Generating Predictable and Convincing Folds for Leather Seat Design

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Abstract

In this paper we describe a method for designing and visualizing folds in leather car seats. Since the manufacturing process cannot completely control the final result, an accurate simulation is neither possible nor needed; instead this tool functions as a sketchpad for the designer, and as a means for communicating the design as 3D model for design and production decisions. The method supports the designers' needs to create realistic looking folds and quickly and easily manipulate their position and appearance. For this, a minimal set of intuitive controls has been selected. The tool covers a range of realistic visual results for the designers and delivers the correct sewing pattern for production.

Categories and Subject Descriptors (according to ACM CCS): I.3.5 [Computer Graphics]: surface modeling, I.3.7 [Computer Graphics]: animation, texture

Keywords: surface modeling, procedural modeling, user interaction, folds, wrinkles

1 Introduction

Modeling realistic looking folds and wrinkles has led to a variety of tools and methods in the fields of character animation, cloth simulation, and in the design process of clothing and shoe fabrication. Wrinkling skin and clothing in character animation has improved the visual experience and quality of animation featured films.

In the manufacturing process of car seats various flat pieces of leather are sewed together. During the sewing process folds and wrinkles can be introduced when the leather is compressed along the seam. These folds are an important design feature but are highly irregular and their shape depends on the process itself and its execution.

Therefore our goal is not a predictive simulation, but a design tool. Our visualization enables designers to communicate their design to manufacturers, who can then in turn use their expertise to evaluate whether it can be realized and if not, what changes have to be made.

Our approach introduces a new method to add wrinkles and folds to sewn pieces of fabric or leather. In this paper we additionally address the problem of highly compressed areas along the outline of a 3D surface and the inward areas where folds emerge.

The irregular look of folds originates from the sewing process. It depends on shear and bend forces applied by the manufacturer during sewing, on internal compression forces and on material properties.

Our method uses a simple model that makes assumptions where folds emerge, how they bend under stress and whether nearby folds attract each other. With this approach we can interactively model soft as well as stiff tissues. To enhance the appearance of our folds, we introduce texture space transformations along the folds to visualize the behavior of real material under compression.

Our method also produces a correct cutting pattern based on the enlargement along the outline which can be used as cutting pattern.

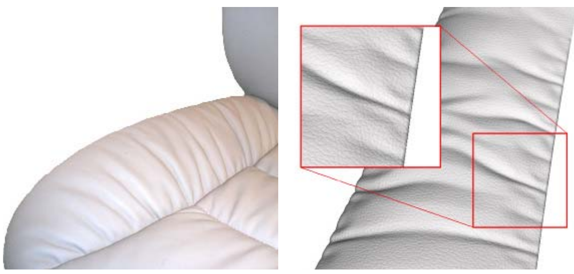

Figure 1: Comparison of folds and wrinkles on a photo on the left and on a virtual 3D surface on the right.

2 Related Work

Related research on wrinkled and folded surfaces was performed in many areas, including: computer graphics, character animation and in industrial areas for textile applications. Methods range from physical based simulation to geometrical approaches depending on the need of accuracy or speed.

Skin aging and facial expressions make heavily use of wrinkling models and methods. The methods described in these fields use rest pose and geometrical approaches [CN02, LC04, DJW*06], spring-mass models, relaxation models [Lov06] and particle based models [OM01], or abstract muscle models [Wat87, MTh88, WMT94] and finite element methods as discussed in [BKMK00] and references therein. Others use a base model with a set of displacement methods to generate wrinkles following the "Simple Facial Animation Object Profile" defined by the MPEG-4 standard [PP01].

Larboulette et al. [LC04] use a geometrical approach by compressing a control curve and alternate the position of the control points to preserve the original length of the curve. The vertices of an underlying mesh (model) are displaced in a defined area of influence.

