Untangling Layered Garments: An Implicit Approach

Thomas Buffet, Damien Rohmer, Marie-Paule Cani

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Untangling Layered Garments: An Implicit Approach

Thomas Buffet[1,2], Damien Rohmer[1], Marie-Paule Cani[1]

[1]LIX, École Polytechnique, CNRS [2]Inria Rhône-Alpes

Abstract

The efficient animation of layers of garments is a challenging task, as it requires handling collisions and contacts between multiple thin surfaces, which may be difficult to untangle once inter-penetrations have occurred. We propose a novel geometric approach, based on implicit surfaces, to robustly handle such situations. At each animation step, our method converts the possibly intersecting garment surfaces to an implicit representation. They are then combined using a new binary operator that guarantees, as output, collision free states of the surfaces. In addition to a precise modeling of contact situations, our method enables to model the relative influence of each cloth layer, based on their relative stiffnesses and thicknesses.

1. Introduction

Figure 1: *Our untangling system based on implicit surface modeling is able to avoid intersections of the garment layers on these static frames of a walking sequence animation (left part: input; right part: our output).*

Efficient clothes animation has been a prevalent domain in graphics and has received a lot of attention for many years due to its wide use, for instance, in animation movies, or in video-games. While wearing multiple layers of cloths is common is the real world, 3D virtual characters from industrial production are often limited to a single layer of cloth on top of their skin. Indeed, handling mutual contact between several thin layers of cloth surfaces is a complex problem. In addition of collision avoidance between garments, the relative thickness of the different layers have an impact on the resulting geometry and behavior of the most visible one. We propose in this work a robust approach, based on implicit modeling, to handle contact between cloth in a static step. More precisely, we consider as input a set of cloth layers exhibiting arbitrary intersections, and compute as output the corresponding garment layers free of intersections. Our approach not only avoid intersection between the resulting surfaces, but also guarantees that garment parts previously in intersections are in precise contact, while taking into account the relative stiffness of each layer in the resulting shape.

Most models of cloth animation separate the detection of collisions from their responses. Early works ([BFA02]) were principally focus on surface/volume collision, in order to handle collision between a garment and a body, but cannot be used for cloth layers. Handling collision between surfaces, also known as "Untangling" in the case of garment, has been tackled in several articles such as [SSIF09] where the history of the clothes throughout the simulation is used, or as [VMT06] and [YNX15] where the intersections contour is considered. [LGA15] used ray tracing heavily paralelized on GPU. [MCKM15] unifies the detection and the handling of collision during the simulation in a very efficient way, but require as input a legal collision-free state. All these methods are very well suited to avoid collision between surfaces, but do not intrinsically take into account the mutual interaction between cloth layers.
Our approach relies on the use of implicit surfaces to model the layers of cloth, and bring a robust solution to avoid intersection between different layers. As explained in [BW97], implicit surface, defined as the iso-value of a field function, intrinsically convey a well defined interior and exterior domain in space associated with the surface. Therefore modeling surface with volumetric field enable a robust and precise handling of collision and modeling of the contact ([Can] , [VGB*14]).

2. Method

Let us consider an input provided as a set of two 3D meshes representing two layers of cloth supposed to be in a static equilibrium. This input can typically be computed using a physically-based simulation, or a geometrical skinning. Each mesh is converted into an

