Simulated fatigue and wrinkle synthesis for clothing appearance design

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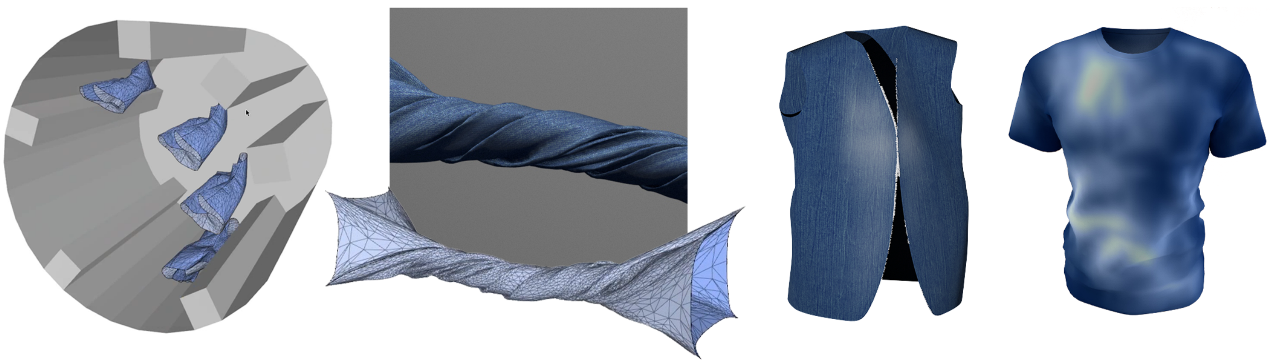

Figure 1: Cloth simulation produces impacts (left) and complex wrinkle patterns (left center) that can mimic fatigue (right center) and specialty dye effects (right).

ABSTRACT

This research investigates the use of cloth simulation in the design of clothing that includes purposeful fatigue and wrinkle effects. Modern clothing manufacturers distress and process garments in a variety of ways, such as artificial wear, or wrinkle-based dying. This work showcases a set of processes that exploit simulated wrinkle and collision histories recorded from in custom animations in order to synthesize information useful in generating the visual appearance of a variety of related wear and wrinkle effects.

CCS CONCEPTS

• **Computing Methodologies → Animation**; *Physical Simulation*;

KEYWORDS

physics-based animation; cloth simulation

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1 INTRODUCTION

The appearance of modern clothing is highly designed, including the production of distressed, processed fabrics, and assembled artifacts. While intended for other purposes, existing cloth simulation technology carries many of the necessary mechanisms to mimic key processes, for example through simulating wear of virtual clothing (Figure 1, left) and synthesizing believable wrinkle patterns (Figure 1, left center). Here we describe techniques for augmenting existing cloth simulation pipelines to develop methods for producing designed artifacts that exhibit purposeful wear (Figure 1, right center) and stylistic design of appearance for clothing (Figure 1, right). Namely, we develop two fronts in this preliminary exploration - wrinkles for appearance based design and collisions to simulate fatigue in cloth.

The motivation of this research is to explore the use of cloth simulation as an aid for pre-visualization for designers to both develop the desired appearance of next generation products, but also to communicate those designs to both manufacturers and buyers. Current industry standards rely on slow and expensive iterative processes between designers and manufacturers to develop prototypes, often across great distances which adds additional delays.

And these prototypes are then used as physical samples shopped around to various buyers. When a product does not sell, this cost of development is lost and therefore the entire process of design remains high risk, leading to designs that are often conservative from season to season, curbing the design process. Our goal is to provide design tools that sidestep the prototyping stage and create virtual artifacts that will directly lead to buyer selection. While this lofty goal is not yet achieved, the novel contributions of this work bring the ideas closer to reality through a set of developed proof-of-concept examples.

In computer animation, high quality cloth modeling has reached a convincing level of realism by simulating a wide range of real-world cloth characteristics [Chen et al. 2013; Kaldor et al. 2008; Miguel et al. 2013; Pfaff et al. 2014]. Further effort has been placed in the creation of realistic visual appearance and rendering of cloth as well [Schröder et al. 2012]. While engineering aims to capture subtle phenomena such as inter-yarn friction to predict the response of cloth [Zeng et al. 2006], computer graphics' aim for visual realism is aligned with the goal of producing convincing virtual prototypes. To this end, we use existing cloth simulation tools, such as ARC-Sim [Pfaff et al. 2014], and augment the simulation systems to extract the desired data for wrinkles and collisions. These are then input to custom appearance and shading networks to produce the visual output desired.