Tang et al. [TW05] introduce a method for folding leather by using two C^1 continuous curves in space. These two curves define the shape of the material in rest pose. If an interpolation of the two curves defines a developable surface then this surface can be flattened to 2D space. This method is a suitable for manufacturing precisely because compression or stretching of tissue is avoided anyway.

Loviscach [Lov06] used a relaxation model based on the preservation of length during kinematics. His approach is fully GPU-based and generates plausible folds. But these folds tend to look softish, have a very regular shape and are not at all suitable for folds that emerge from stiff material compression like leather.

Decaudin et al. [DJW*06] introduce a geometric approach to create folded, sheared and compressed clothing. This method has similar drawbacks as the methods mentioned so far. It is good for clothing design but can not cope with high compressed stiff tissue where the thickness of the material plays an important role during compression.

3 Folding process in reality

To manufacture a car seat with folds (as one can see in figure 1) several steps must be taken. The designer chooses a specific seat design and sketches the folds. The sketches are reviewed by the manufacturer to be accepted, altered or rejected.

If a design is accepted, the cutting pattern has to be changed for each piece involved in the folding process since additional material is needed for folds. For the altered version the original pattern is cut into smaller pieces by hand and spread to expand the outline. Sticky tape is then used to fix the gaps and form the new pattern which then in turn will be used in the cutting process. Figure 2 shows the virtual cutting patterns, the original one with cuts marked in red (a), the altered version where the left side is elongated by spreading the cuts (b), in comparison with a photo of an altered pattern from the real process (c).

The new pattern is used to cut out pieces from the needed material. During the sewing process of two pieces folds are introduced when the elongated material is compressed along the seam (see figure 3a).

Depending on the applied compression forces and the material's thickness in some areas the material cannot fold anymore which leads to wrinkles that emerge due to material's inner structure. The wrinkles are visible in the valleys of the folds as one can see in figure 3b.

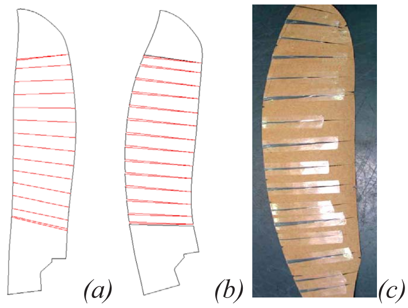

Figure 2: Schematic view of a 2D original pattern with marked cuts (a) and altered pattern with fold-cuts spread (b). In (c) a photo of an altered pattern in the real process was taken. One can see the sticky tape in this photo very well, by courtesy of BMW Group.

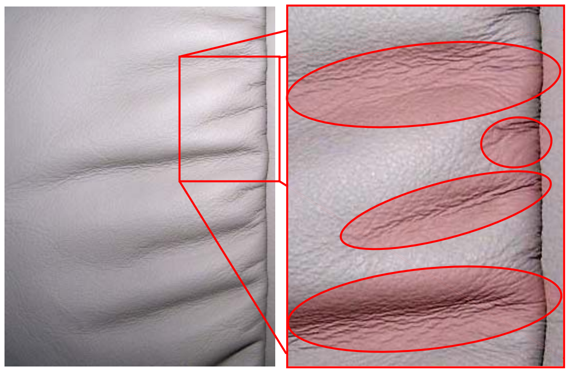

Figure 3: Photos of folds and wrinkles. In the distance folds are visible (a), the close-up shows the structure of the wrinkles (b) by courtesy of BMW group.

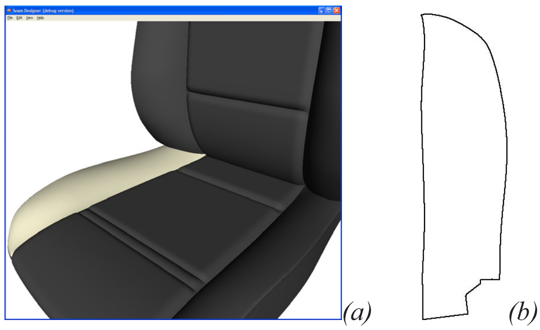

Figure 4: 3D model with selected piece (highlighted) and its original 2D pattern (for cutting machine).