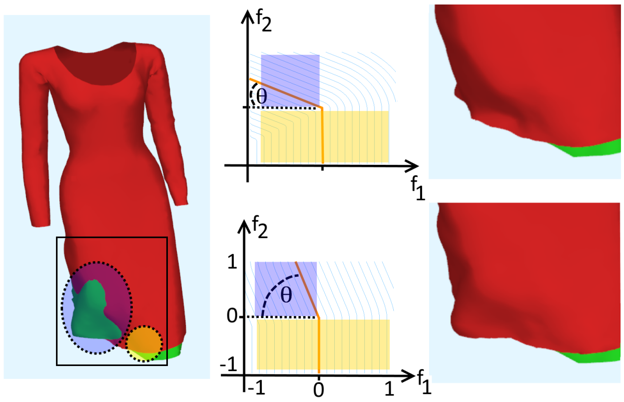

Figure 2: *Left : Penetration between a red and a green layer. Colored in blue is a collision zone, in yellow a zone "far" from collision. Middle: two Operators O_1 with a varying profile-curve. In both cases the profile curve is simply a straight segment, orange colored. The equivalent of the blue and yellow zone also have been colored. Right : our result with the corresponding operators, zoomed in the rectangle. In the yellow zone, no visible change. In the blue zone, the layers have been untangled. The relative influence of each layer depend on θ: top-right, the red layer is dominating. Bottom-right, the green layer has a greater influence and impose its form on the red one.*

implicit surface as the 0-isovalue of a Hermite Radial Basis Function (HRBF) (f_1, f_2) as proposed by Wendland *et al.* [Wen04] . Next, two new fields (f_1', f_2') are computed as the result of some new operators (O_1, O_2) applied on the original fields such that $f_1' = O_1(f_1, f_2)$ and $f_2' = O_2(f_1, f_2)$. The associated iso-surfaces shall be collision-free while ensuring contact where collisions occurred in the input.

We develop in the following our definition of our new operators (O_1, O_2). For simplicity, we only describe O_1, and O_2 has a symmetric expression with respect to the fields. We separate two cases. First, when the surfaces are far from any collision, the geometry of the surfaces shouldn't be altered. This means that the 0-isovalue of the field f_1' should be the same as the one from f_1, and leads to the following relation $f_1 = 0 \,\&\, f_2 < 0 \Rightarrow O_1(f_1, f_2) = 0$. Second, in region where collisions occur, the 0-isovalue of f_1' is modified. In order to control shape of the resulting geometry after application of the operator, we introduce a *Profile Curve* $\mathcal{C}$ defined as the subset $\{(f_1, f_2) \in \mathcal{C} \;\Rightarrow\; O_1(f_1, f_2) = 0\}$. $\mathcal{C}$ is a curve passing by the point $(0,0)$, and going toward the border. We chose $\mathcal{C}$ to be a straight line, and its angle $\theta \in [0, \pi/2]$ parameterizes the influence of one layer onto the other one as illustrated in Fig. 2. The actual operator is generated numerically from the boundary conditions and the constraint defined by $\mathcal{C}$ in solving a diffusion equation as described by Vaillant et al. [VGB*14].

Considering a common 0-isovalue for f_1' and f_2' can model contact for surface, however, real cloths have non null thickness that may be visible (ex. leather clothes), and this can deepen penetration, or even create new collision. We handle in a unified way such thickness in our method in modeling a shift operator S to generate a new field f_1'' such that $f_1'' = f_1' + S(f_1', f_2')$. We compute S similarly to the previous operators using the two following constraints. First, the final position of the 0-isosurface of the field should be offsetted with respect to the thickness of the clothes. Second, the fields (f_1'', f_2'') should remain monotonous when following a trajectory normal to the cloth in order to avoid local minimum that would perturb the projection algorithm described next. This condition is met by imposing boundary conditions so that $|d_{f_1'} S(f_1', f_2')| < 1$. Intuitively, the operator shouldn't shift the field more than it is varying. As a last step, the vertices of the initial meshes are projected onto their new respective implicit surfaces $f_{1/2}'' = 0$ in integrating the vertex positions along the direction of the field gradient, leading to untangled meshes.

3. Results and conclusion

As seen in Fig.1 and 2, our method based on implicit model successfully untangle surface layers in collision, while letting the user parameterize the relative stiffness of each layer graphically. Our approach has the advantage of controlling the varying behavior in a unified way using an operator acting on field function. So far, we defined a binary operator suitable for two layers, but extending it to n-ary operator could allow us to handle multiple layers in a single step while handling their mutual influences. We also plan to handle, within the definition of the operator, the possibility to generate wrinkles in order to avoid surface compression when deforming the cloth surface.

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