TOWARDS MECHANICAL LEVEL OF DETAIL FOR KNITWEAR SIMULATION

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ABSTRACT

This paper introduces the foundations of a new mechanical level of detail method dedicated to knitted fabric simulation. This method consists as a reduction of the knitted cloth parameters number, decreasing the configurations space dimension of the studied cloth. We stress the importance of the choice of an efficient parameters reduction function in order to make the method usable. The consequences of this reduction on the underlying equations of motion are then detailed. Finally, we present some numerical results and animation snapshots that illustrate the advantages of this new level of detail scheme.

Keywords: Lagrangian formalism, generalised coordinates, dynamic animation, level of detail.

1. INTRODUCTION

For two decades, virtual cloth animation is a particularly important research topic for the computer graphics community. In fact, the simulation of the cloth behaviour represents a great industrial challenge, leading to a large range of applications. From virtual prototyping in order to make low cost feasibility studies to virtual cloth animation for online selling, these computer graphics applications have become conceivable today. For all these reasons, cloth animation needs to be based on a precise model, able to take into account both geometric and physical properties of the fibres. On one hand, the literature abounds in papers dealing with woven cloth. In the early eighties, Jerry Weil proposed a geometric model for hanging cloth [Weil86]. The introduction of dynamics in the woven cloth modelling scheme [Terzopoulos87] [Breen92] [Eberhardt96] induced real improvements, leading to realistic animation of virtual clothes [Carignan92] [Volino95] [Provot95]. On the other hand, the knitted cloth study is still marginal. This fact can easily be explained by the complexity of the knitted cloth structure of which the stitches fitting plays an important part in the global dynamic behaviour. This reflection got us to develop a model for knitwear at the mesoscopic scale, meaning fibre scale (the mesoscopic scale consists of an intermediary scale between macroscopic and microscopic scales, the exact definition of this term is given in [Magno99]). In opposition to models dedicated to woven clothes of which the simple structure authorises a modelling at the macroscopic scale allowing real-time simulations [Barraf98] [Meyer00] [Eberhardt00], the choice of a mechanical model at the mesoscopic scale for the study of knitted cloth motion seems to be justified and above all necessary. This model is respectful of the intrinsic yarn properties (mass repartition and elasticity) and is the only one able to take into account the stitches structural complexity. Unfortunately, the precision of this model leads to equations systems of great dimension of which the resolution is very time consuming, making our approach unsuited for the study of the behaviour of large knitted clothes. It thus seems important to bring modifications to our model in order to make it able to produce knitted clothes animations with reasonable computation times. The solution we propose in this paper introduces a new and robust method leading to mechanical level of detail for dynamic animation, allowing to adapt the data size to manage during the resolution process. This idea of mechanical level of detail is well know for mass-spring models. Its application consists as a refinement or a deterioration of the discreet material points lattice [Palazzi94] [Hutchinson 96]. Because this method deals with the discreet nature of mass spring models, it is inconceivable in our framework where we consider material systems as purely continuous objects. We thus introduce a new method conciliating both our concern for dealing with continuous objects and the guarantee of an important reduction of the equations system size.

2. A MECHANICAL MODEL FOR KNITWEAR SIMULATION

Our interest in dynamic animation of knitted fabric is the result of a several years long industrial partnership with the Institut Textile de France[1]. This institute obviously collaborates with the fashion industry but also with cutting-edge technologies consumers just like the aeronautics industry. Needing efficient simulation tools, ITF came naturally to initiate a long-term partnership with the LERI, the computer sciences laboratory of the University of Reims. During his PhD, Jean-Michel Nourrit built a model both geometric and dynamic to represent stitches structures. Yarns are modelled by material spline curves, meaning they encompass mass repartition and internal elasticity. The knitted cloth structure is represented by a set of contact constraints applied on the constituent yarns of the modelled cloth [Nourrit99]. The chosen modelling scheme based on the 3D paths of the constituent yarns has to be distinguished from the popular 2D lattices used to model woven cloth. In fact, the thickness of a piece of knitted fabric is really significant. Our model already proved his ability to simulate deformations peculiar to knitted cloth [Remion00a]. Unfortunately, this accurate model seems to be maladjusted, because of its precision, for dynamic animation of large cloth.