4 Folding virtual models

Before we talk about or approach, it is necessary to define our nomenclature.

In 3D space we call each seat part a *piece* whereas in 2D space we refer to it as a *pattern* (figure 4 a&b). So a *pattern* is the flat counterpart to the *pieces* 3D surface. The pattern's shape is used by the cutting tool. Therefore each *piece* has an associated *pattern*, and vice versa.

In this paper we call the large scale bumps in the material *folds* whereas the term *wrinkle* is used for the tiny, small bumps along a seam between the folds which evolve from high compressed material (see Figure 3 a&b).

The basic idea of our approach was to mimic the manual design process of fold sketches and cut pattern alteration and give the designer a tool which generates realistic looking folds. The visual results can be used by designers to communicate their design to manufacturers, who can then in turn use their expertise to evaluate the design whether it can be realized and if not, what changes have to be made.

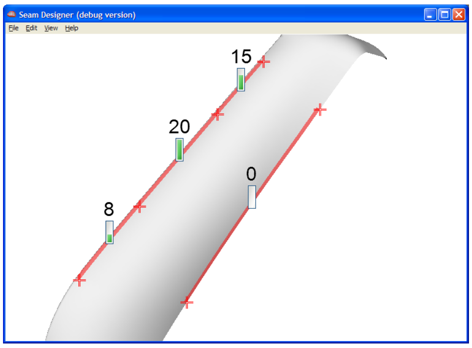

Figure 5: The left path is divided into three segments with different compression rates.

4.1 User interface

To mimic the design process and design cycle of folds in our virtual tool, the user has to select a piece of the 3D model (fig. 4). Afterwards he defines two *paths* along the piece's outline (see fig. 5). These paths define the region wherein folds should appear and where material is compressed.

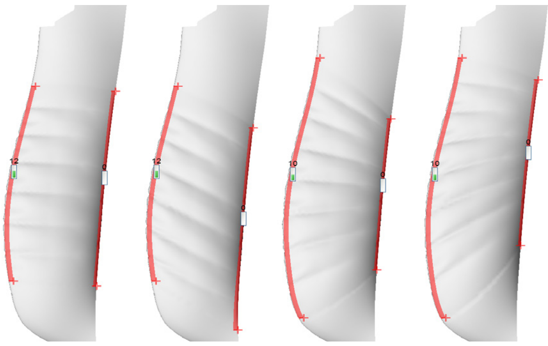

Figure 6: The relative position of the two path and their start and end points define a general direction of folds. Parallel (a), parallel sheared (b), spread (c), sheared and spread (d).

As in the manual design process each path in the virtual folding process can be divided into smaller *segments*. The compression of each *segment* can be changed individually. The compression is specified by changing the percentage of material to add along the segment (fig. 6). During the modification of the percentages the 3D model is updated and the emerging folds are shown, so that the user can make changes interactively to fit the design.

The general direction of the folds is defined by the start and end points of the two paths. To get parallel folds the paths should be of the same length and the start and end points should lie opposite (fig. 6a). If the length of each path is kept the same but the start and end points are shifted in a way the folds will be sheared (fig. 6b), to get folds that spread out one path should be longer than the other (fig. 6c&d). With this simple interface many different shapes can be generated.

4.2 Seeding points and fold curves

As we found in the real application of folds and based on the result of the method introduced by Larboulette [LC04] folds emerge nearly periodically along a path.

Real folds emerge every 20mm to 25mm, so we generate fold curves with nearly the same periodical spacing in our model. These fold curves build the 1st order folds and run over the whole pieces (see fig. 6). 2nd and 3rd order *fold curves* are introduces between 1st order folds. Two 2nd order folds are seed in between 1st order folds and two to three 3rd order folds between 2nd order folds depending on the curvature of the 3D model and the compression level (see fig. 7a). The length of each fold is determined by its order. This enhances the visual results and mimics the deformations from inner and outer forces of a real material under compression and at the outline of the piece where the seam prevent emerging folds.

