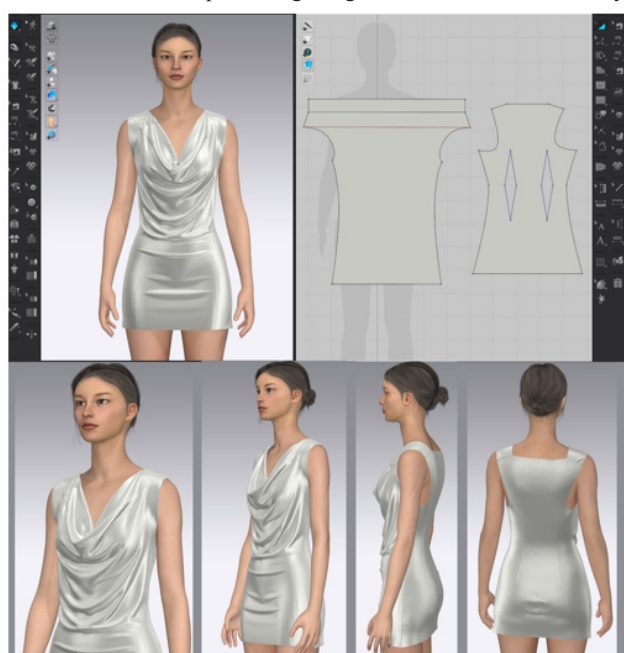
**Cowls:** A Cowl is a structural design element where a section of the garment most commonly the neckline or back is draped to create soft, cascading folds. Unlike the sharp, triangular geometry of a godet, the cowl relies on gravity and the natural elasticity of fabric cut at a 45-degree angle to the grainline.

The baseline analysis in Figure 15a highlights the limitations of conventional construction in achieving gravity-driven shaping. The absence of Cowl interventions results in a rigid structure that lacks fluid volume and spatial depth. This comparative benchmark validates that without specific bias-cut or draped structural logic, the fabric remains static and fails to produce the organic, rhythmic folds characteristic of sophisticated aesthetic garment forms.



**Figure 15a** Baseline Simulation CLO3D simulation of a garment without Cowl draping, exhibiting a rigid structure and limited soft volume, (Source: Author's CLO3D simulation).

The simulation in Figure 15b validates the capacity of draping techniques to generate organic form and fluid movement. The results demonstrate that Cowls applications create controlled surface modulation and soft volumetric expansion through gravity-driven fabric behavior. The CLO3D analysis confirms that by manipulating the orientation and weight of the fabric, the structural architecture produces rhythmic folds that enhance the aesthetic complexity of the silhouette without compromising the garment's functional stability.



**Figure 15b** Cowl Simulation CLO3D simulation demonstrating how Cowl draping generates organic form, fluid movement, and soft rhythmic effects in the garment structure, (Source: Author's CLO3D simulation).

**CLO3D Simulation Insights:** CLO3D simulations provided virtual pattern testing for all structural elements, enabling visualization of drape, tension distribution, and volumetric development. Observed outcomes indicate:

- Panels and seams maintain structural stability while influencing contour lines.
- Pleats, godets, and gathers produce predictable volumetric effects according to placement and fold geometry.
- Flounces and pintucks affect edge movement, linear rhythm, and localized fabric tension.
- Overall, simulation results corroborate visual documentation, demonstrating how structural decisions dictate aesthetic form and silhouette consistency.

**Figures 10-15.** CLO3D simulation snapshots illustrating the interaction of structural elements, fabric behavior, and silhouette formation.