The parameters that define a piece of knitted cloth are given by constituent yarns control points positions. But this important number of degrees of freedom is not sufficient to represent the possible configurations of the studied cloth. The stitches structure is then modelled by using contact constraints between the yarns. These constraints, that implicitly and significantly reduce the number of degrees of freedom, generate new unknowns corresponding to the bonding forces guaranteeing the constraints achievement. This fact implies an important increase of the linear equation system size. We now present a solution to reduce the system size based on parameters reduction.

[1] http://www.itf.fr

3. PARAMETERS REDUCTION

It thus seems reasonable to initiate a reduction of the parameters number since many unknowns that appear in the temporal resolution step do not correspond to real degrees of freedom but rather to forces decreasing the dimension of the possible configurations space. So, using a simplifying assumption, we construct a level of detail scheme in order to upgrade our initial model. This improvement is achieved by a reduction of the initial parameters number. Then the reduction process leads to a lower number of relevant parameters, closer to the real number of knitted cloth degrees of freedom but able to keep a rich enough macroscopic behaviour. This approach has two main advantages. First, it allows an important reduction of the number of parameters. And above all, it allows to remove all contact constraints. In the following of this section, we detail our solution to the level of detail problem.

We chose to use a parametric bounding volume V encompassing the stitches set. Since the variations along the knitted cloth thickness are relatively small, it seems relevant to use a volume of which the thickness variation is linear. More precisely, this volume is deduced from the linear interpolation of two parametric surfaces S_1 and S_2 parallel to the “mean surface” of the knitted cloth (Figure 1). These two surfaces S_1 and S_2 are separable bicubic spline surfaces defined from the same number of control points, respectively expressed as $p^{S_1,\mathbf{i}}$ and $p^{S_2,\mathbf{i}}$ $\left(\mathbf{i}\in\mathbb{N}^2\right)$, made of the same number of patches.

For the convenience of notations, bounding volume control points are indexed by 3-dimensional multi-indices $\mathbf{k}=\left(k_1,k_2,k_3\right)$ as follows:

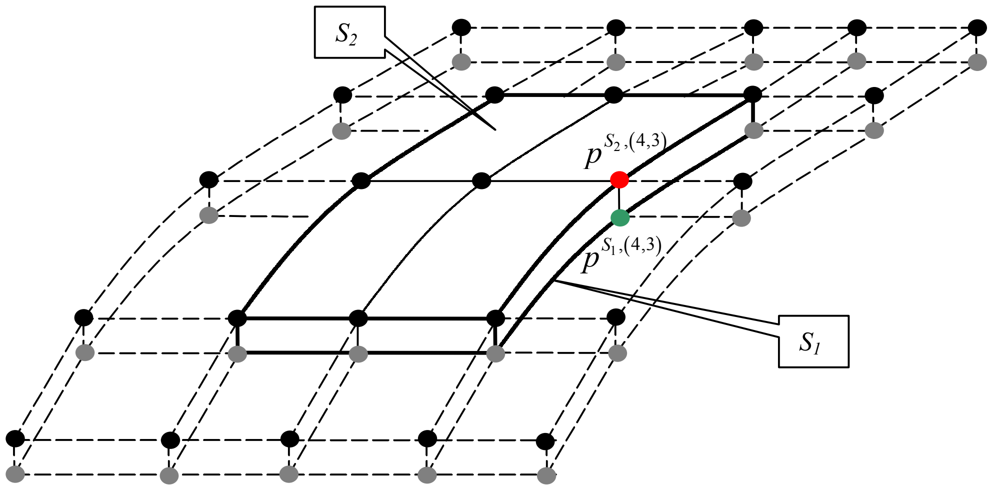
$$p^{V,\mathbf{k}}=\begin{cases}p^{S_1,(k_1,k_2)} & \text{if} \quad k_3=1\\ p^{S_2,(k_1,k_2)} & \text{if} \quad k_3=2\end{cases}$$

So, the position of a point P of parametric coordinates $\mathbf{w}=\left(\omega_1,\omega_2,\omega_3\right)$ in the patch number $\mathbf{j}=\left(j_1,j_2\right)$ of the bounding volume V is given by:

$$\begin{aligned}P\left(\mathbf{j},\mathbf{w},t\right)=\left(1-\omega_3\right)&\sum_{\mathbf{i}} b_{\mathbf{i}}^{\mathbf{j}}\left(\omega_1,\omega_2\right)q^{V,(i_1,i_2,1)}\\ &+\omega_3\sum_{\mathbf{i}} b_{\mathbf{i}}^{\mathbf{j}}\left(\omega_1,\omega_2\right)q^{V,(i_1,i_2,2)}\end{aligned}$$

where $b_{\mathbf{i}}^{\mathbf{j}}$ corresponds to the blending function associated to the control point **i** for the patch **j**.