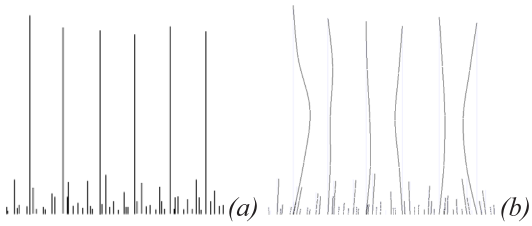

Figure 7: Seeding points define where folds emerge – 1st, 2nd and 3rd order curves are shown (a). Interaction with neighboring folds depends on material properties (b).

In figure 7 the different orders of fold curves in the 2D domain are shown. To simulate stiffness and other material properties each *fold curve* influences neighboring *fold curves* based on attracting and repelling forces along each fold. This leads to soft bending curves as one can see in figure 7b. The influence is greater for soft materials whereas for stiff materials the fold curves keep very straight. See the right picture in figure 1 for a soft material example.

Each *fold curve* in the 2D domain corresponds to a subset of vertices in the 3D model. Vertices in vicinity of a *fold curve* are displaced in direction of the surface normal. The *folding kernel* a displacement and weighting function along the fold curve describes the shape of each fold (see fig. 9). The vertex's new position is computed by its original position plus its surface normal multiplied by the result of the folding kernel's function.

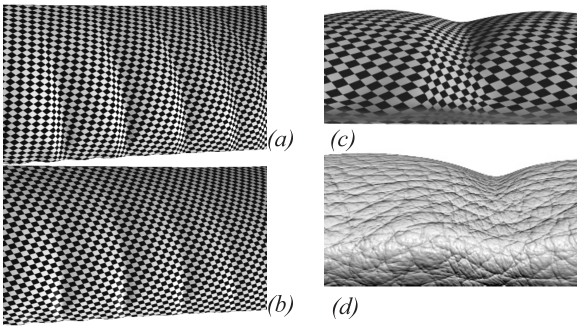

Figure 8: Compressed texture space enhances the visual result of folds.

This process is mimicked as in reality. The pattern is virtually cut along folds and each cut is spread due to the elongation of the material (see fig. 2).

The compression of material in the valleys between the folds is visualized by distorting texture coordinates. In the spread regions texture space is crunched to visualize the tiny wrinkles that emerge due to the compression occurring in reality. The compression vanishes in the direction of the fold curve and the material begins to bend and form the typical shape of the folds. Figure 8a&b shows the results with and without compression for a test texture. Figure 8c&d shows a close up of this effect with a test texture and a leather material texture.

5 Conclusion and future work

With our approach we can produce folds for any material from soft to stiff based on fold curves and a displacement function along the folds – the fold kernel. So we can produce any shape of folds also folds looking like paper or carved wood (see fig. 9).

We have extended existing methods with attracting and repelling forces to softly bend fold curves in vicinity. To enhance the visual result as experienced in reality we introduced texture coordinate deformation to accommodate the wrinkles in valleys between folds.

We have also shown a way to generate a correct 2D silhouette for the cutting process derived from the original silhouette of the cutting pattern.

For future work we have to enhance the areas of wrinkles by rescaling the normal maps to get more convincing results and to better match the real behavior of the material in these regions.

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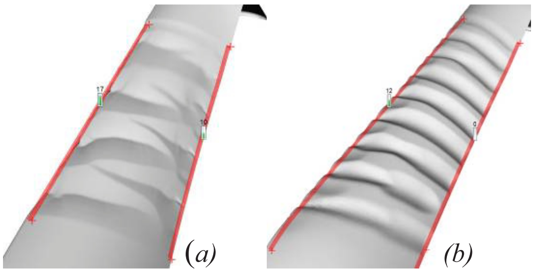

Figure 9: Paper-like folds (a). Depending on the fold kernel the shape along a fold path can be changed (b) (carved wood style?).

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