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# Towards Sketched-based Garment Design and Animation

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**Abstract**—One of the most tedious tasks in the virtual clothing process is the garment creation phase with its direct pre-visualization, and animation on the body. In this paper, we propose a new approach for garment design from the outlines drawn directly on a 3D mannequin. These outlines represent the boundaries of closed regions that are quad meshed to generate the garment pieces. The garments can then be animated in a simulation system based on Finite Elements and using a discretization of the generated mesh into triangular elements containing a reconstructed metric of the cloth surface. This allows previewing the garment on bodies with various poses and animations.

## I. INTRODUCTION

The garment design process is essentially made of two major stages. The designer first conceives the outlines of his/her design and then adds the details in a second stage. We start by setting a 3D mannequin in our working environment. Based on this 3D mannequin, we use a simple mouse or pen tool to sketch the outlines of the cloth. Out of a network of boundary polylines, we construct high quality quad meshes representing cloth pieces. Every piece of the generated cloth is associated to an underlying body part or sub-mesh. This association, established during the sketching phase, is important to correct the cloth parts penetrating the body and for animation and collision detection later on.

Our approach reduces the problem to finding a good meshing algorithm to construct cloth pieces from an input net of polylines entered by the user. The work done addressing quad mesh generation may be found in different branches of science. In general, there are four approaches towards a solution: advancing front [1], node placement [2], parametric curves [3], and the topological approach [4].

The literature presents us with criteria to compare the results of various schemes. Nasri et al. in [4] quantified this criteria by the *distortion* of the mesh. The *distortion* of a mesh is the sum of distortion on all the vertices of the mesh. On a vertex, it is the deviation of its valence from the regular setting (4 for interior, 3 for boundary, and 2 for corner vertices). Nasri et al. based their quad meshing scheme on instances of the problem where the minimum of this *distortion* is attainable. In this paper, we extend their work to present a scheme that fills an  $n$ -sided region with a minimal distortion mesh if the

boundary lengths have a sufficiently fair distribution and with higher distortion meshes otherwise.

Our system needs to offer nice previsualisation of the generated garment. As such, we propose to combine the garment generation with a simulation system offering realistic preview of the garment, on either various body poses, or animated characters.

Early garment simulation systems relied on particle systems, typically implemented as grid-based spring-mass systems offering a very simple and approximate representation of the cloth behavior [5], [6], [7]. Performance advances were brought when new implicit numerical integration methods started to be used [8], [9], [10].

Finally, accuracy was brought when adapted Finite-Element models [11], [12] were combined to these techniques for representing adequately the mechanical properties of cloth in the context of large deformations [13], [14], [15]

For the purpose of visualization, we implemented a fast Finite-Element simulation system which combines the ability of representing accurately the nonlinear anisotropic behavior of cloth materials along a particle-system representation allowing the use of efficient numerical integration methods along the possibility of handling collisions and geometrical constraints efficiently [16]. Thanks to a dedicated collision processing, the cloth responds appropriately to the motion of the body, which can set to various poses or perform various animations.

The remainder of this paper is organized as follows. The cloth modeling application along with its three main phases sketching, meshing, and refitting are detailed out in Section 2. We describe the mechanical simulation system in Section 3. Section 4 is a briefing of the conclusion and future work.

## II. THE CLOTH MODELING APPLICATION

The cloth modeling application consists of a triple-phased process (see Fig. 1). First, the user draws the nets of polylines that represent the descriptive outlines of the cloth. Then, the closed regions in the net of polylines are filled with quad meshes. In the last phase cloth-body associations are established so that every piece of cloth has a corresponding underlying body part. We use these associations to resolve cloth-body interpenetration. Simple operations such as mirror and join can be applied later on the resulting mesh.

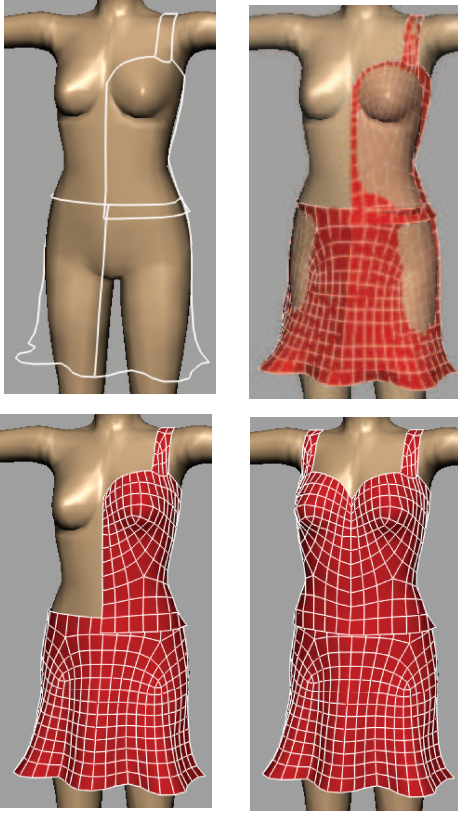


Fig. 1. Cloth generation from boundary sketched on a mannequin.