2 WRINKLE SYNTHESIS

The hills and valleys of folds hold information about how the clothing has been handled over time. Wrinkling and folding of clothes over time can lead to wear, as evidenced by a broken-in pair of jeans, but wrinkles also often serve as inputs into purposeful dye and other fabric effects, such as the signature appearance of tie dye (see Fig2).

In everyday wear, repeated folds indicate which areas of clothing wear down, which can lead to discoloration (fading) of the fabric. To simulate this process, we compute the curvature of the fold in aggregate over time and store this fold "history" to mimic the wear process. Specifically, we compute curvature between neighboring triangles in the fabric mesh and record folds above a given value for each time step. This fold "intensity" is accumulated over time during the course of the simulation. This accumulation leads to wear of the fabric, which is visualized through discoloration of the blue fabric in Figure 1a.

Wrinkles are also used in the textile industry in design of rich visual surface effects. The hills and valleys of folds during dying (and other processing) change the outcome by limiting where dye can reach as well as the amount of exposure. There are several ways to create a tie dye t shirt, controlled by how the garment is folded as well as where the dye is applied.

Figure 2: Swirl tie-dye effect. We create this tie dye effect to a swirled shirt pressed into a flat pancake shape (bottom row). Each radial slice is colored with a different color dye leading to the texture map shown (middle). This process results in the popular spiral shape on the final rendered design (top).

3 FATIGUE SIMULATION

Wear of the fabric happens due to natural use over time, or it can be added intentionally through manufacturing processes such as laser etching. We can mimic such processes, for example by putting cloth through a virtual laundry simulation (as in Figure 1). Notably, impacts from the tumbling action of dryers is known to contribute to fabric damage [Society 1999]. Clothing manufacturers use a variety of tools to rip and tear garments either by hand, or with chalk, scissors, or even sandpaper. There are many different levels of such design directed *abrasions* that are popularly seen on fabric, especially denim.

The output of directed simulations like those shown in the video can include both information about the wrinkles (as above) as well as the impacts that lead to fatigue. While folds create some of the interesting effects, the impacts on the clothing also lead to wear in real-world clothing. The more impacts that the article of clothing experiences in a certain region, the more wear that fabric suffers. By augmenting the simulation to record when the mesh is in contact, we approximate the history of impacts that lead to fatigue. Specifically, we build a data structure within ARCSim that accumulates impacts by incrementing indices within the triangle mesh at each timestep based on contact. While real-world fatigue is derived from a variety of factors, this simple history was effective at revealing where the bulk of impacts were present over the duration of the simulation.

To this end, we showcase how a vest collides inside a dryer. Due to the pointed convexity of the front of the garment, the vest specifically creates more impacts on these edges and nearby interior as shown in the visualization of the collision history in Figure 3. When coupled with custom surface models, the appearance of fatigue can be automatically generated. As shown in Figure 3, to specifically create the effect of the denim vest, we build two custom tools, one to handle fading (in Substance Designer) and the other to include fraying (in Houdini). The latter is adapted from a fur simulation that seeds the hairs on the edge of the vest based on the collision history from the simulation.

In the textile industry, purposeful abrasion can be found in many forms, including sandpaper, prewashing, and a variety of other friction and collision scenarios. In all, the amount of abrasion in a specific region of cloth can accumulate the effect of wear of the fabric. While we generate examples based on scenarios that are realistic, the tools do not limit the designer to these animations and allow input at any level. Thus wear of the fabric can appear natural over time due to use, or it can be applied intentionally through artist-driven design.