## Discussion

The findings of this study substantiate the proposition that aesthetic garment form is not a secondary outcome of surface ornamentation, but a deliberate result of structural engineering. By integrating conventional pattern-making principles with CLO3D virtual prototyping, the research demonstrates that internal construction, defined here as pattern configuration, functions as the primary determinant of silhouette, spatial volume, and dynamic behavior. At the primary structural level, this logic is governed by contouring and segmentation. Figure 1 (Seams and Panels) and Figure 3 (Yokes) illustrate that dividing a planar textile into discrete zones enables the formation of a three-dimensional shell capable of accommodating anatomical complexity. While seams establish essential junctions for shape development, Figure 2 (Darts) confirms the role of controlled volume reduction in achieving a contoured fit. The transition from the baseline simulation in Figure 10a, which lacks these structural interventions, to the integrated configuration in Figure 10b demonstrates that seams, panels, darts, and yokes must be applied to achieve a stable and defined silhouette.

At the level of geometric augmentation, the study examines fabric expansion through calculated surface insertion. The analysis of Figure 4 (Flounces), Figure 5 (Pleats), and Figure 7 (Gathers), supported by their respective simulations in Figures 11a & 11b and Figures 12a & 12b, illustrates the visual transformation of garments before and after the application of these elements. The results indicate that the introduction of additional surface area at defined coordinates, such as hemlines or seam intersections, produces measurable radial expansion and hem displacement. Within the CLO3D simulation environment, the resulting flare and visual weight correspond directly to pattern radius and grain orientation. These findings confirm that such insertions operate as functional structural modifications, fundamentally altering the garment's spatial footprint and its interaction with gravity.

At the level of mechanical regulation, volume is controlled through systematic compression techniques. The evaluation of Figure 6 (Godets) and its simulation in Figures 13a & 13b shows that directional folding generates structured periodicity, contributing to form stability and controlled rigidity. In contrast, Figure 8 (Pintucks) and the simulation in Figures 14a & 14b demonstrate a more fluid configuration, where localized stitching produces subtle surface texture while stabilizing the fabric grain. Collectively, these results indicate that mechanical manipulations enable precise regulation of material density and controlled expansion of silhouette.

The final structural layer involves the interaction between gravity and grain orientation, as observed in Figure 9 (COWLS) and its simulation in Figures 15a & 15b. The analysis indicates that the characteristic softness and fluidity of cowl drapes arise from deliberate placement along the bias grain, allowing the fabric to deform naturally under gravitational forces. The CLO3D simulations confirm that such complex draping behaviors can be reliably predicted within a controlled virtual environment, extending capabilities traditionally limited to physical draping practices.

Taken together, the progression from Figure 1 through Figure 15 establishes that aesthetic garment form must be understood as a holistic structural system. The visible silhouette is not an independent visual attribute, but the external manifestation of an internally regulated construction logic. The alignment of pattern engineering principles with digital simulation, as demonstrated in this study, supports the development of a rigorous digital-first design framework in which form, volume, and drape are systematically governed by structural configuration.<sup>39–48</sup>

## Conclusion

This study validates that structural elements are the fundamental determinants of aesthetic garment form, functioning as both the mechanical and visual generators of silhouette and spatial rhythm. Through the synthesis of qualitative documentation and pattern-based CLO3D simulations, the research confirms that internal construction comprising elements such as Seams, Darts, and Yokes regulates tension and volume to establish coherent aesthetic outcomes that transcend surface decoration. The integration of virtual simulation proves that garment identity emerges from engineered pattern architecture rather than incidental design choices. The comparative analysis of macro-level interventions, such as Godets and Flounces, and micro-structural elements, such as Pintucks and COWLS, demonstrates a predictable relationship between pattern geometry and three-dimensional behavior. CLO3D simulations have proven to be a critical tool for iterative experimentation, offering precise insights into drape and volumetric distribution while reducing the need for material-intensive prototyping. Conceptually, this research reinforces the practice of fashion design as an engineered discipline where aesthetic identity is inseparable from structural integrity.

By prioritizing the mechanical and spatial functions of construction, this study contributes a rigorous analytical framework for both scholarly research and practical application. Future research may expand these findings by integrating physical fabric validation with digital modeling across a broader range of materials. Ultimately, the study establishes that the visual qualities of contemporary fashion are deeply embedded in structural decision-making, positioning construction as the primary conduit for aesthetic expression.

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## Conflicts of interest

The author declares no conflict of interest.

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