The sketching environment is a multi-view (perspective and orthographic) paneled window. The template model, aligned along the y-axis in a standing position, is the basic element in the scene. In the perspective view any line's depth value is extracted from the mesh on which it is drawn. When the user draws in the front view, the input lines either lie in the  $xy$  plane or on the mesh of the model with a user defined offset. As the user draws, switching between different views changes the actual geometry of the input lines.

When the outlines of the cloth are determined, we use the quad meshing algorithm presented in [4] to generate the garment pieces. Given the number of edges connecting the two corners of the sides of the region  $l_i$ , the topological distances  $d_i$  (see Fig. 2), that define the dimensions of the rectangular subregions, are computed using the following formula.

$$d_i = \frac{1}{2} \times \left[ \sum_{k=1}^{\lceil p \rceil} l_{i+4k-3} - \sum_{k=1}^{\lfloor p \rfloor} l_{i+4k-1} \right]$$

where  $i = 0 : n - 1$

and  $p = \begin{cases} n/2, & \text{if } n \text{ is odd;} \\ n/4, & \text{if } n \text{ is even and } n/2 \text{ is odd.} \end{cases}$

It was shown that an  $n$ -sided region may be filled with a quad mesh with at least one extraordinary vertex with valence  $n$ . For regions that have the lengths of some of its sides too large compared to the rest, the quad mesh can not be

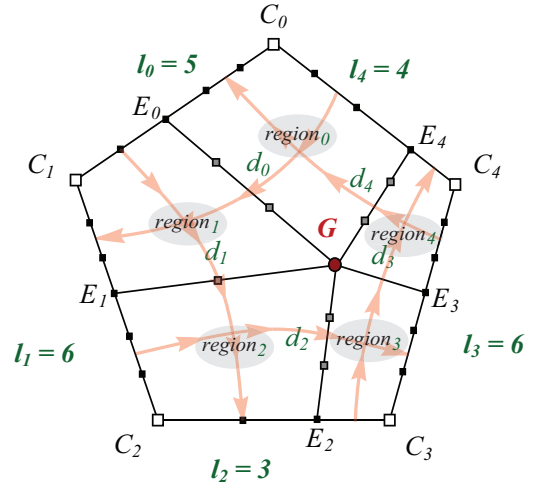


Fig. 2. The flow of lines (in light red) infer the partitioning to rectangular subregions.

constructed with only one extraordinary vertex or face. In such regions, the system that computes the distances  $d_i$  ( $1 \leq i \leq n$ ) from the dislocation to the sides in the general approach yields one or more negative values. The authors in [4] describe these cases but do not present an alternative way to handle them. In what follows, we will lay out an algorithm that solves this problem.

For every negative distance with index  $i$ , the sides that contribute to the summation with the negative coefficients are identified by the indices:  $i + 4k - 1$  ( $1 \leq k \leq \lfloor \frac{n}{2} \rfloor$ ). These lengths are marked as *large* lengths. When all the distances are calculated and *large* lengths are marked, the additional dislocations in the region may be found as follows:

- 1) For every side of index  $i$  associate the two regions  $i$  and  $i + 1$  (see Fig. 2). If  $l_i$  is *large*:
  - a) if neither  $l_{i-1}$  nor  $l_{i+1}$  are *large*, regions  $i$  and  $i + 1$  are marked as distorted.
  - b) if  $l_{i+1}$  is *large* and  $l_{i-1}$  is not, region  $i + 1$  is marked as distorted.
  - c) if  $l_{i-1}$  and  $l_{i+1}$  are *large*, regions  $i$  and  $i + 1$  are marked as distorted.
- 2) If  $d_i$  is negative, give it a value 2 if length  $i$  is large otherwise set it to 1. While there are still distances being modified or set, for each distance where length  $i$  is not *large*:
  - a) if  $d_{i-1}$  is known,  $d_{i+1} = \min(l_i - d_{i-1}, d_{i+1})$  if  $d_{i+1}$  is known or  $d_{i+1} = l_i - d_{i-1}$  otherwise
  - b) else if  $d_{i+1}$  is known,  $d_{i-1} = \min(l_i - d_{i+1}, d_{i-1})$  if  $d_{i-1}$  is known or  $d_{i-1} = l_i - d_{i+1}$  otherwise.
  - c) else,  $d_{i-1} = \lfloor \frac{l_i}{2} \rfloor$  and  $d_{i+1} = \lceil \frac{l_i}{2} \rceil$
- 3) Merge adjacent distorted regions. The obtained partitioning of the region contains 4-sided distorted and rectangular regions both of which may be filled by a quad mesh with maximal total distortion equal to 4 [4].

