Simulating woven fabrics with Weave

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Figure 1: Left: Woven jacket in *Peter Rabbit* movie, rendered using *Animal Logic*'s path-tracer *Glimpse*. Top row: Stitch patterns. Bottom row: Thread displacements, fuzz and frayed edges. ©Sony Pictures Animation. All rights reserved.

ABSTRACT

In *Peter Rabbit*, modeling and surfacing artists needed to create photorealistic clothing for CGI characters. Existing techniques such as using repeating texture and displacement maps do not hold up for close-up shots. Peter's iconic blue denim jacket also needed to seamlessly match a real, hand-stitched and worn reference used in the live action shoot. Furthermore, we needed to support many different types of fabrics for dozens of characters. We had initially developed a system called *Weave* for simple capes and flags in *The LEGO Movie* and *The LEGO Batman Movie*, but to support higher levels of detail and flexibility, we extended it to procedurally generate highly customizable patterns of woven fabrics. The novelty of our system lies in its capability to generate realistic weaving and stitching patterns, fuzz, wear and tear in a simple and artist-driven framework.

CCS CONCEPTS

• **Computing methodologies** → **Parametric curve and surface models**;

KEYWORDS

parametric curve modeling, weave, thread, stitch, fuzz, fabric.

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1 OVERVIEW

In the preprocessing step for fabric simulation, artists use *Marvelous Designer* [Inc 2017] to create a reference cloth mesh together with its UV layout, which is used to control the arrangement of threads. Guide curves can be optionally used on the reference surface for stitch generation. *Weave* takes the cloth mesh, UV layout and guide curves as inputs, then generates interlacing threads, stitches and fuzz curves on the mesh.

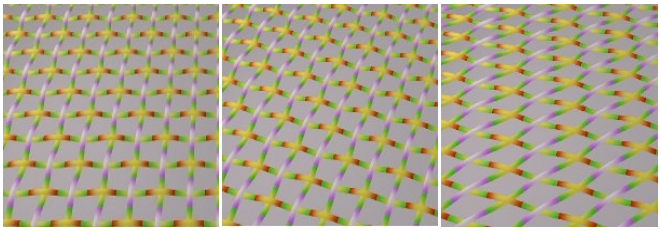
The system allows the artists to choose from predefined patterns or create their own weave styles, and add arbitrary displacements to the threads. They can create holes or runs along the threads, as well as fray the edges to resemble the look of worn-out fabrics. To add further realism, they can procedurally add fuzz breaking out from the main threads.

In the postprocessing step, cloth motion is simulated using Houdini. The final animated woven fabrics are rendered using Animal Logic's proprietary path-tracer *Glimpse* [Heckenberg et al. 2017].

2 MAIN WEAVE CONSTRUCTION

The core part of *Weave* generates threads as 3 distinct sets of curves: u-threads (longitudinal), v-threads (lateral) and frayed threads.

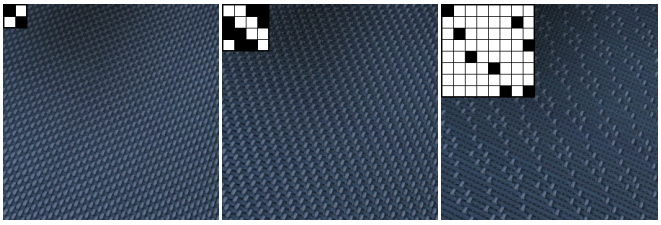
Primary u and v directional threads are arranged according to the input UV layout, thread densities, rotation and shear angles, as illustrated in Fig. 2. The generated curves naturally track the deformation of the underlying mesh due to their adherence to the associated UV-space.



(a) (b) (c)

Figure 2: (a) Default threads, (b) threads rotated by 10^o and (c) sheared by 20^o.

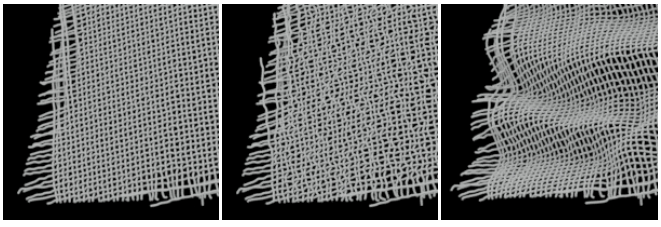
Intersections between u and v threads are computed in parallel for high performance. A user-defined binary weave pattern controls whether a u thread or a v thread is on top at each intersection point. Fig. 3 shows some weave patterns and our corresponding 3D results.



(a) (b) (c)

Figure 3: Weave patterns: (a) plain, (b) denim, (c) 8-H satin.

Thread thickness is defined for u and v threads as a relative scaling factor. An amplitude map is used to specify the height gap between interleaving threads. In addition, random offset and curve displacement maps can be used to add arbitrary deformations to the threads (Fig. 4). Surface parametrized (u, v) random offsets shift the corresponding threads on the mesh surface, maintaining their relative order. Curve displacements push the thread points along the underlying surface normals (Fig. 1).



(a) (b) (c)

Figure 4: (a) Threads without deformation, (b) with random offsets and (c) with displacements.

Our tool also allows artists to define a hole-map to split the threads, creating holes in the fabrics. Frayed edge options can be additionally used to simulate the splitting of fibres at the end of the weave threads (Fig. 1). Options include fray probability, fibre width, length and angle with respect to the parent thread, as well as the amount of spread, twist and scraggle on the frayed edges.

3 STITCHES

Stitches are created independently of the main weave threads. Artists use an interactive in-house tool to create a set of guide curves on the surface of the reference cloth mesh. Stitch curves are then generated to follow these guide curves, and contain extra control points above and below the mesh.

At each point we define a local coordinate system, with the y-axis pointing along the curve direction, z-axis along the mesh normal, and x-axis on the mesh tangent plane. Changes in the y-direction allow customizable stitch types, such as zigzag or spiral (Fig. 1). The x-value represents the curve shift from left the right on the mesh plane and z-value represents the shift along the mesh normal. The points are driven by a set of parameters, defining the widths, depths, lengths and random offsets of the output stitches.

For further realism, stitches are used to deform the intersecting weave threads and simulate "pillowing" effects.

4 FUZZ

In addition to the weave threads and stitches, we observe that fuzz breaking out from the main threads adds further realism to garments, especially in close-up shots (Fig. 1). We simulate this fuzz using an additional set of curves, originating from the main threads with probability defined by a density map. Similar to other curve types in our system, fuzz appearance can be controlled by a rich set of parameters, such as how these fibres scraggle, rotate about the surface normals, or incline towards the cloth mesh. The widths and lengths of the fibres can also be adjusted to resemble different stages of wear and tear on clothing.

5 RENDERING

The outputs of our *Weave* system are Catmull-Rom curves, with width and normal-projected base mesh (u, v) information at each control point. Colours are derived from u-v aligned texture maps. Bump-maps may also be used to add subtle fabric shading variations. To keep our representation light and fast to render, we do not support displacement of the curve surface itself. Rendering is achieved using *Glimpse*, our in-house path-tracer [Heckenberg et al. 2017]. We convert curves into piecewise parametric conic sections, connected via filleted spheres, with fuzz independently diced into camera-facing bezier curves. Subdivision is performed on the fly, with parameteric intersection information used to find colour and normal data for shading. We use a typical BSDF, incorporating a Jensen dipole for multiple scattering, a single scattering component, and specular/diffuse lobes. Reference measured data is used to parameterize the shading model, with artistic tweaking to obtain the final look.

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