In a second step, we define a “stitches fitting” function, making the assumption that constituent yarns control points parametric coordinates are constant inside the bounding volume V. This assumption can be compared to Free Form



Bounding volume made of (2,2) patches, defined from (5,5,2) control points
Figure 1

Deformations [Sederberg86] if we consider yarns control points as frozen points in a deformable volume. But the deformations applied to the bounding volume V are induced by external forces when Free Form Deformations are simply geometric. This means that the proposed method is based upon dynamics and not only geometry. The “stitches fitting” function allows, from bounding volume control points positions $\left(p^{V,\mathbf{i}}\right)_{\mathbf{1}\leq\mathbf{i}\leq\mathbf{n}}$, to compute control points positions of constituent yarns.

Let a knitted cloth made of r stitches rows, thus composed of r yarns, the n_f control points of the yarn number f are expressed as $\left(p^{f,i}\right)_{1\leq i\leq n_f}$ $(1\leq f\leq r)$. And generalised coordinates $\left(\varepsilon_i^f\right)_{1\leq i\leq 3n_f}$ of the yarn number f are given by the following expression:

$$\varepsilon^f = \left(\underbrace{p_1^{f,1},\ldots,p_1^{f,n_f}}_{x},\underbrace{p_2^{f,1},\ldots,p_2^{f,n_f}}_{y},\underbrace{p_3^{f,1},\ldots,p_3^{f,n_f}}_{z}\right)^T$$

We use the same notation for generalised coordinates $\left(\varepsilon_i^V\right)_{1\leq i\leq 3n}$ of the bounding volume V. Since these control points are indexed by 3-dimensional multi-indices, we define a bijection $\alpha_{\mathbf{n}}$ as follows

$$\alpha_{\mathbf{n}}:\{1,\ldots,n_1\}\times\{1,\ldots,n_2\}\times\{1,\ldots,n_3\}\rightarrow\{1,\ldots,n_1.n_2.n_3\}$$

that binds every multi-indice $\mathbf{i}$ with a unique integer in this way:

$$\forall\mathbf{i}\in\{1,\ldots,n_1\}\times\{1,\ldots,n_2\}\times\{1,\ldots,n_3\}:$$
$$\varepsilon^V_{\alpha_{\mathbf{n}}(\mathbf{i})+(k-1)n}(t)=p_k^{V,\mathbf{i}}(t)\quad 1\leq k\leq 3$$

Using these notations, we finally give the definition of the function $\gamma^f:\mathbb{R}^{3n}\rightarrow\mathbb{R}^{3n_f}$ that computes generalised coordinates $\left(\varepsilon_i^f\right)_{1\leq i\leq 3n_f}$ of the yarn number f from the vector $\left(\varepsilon_i^V\right)_{1\leq i\leq 3n}$:

$$\varepsilon^f_{i+(k-1).n}=\left(\gamma^f\left(\varepsilon^V\right)\right)_{i+(k-1).n}=P_k\left(\mathbf{j}^{f,i},\mathbf{w}^{f,i},t\right)$$
$$1\leq i\leq n\quad,\quad 1\leq k\leq 3$$

where $\mathbf{w}^{f,i}=\left(\omega_1^{f,i},\omega_2^{f,i},\omega_3^{f,i}\right)$ are constant parametric coordinates, inside the patch number $\mathbf{j}^{f,i}=\left(j_1^{f,i},j_2^{f,i}\right)$, of the control point number i belonging to the yarn number f. One can see that the function $\gamma^f:\mathbb{R}^{3n}\rightarrow\mathbb{R}^{3n_f}$ is a linear map. We thus note $\Gamma^f\in M\left(\mathbb{R}^{3n_f},\mathbb{R}^{3n}\right)$ the corresponding matrix. Because the weight of parametric coordinates $\mathbf{w}^{f,i}$ in the linear control points combination is the same for the x, y or z axis, the coefficients of Γ^f associated to each generalised coordinate $\varepsilon^{V,}_{l+(k-1).n}$ are identical for k=1,2,3. In consequence, regarding to the structure of vectors ε^V and ε^f, the matrix Γ^f is a block matrix expressed as:

$$\Gamma^f=\begin{pmatrix}\tilde{\Gamma}^f & & \\ & \tilde{\Gamma}^f & \\ & & \tilde{\Gamma}^f\end{pmatrix}\quad\text{where}\quad\tilde{\Gamma}^f\in M\left(\mathbb{R}^{n_f},\mathbb{R}^n\right)$$

$$\tilde{\Gamma}_{ik}^{f} = \begin{cases} \left(1-\omega_3^{f,i}\right)\cdot b_{\alpha_{\mathbf{n}}^{-1}(k)_1}^{j_1^{f,i}}\left(\omega_1^{f,i}\right)\cdot b_{\alpha_{\mathbf{n}}^{-1}(k)_2}^{j_2^{f,i}}\left(\omega_2^{f,i}\right)\cdot \varepsilon_k^V \\ \quad \text{if} \quad \alpha_{\mathbf{n}}^{-1}(k)_3 = 1 \\ \omega_3^{f,i}\cdot b_{\alpha_{\mathbf{n}}^{-1}(k)_1}^{j_1^{f,i}}\left(\omega_1^{f,i}\right)\cdot b_{\alpha_{\mathbf{n}}^{-1}(k)_2}^{j_2^{f,i}}\left(\omega_2^{f,i}\right)\cdot \varepsilon_k^V \\ \quad \text{if} \quad \alpha_{\mathbf{n}}^{-1}(k)_3 = 2 \end{cases}$$

Let ε the vector corresponding to the concatenation of generalised coordinates of all constituent yarns.

$$\varepsilon = \left(\underbrace{\underbrace{\varepsilon_1^{1,1},\cdots,\varepsilon_1^{1,n_1}}_{yarn\ 1},\cdots,}_{x}\underbrace{\underbrace{\varepsilon_2^{1,1},\cdots,\varepsilon_2^{1,n_1}}_{yarn\ 1},\cdots,}_{y}\underbrace{\underbrace{\varepsilon_3^{1,1},\cdots,\varepsilon_3^{1,n_1}}_{yarn\ 1},\cdots}_{z} \right)^T$$

The vector ε encompasses all the initial degrees of freedom of the studied knitted cloth. And we have the following relation between the complete and reduced set of parameters.

$$\varepsilon = \Gamma \varepsilon^V \qquad \text{avec} \qquad \Gamma = \begin{pmatrix} \begin{pmatrix} \tilde{\Gamma}^1 \\ \vdots \\ \tilde{\Gamma}^{n_r} \end{pmatrix} & 0 & 0 \\ 0 & \begin{pmatrix} \tilde{\Gamma}^1 \\ \vdots \\ \tilde{\Gamma}^{n_r} \end{pmatrix} & 0 \\ 0 & 0 & \begin{pmatrix} \tilde{\Gamma}^1 \\ \vdots \\ \tilde{\Gamma}^{n_r} \end{pmatrix} \end{pmatrix}$$

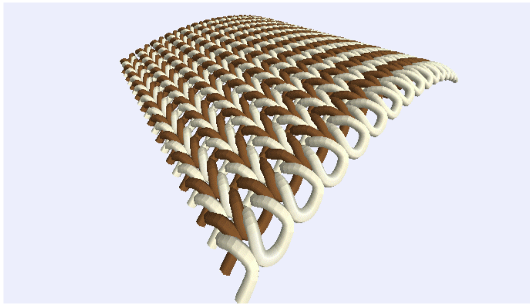
In order to make this reduced set of parameters usable, we have to ensure that the choice of this "stitches fitting" function is reasonable, meaning that it does not induce an important deterioration of the knitted cloth behaviour at the macroscopic scale.

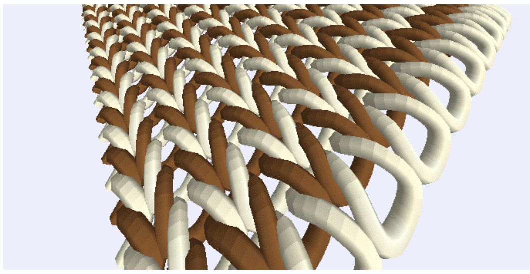
4. QUALITATIVE VALIDATION

It appears that the level of detail method we propose is usable only if the "parameters reduction" function (i.e. the "stitches fitting" function for the case of knitted clothes) keeps enough degrees of freedom in order to ensure that the system evolution in this new and reduced kinematics space is quite similar at the macroscopic scale to the initial model evolution.

