Efficient multi-layered cloth animation using implicit surfaces

Figure 1: Examples of multi layered cloth simulation from [OTSG09] and [MCKM15].

1- Context and previous work

Animating in real-time complex and realistic virtual garments on top of an animated character is a long-standing challenge in the computer graphics field. Animated garments are subject to large dynamic deformations, exhibiting complex wrinkling patterns related to their length preserving behavior and multiple, long-lasting contacts with the underlying body. One of the most complex cloth animation problem concerns multi-layered garments, where several cloth layers are stacked on top of each other. Dancing and wedding gowns (see Figure 1), or a coat worn on top of a sweater, itself on top of a shirt, are examples of multi-layered garments. This internship aims at providing a new method for handling multi-layered cloth animation in an efficient way.

Even in the case of single-layered garment, the complexity of the animation usually requires the use of a numerical simulation taking as boundary condition the initial shape of the cloth, and a given animated mannequin. Several aspects of cloth simulations have been studied such as providing stable simulations [BW98, CK02], efficient solvers [MHHR07, Wan15], dynamically adapted meshes [NSO12], or plausible wrinkles patterns [RPC+10, MC10].

Plausible clothing animation is also intrinsically linked to collision detection and response. Clothes are constantly in contact with the underlying mannequin body, sometimes with other external objects, and there may be additional self-collisions within the cloth itself. Providing efficient and accurate collision and self-collision processing methods is therefore a key element. A large number of works have focused on collision handling. Some of them use spatial sorting structures for self-collision [BFA02], or external volumetric bodies [THM+03, FBAF08, AFC+10, LGA15]. Other techniques such as continuous collision detection, stochastic methods, or complementarity constraints, do not require spatial discretization and may improve accuracy at the price of a higher computational cost [TKH+05, OTSG09]. Collision response called cloth untangling aim at deforming the cloth in a non-collision state. It can be performed using geometrical principles [BAK03, VMT06, WHG06] or using the cloth history [SSIF09]. In all cases, collision handling is one of the main bottlenecks in terms of computational robustness and efficiency of garment animation.

In the case of the animation of multi-layered garments, collisions between different cloth layers become the main element guiding the final dynamic behavior and appearance of the garments. Collision in multi-layered cloth is notably challenging as the contact surfaces are tightly packed in space, while exhibiting complex geometry. Moreover all the layers may potentially be interacting with each other, in the case of general garments (for instance, a skirt could be interacting with both the sweeter worn on top of it, and with the coat). Therefore volume based collision approaches are not adapted, and collision must actually be accurately computed with respect to each surface. Note that multi-layered cloth collision has recently attracted some attention [HWZ15, MCKM15].

Independently from garment animation, implicit surfaces, which are surfaces defined as a constant value -called isovalue- of a field function in space have been developed, originally in the context of 3D modeling. They possess the intrinsic property that two surfaces with different isovalues are necessarily collision free. This property may be of interest to efficiently handle collisions and has been already successfully applied to skinned character [VBG+13]. Interestingly, early attempts of using implicit surface in the context of cloth animation were already made, but were limited to very simple shapes [PR99, RPMC01].

2- Objective

We propose to take advantage of the collision-free properties of implicit surface for multi-layered cloth animation. More specifically this project aims to handle efficiently the collisions and friction between the multiple layers of clothing worn by an animated character, by developing an adapted dynamic implicit representation for the cloth surfaces.

Given several cloth layers provided as meshes, the basic dynamic motion will be computed using standard physically based simulation. Each surface will be associated to a field function in which each vertex may be associated to a different iso-value, defining therefore a *MultiLayer Scalar Field* (MLSF). The novelty of this project will be to define the deformation to apply to the different field functions such that they follow the motion of their associated cloth surfaces, while avoiding collision with respect to each other.

One of the possible avenues of investigation consists in developing a level-set inspired deformation for MLSF. Given a motion defined by the physically based model, the level-set equation expresses this motion as a deformation of the volumetric field and has been widely used in fluid simulation [FF01]. Level sets have also been extended to handle space partition [VC02, LSSF06, Kim10]. Integrating such equation in the case of overlapping field functions will be studied and may lead to a new adapted formulation of deformations.

3- Requirements

We are looking for highly motivated candidates able to efficiently develop and experiment computer graphics algorithms in a research context. Therefore, candidates should have a good background in the following fields:

- Computer Graphics: 3D geometry, physically-based simulation.
- Computer Science: C++ development.

4- Internship information

The internship will take place within the Inria Grenoble research center, in the Imagine research team, part of Laboratoire Jean Kuntzmann.

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