Spring–particle model for hyperelastic cloth

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Abstract

1 Introduction

The modeling of cloth has been mainly oriented to satisfy visualisation problems. The techniques used goes from pure geometrical to physical simulations. Physical simulation are continuum mechanics, finite element analysis [3], and multiparticle methods. [1]. A survey of cloth modeling methods is found in [2]. The simulation in most of the cases is good enough for the visualisation purposes and aim to model the drape of fabric materials where rotational (bending) deformation is large and membrane deformation very low.

This study use miltiparticle methods and is intended to simulate fabrics whose application is mainly under stretching situations. These situation are typical of garments such as underwear, blouses, made of materias as spandex or lycra. In these garments, the stretch forces are very large compared to the weight of the cloth itself or the bending forces. This materials in general present non–linear deformations with orthotropic properties. This material are usually hyperelastic materials

2 Metodology

Consider a rectangular piece of woven fabric to be partitioned into an array of points named *nodes*, numbered from left to right and from bottom to top as is shown in figure 1 and stored in matrix N of dimension $n \times m$. Beside the point location, every node $N_{i,j}$ has information relevant to the springs connected to the node, its movement restriction, and information about contact with the surface of the rigid object.

The links between nodes are represented by spring forces, which are 3–D vectors $\vec{S}_k \in \mathbb{R}^3$. Those vectors are numbered consecutively from left to right and from bottom to top as is shown in Figure 1 and stored in a vector $\mathbf{F} = [\vec{S}_1, \vec{S}_2, \cdots, \vec{S}_k, \cdots, \vec{S}_T]$, where T is the total number of springs within the grid.

Initially the grid lies on a plane π and the springs are in equilibrium due to the absence of any external loads.

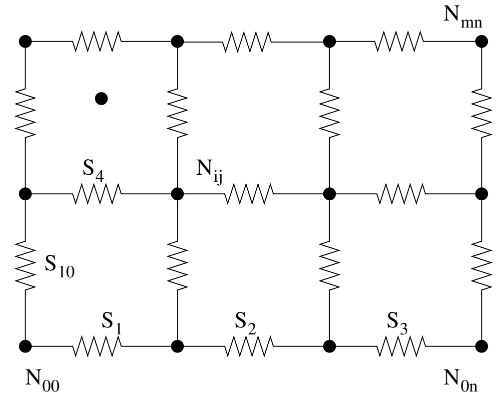


Figure 1: Numbering nodes and springs on the grid

Then the grid is restricted deformed and the rigid object is put in place. When the grid is released, each spring of the grid produces a force $\vec{S}_k$ which is a function of the stress $\sigma(\epsilon_k)$, the associated area A_k, and in the direction of the nodes that the spring is attached

$$\mathbf{S}_k = S\left(\sigma(\epsilon_k) A_k\right) \frac{\vec{N}_{\text{jn}} - \vec{N}_{\text{op}}}{\|\vec{N}_{\text{jn}} - \vec{N}_{\text{op}}\|} \ . \tag{1}$$

The pair $N_{\text{jn}}, N_{\text{op}}$ represent the coordinates of the nodes which connect the spring k in the deformed grid.

To represent the weft and warp properties of the fabric, the grid has different material properties along the x and y axes. These are represented by a stress–strain non–linear functions $\sigma(\epsilon)$, $\sigma : \mathbb{R} \to \mathbb{R}$. The original non–linear $\sigma(\epsilon)$ obtained from a laboratory test is approximated by a piecewise linear function as is shown in Figure 2.

2.1 Node movement

Once the initial grid is deformed, every node $N_{i,j}$ experiences a resultant force $\mathbf{R}$ which shoves it until it reaches an equilibrium location. This force is a 3–D vector and is given by $\vec{R}_{i,j} = \sum_k \vec{F}_k$. The new location of the node $N_{i,j}$ generated by $\vec{R}_{i,j}$ force is given by

$$N_{i,j}^{(t+1)} = N_{i,j}^{(t)} + \frac{\vec{R}_{i,j}^{(t)}}{\|\vec{R}_{i,j}^{(t)}\|} p_{i,j}^{(t)} \ . \tag{2}$$

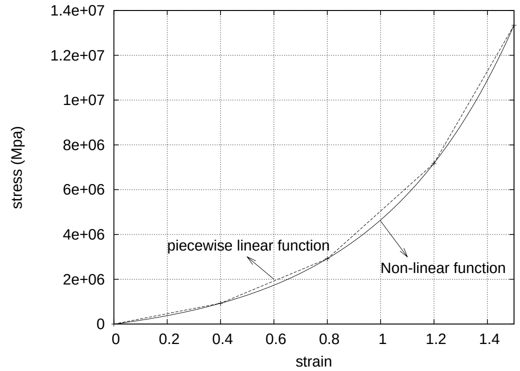


Figure 2: non–linear stress–strain relationship

The movement of $N_{i,j}$ can be: (i) free, (ii) restricted by the surface of the rigid object, and (iii) constrained by the initial boundary conditions.

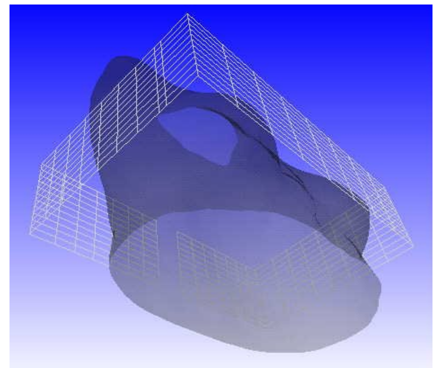
3 Example

This example simulates the contact between a fabric and a woman torso. The interaction of the fabric with a woman torso is shown in Figure 3. Initially, the fabric was deformed to sourround the torso and then released. The simulation stop after 300 iterations.

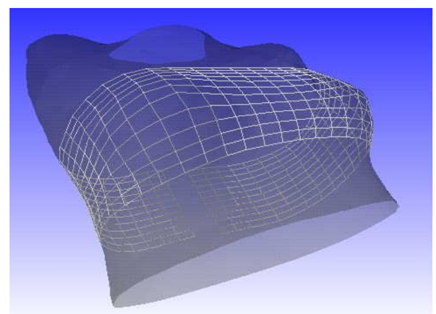
As the properties of the fabric usually depend on its orientation, the stresses are calculated on the weft and warp directions independently. The stress value at a node $N_{i,j}$ is obtained as an average of the stresses from all the springs which surround it. The value for the stress of spring k at iteration t is calculated as $\sigma_k = \|\vec{S}_k\|/A_k$. Figure 4a shows the stress over weft direction of the fabric.

4 future work

The next step in this study are the computation of forces acting over the contact rigid body, plastic deformation of the fabric (manufacturing process) and interaction with non deformable bodies.



(a) initial state



(b) final state

Figure 3: A woven fabric around a woman's torso.

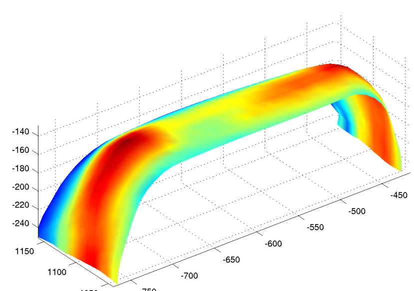


Figure 4: Stresses over the weft direction of the fabric

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