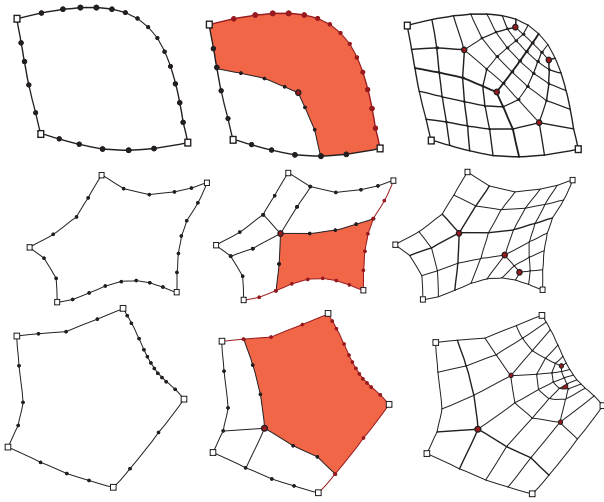


Fig. 3. Examples of regions filled by quad meshes of non-minimal distortion Form left to right: the region defined by boundary polylines, distorted subregions (light red) and *large* lengths (dark red), and the resulting quad mesh.

### III. MECHANICAL GARMENT SIMULATION

The first task of mechanical simulation is the construction of a suitable geometric representation of the garment object, fitting the requirement of the mechanical simulator.

The mechanical simulator uses triangle elements, which is suitable to a precise computation of weft, warp and shear strains and stresses of the cloth material [Volino and Magnenat-Thalmann, 2009]. Strains and stresses can be related by any kind of relationship, reflecting the anisotropic nonlinear behavior of cloth materials. Thanks to a lumped-mass approximation, the model can be formulated as interaction forces relating particles belonging to the same triangle, depending on their relative position. It is therefore essential for the simulation mesh to offer suitable geometric properties for efficient mechanical simulation (regularity of the mesh, no degenerate (flat) mesh elements...). Hence, rather than using the generated patch mesh directly, we perform an adaptive rediscrretization of the mesh into triangle elements according to size limits and the Delaunay criteria. To this mesh is then associated a set of "material coordinates" representing the metric (rest shape) of the cloth elements. Assuming the initial design roughly represents the tensile cloth deformation at rest, these material coordinates are extracted from the initial shape of the element mapped on its patch. The warp orientation is obtained by the closest orientation to vertical direction, and weft orientation defined accordingly. The reconstructed weft-warp coordinate system is used to compute represent the mechanical deformation of the cloth surface accurately according to the native orientation of the weave pattern. Our mechanical simulation animates the garment according to:

- The internal elasticity of the cloth material, represented by weft, warp and shear strain-stress curves.
- Gravity, which pulls the garment downward.
- Collision forces, which prevent the penetration of the



Fig. 4. Mechanical garment simulation using various postures and animation of the character.

garment inside the surface representing the body.

Cloth materials are properly represented through nonlinear strain-stress curves extracted from tensile tests performed on actual materials, or extracted from standard fabric characterization procedures [17]. These are handled as viscoelastic behaviors of the surface continuum within each triangle element of the cloth using a Green-Lagrange strain representation. The resulting stress converted back to particle forces and derivatives by the mechanical simulation system. Obtaining such a particle system representation, numerical integration is performed using Inverse Euler steps, ensuring an adequate trade-off between accuracy, performance and robustness. The proposed implementation remains particularly accurate and robust to large deformations, thanks to a precise handling of the forces and its derivatives, without producing artifacts resulting from linearization.

Collisions are detected using a Bounding Volume Hierarchy

algorithm, which detects proximities between cloth vertices and body polygons. These collisions are integrated into the simulation system as geometrical constraints. The simulator performs geometric position and velocity corrections ahead of a dynamic enforcement of the constraint through force filtering. Collision processing is integrated directly into the body animation system, taking advantage of the skin deformation system to compute appropriately the geometrical properties of the collisions and obtain collision response accordingly, with precise representation of friction effects.

#### IV. CONCLUSION AND FUTURE WORK

Our approach paves the way for a sketch-based garment design application. The modified quad meshing algorithm for constructing pieces of cloth from the outlines combined with a simulation system offering realistic preview of animation provides interesting perspectives of the designer, who should be able to assess the dynamic behavior, the fitting and the garment style according to body poses and motion.

As future work, the sketching interface will be improved and fully developed. The extraction of high-accuracy garment patterns from the obtained 3D garment surface will be addressed to be able to simulate very precisely the behavior of the garment.

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