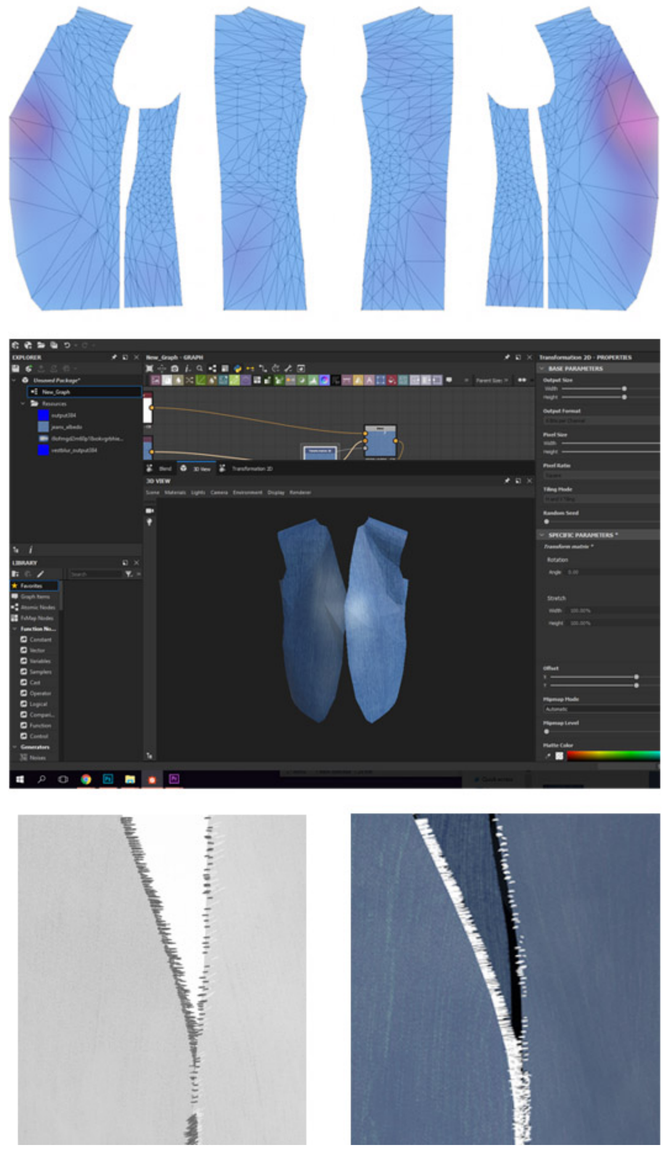

Figure 3: Faded vest simulation. The output of a laundering process leads to an impact history showing the areas of potential wear (top row). This information is passed through a custom shading network to create the visual appearance of fading (middle) and adds fray to the edges that exhibited the highest wear (bottom).

4 CONCLUSIONS

The research presented here is only a preliminary investigation in the concept of simulated fatigue and wrinkle synthesis for clothing appearance design. As an initial pass through the topic, we have explored the augmentation of off-the-shelf systems in the development of realistic and designer driven appearance effects. In the future, we wish to explore more tight coupling between the real-world processes and the outputs of our simulations. Further, the artist or designer driven flow from concept to finished design needs better representation in our approach. However, we are excited to showcase the potential for augmenting simulation of cloth to produce predictive as well as controllable appearance in textile garments.

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REFERENCES

Zhili Chen, Renguo Feng, and Huamin Wang. 2013. Modeling Friction and Air Effects Between Cloth and Deformable Bodies. *ACM Trans. Graph.* 32, 4, Article 88 (July 2013), 8 pages. https://doi.org/10.1145/2461912.2461941

Jonathan M. Kaldor, Doug L. James, and Steve Marschner. 2008. Simulating Knitted Cloth at the Yarn Level. In *ACM SIGGRAPH 2008 Papers (SIGGRAPH '08)*. ACM, New York, NY, USA, Article 65, 9 pages. https://doi.org/10.1145/1399504.1360664

Eder Miguel, Rasmus Tamstorf, Derek Bradley, Sara C. Schvartzman, Bernhard Thomaszewski, Bernd Bickel, Wojciech Matusik, Steve Marschner, and Miguel A. Otaduy. 2013. Modeling and Estimation of Internal Friction in Cloth. *ACM Trans. Graph.* 32, 6, Article 212 (Nov. 2013), 10 pages. https://doi.org/10.1145/2508363.2508389

Tobias Pfaff, Rahul Narain, Juan Miguel de Joya, and James F. O'Brien. 2014. Adaptive Tearing and Cracking of Thin Sheets. *ACM Trans. Graph.* 33, 4, Article 110 (July 2014), 9 pages. https://doi.org/10.1145/2601097.2601132

Kai Schröder, Shuang Zhao, and Arno Zinke. 2012. Recent Advances in Physically-based Appearance Modeling of Cloth. In *SIGGRAPH Asia 2012 Courses (SA '12)*. ACM, New York, NY, USA, Article 12, 52 pages. https://doi.org/10.1145/2407783.2407795

American Chemical Society. 1999. Cotton Fabrics Damaged By High Dryer Temperatures. *ScienceDaily* (1999).

X. S. Zeng, V. B. C. Tan, and V. P. W. Shim. 2006. Modelling inter-yarn friction in woven fabric armour. *Internat. J. Numer. Methods Engrg.* 66, 8 (2006), 1309–1330. https://doi.org/10.1002/nme.1596 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/nme.1596