Directing Cloth Draping through Blended UVs

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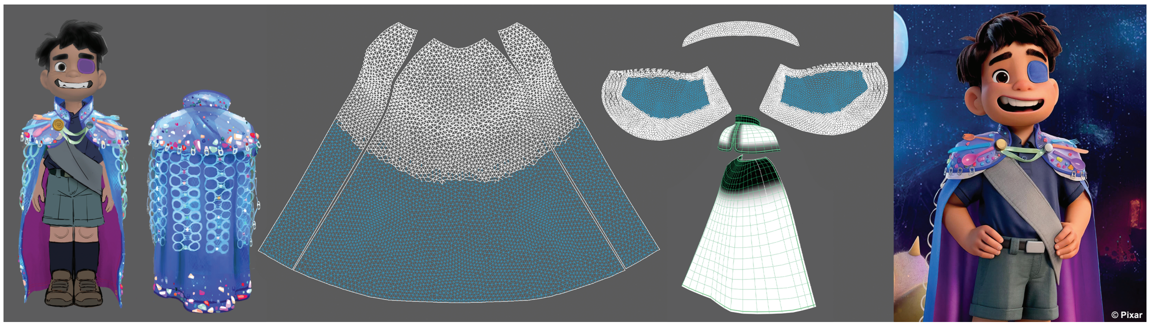

Cloth draping is a prevalent tailoring process that gives 3D form to sewn 2D panels of fabric. However, when dressing animated characters, artists often prefer to model garments with delineated spatial structures and clean silhouettes at the cost of diminishing the presence of folds and wrinkles produced by draping. To reconcile stylization and realism, this work describes a new approach for directing cloth draping that accommodates 3D shaping and 2D pattern making simultaneously. Our key contribution is a method that generates custom UVs blending the distortion induced by 3D shapes into 2D fabric panels. As a result, we can retarget cloth simulations to compute physically plausible draping deformations that smoothly transition to prescribed 3D forms. To assist the garment design, we also propose a flattening tool that constructs low-resolution UV panels amenable to 2D manipulation. We showcase our results with a series of garment assets and cloth animations from Pixar feature films *Inside Out 2* (2024) and *Elio* (2025).

1 Preliminaries

For more than a decade, Pixar has used an in-house 3D system named *C3D* as its sole cloth tailoring tool [Waggoner and de Goes 2022]. In this system, a traditional 3D modeler authors a low-resolution mesh that outlines the garment directly in 3D, and C3D then generates separate simulation and render meshes, each optimized for its particular need. Compared to traditional tailoring techniques, C3D frees the artist from deconstructing a 3D cloth shape into 2D patterns, while still processing the input mesh into a simulation-ready asset. As a result, C3D facilitates the design of stylized garments fit to extreme body proportions commonly found in character animation. From a pipeline standpoint, C3D also unlocks concurrent workflows with quick iterations by downstream departments, notably simulation and shading.

Another distinct aspect in C3D is the construction of the fabric rest state used by our physics simulator (*Fizt*) when computing cloth forces. Instead of 2D panels, C3D encodes the cloth neutral configuration through the so-called *fractured* UVs. More concretely, after tessellating the simulation mesh, C3D disconnects all its 3D triangles and then lays out each one of them rigidly in UV space with a spatially consistent warp-weft orientation. These custom UVs define a material space for the cloth that captures 3D features, thus biasing cloth draping towards its original 3D form. However, by departing from the 2D representation, C3D can only replicate panel-based results when the input mesh is carefully modeled as 3D flat pieces. To further extend artistic reach, we describe next C3D developments allowing for cloth draping that combines the advantages of 2D panels and 3D shapes.

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2 Contributions

Our work draws inspiration from 3D tailoring techniques, such as pressing and padding, that mold pieces of fabric by introducing material distortion during cloth draping. Instead of emulating these physical procedures, we incorporate material distortion in C3D by interpolating the stretching and shearing from the 3D shapes across the 2D panels.

Since C3D operates from 3D meshes, our method starts by computing low-distortion UVs that create 2D panels with minimal user input. In particular, we leverage the fact that user-annotated edges available in C3D (constraining the tessellation of the simulation mesh) often resemble panel boundaries. Therefore, we repurpose these input edge sets and cut the input mesh into 3D patches. Similar to Sawhney and Crane [2017], we unwrap 3D patches into 2D panels by first flattening the boundary of each patch and then computing UVs through harmonic interpolation within each patch. A key difference in our implementation is the joint optimization of all boundary loops, which ensures that every cut edge receives the same length in UV space on both its adjacent panels. Due to the low-resolution of the input 3D model, the resulting 2D panels are well-suited to pattern-making techniques, including slash-spread for gathers and ruffles. Finally, we transfer these UV panels from the input mesh to the simulation mesh through C3D remeshing routine.

To inject material distortion, we formulated a blending scheme that mixes C3D fractured UVs with our auto-generated 2D panels. For each triangle of the simulation mesh, we extract the 2×3 matrix $\mathbf{F}$ that deforms the 3D triangle onto its associated UV shape. Next, we compute the singular value decomposition $\mathbf{F} = \mathbf{U}\mathbf{S}\mathbf{V}^t$, where $\mathbf{U}$ is a 2×2 matrix indicating a 2D orthonormal frame, $\mathbf{V}$ is a 3×2 matrix with columns corresponding to orthonormal tangents to the 3D triangle, and $\mathbf{S}$ is a 2×2 diagonal matrix with principal stretches $s_1 \geq s_2 > 0$. In our setup, artists can also author two blending values α and β per face of the input mesh, which C3D transfers to the simulation mesh in order to weight the desired amount of scaling and anisotropy. Equipped with these weights, we define the blended stretches as $\log \widetilde{s}_1 = \alpha/2\,(\log s_1 + \log s_2) + \beta/2\,(\log s_1 - \log s_2)$ and $\log \widetilde{s}_2 = \alpha/2\,(\log s_1 + \log s_2) + \beta/2\,(\log s_2 - \log s_1)$, both calculated in log-space to equally account for compression and stretching. At last, we construct the blended UVs by transforming each 3D triangle with the matrix $\mathbf{U}\widetilde{\mathbf{S}}\mathbf{V}^t$, where $\widetilde{\mathbf{S}}$ is a diagonal matrix with the blended stretches. As a result, we can restore 3D proportions when α and β approach zero, while favoring flat panels as the weights increase to one.

3 Results

Our directable draping technique was used by Pixar features *Inside Out 2* and *Elio* to produce dozens of unique garments. The teaser figure exhibits the art reference and the final render for one of Elio's capes, with the center image displaying our blended UVs and color-coded weights (here we used $\alpha \equiv \beta$). In this example, fractured UVs were employed to retain the volume of the cape's upper part (in black) to better hold the shoulder volume, while the cape's bottom part is more free flowing driven by 2D panels (in white). Similarly, we kept structured outlines for both the capelet and the collar by favoring the 3D shape encoded by the fractured UVs, while creating gathers inside the capelet based on the dart-excess manipulation of the 2D panels. The supplemental video provides additional draping results comparing our blending approach versus simulations using fractured UVs deduced from the 3D input mesh and traditional 2D panels.

References

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