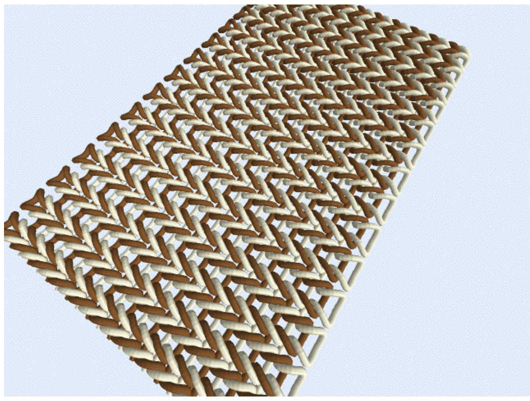
Obviously, this parameters reduction has some consequences on stitches local deformations, possible in the initial parameters set but reasonably negligible for the reduced parameters set at the macroscopic scale.

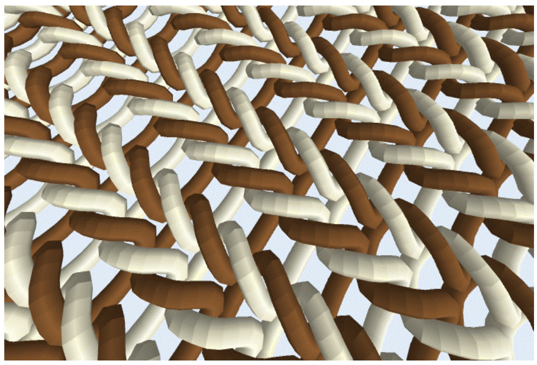
To validate the choice of the function Γ previously defined, we impose several geometric deformations to the bounding volume V. Stitches are then reconstructed from the deformed volume in order to judge the stitches automatic fitting quality. This quality consists as a constraint of non penetration for the constituent stitches and a restriction in the fibres extension.



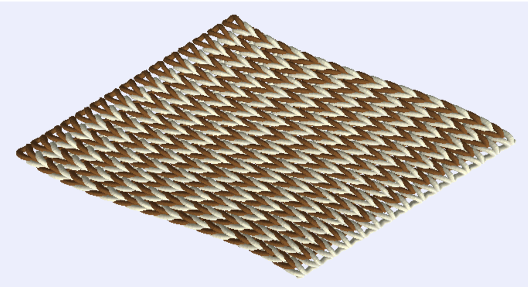


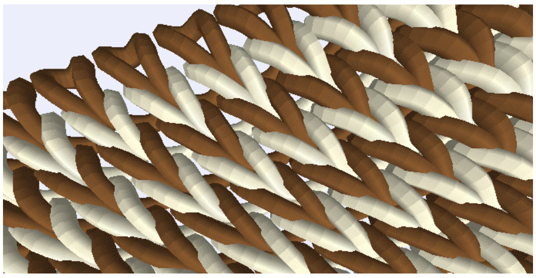
Flexion along the row axis
Figures 2, 3



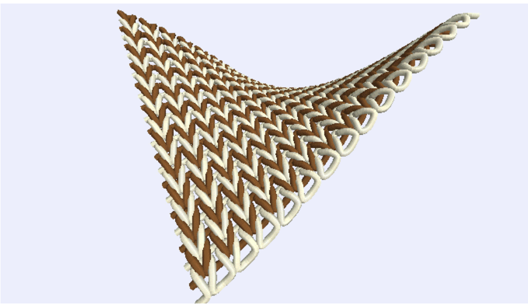


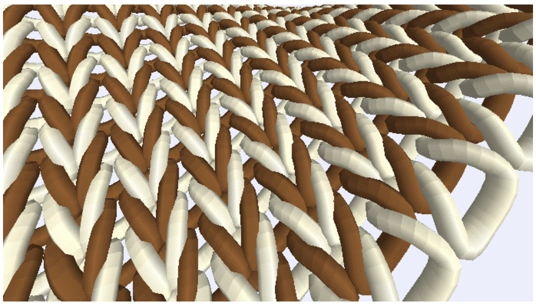
Traction along the row axis
Figures 3, 4





Shearing along the row axis
Figures 5, 6





Torsion along the row axis
Figures 7, 8

A detailed visual study of the deformed knitted fabric shown in the figures 2 to 8 leads to the conclusion that the choice of our "parameters reduction" function is well suited. As we mentioned previously, the pertinence of this "parameters reduction" function Γ is crucial for the success of our method. Then, we can go further in the construction of our new level of detail scheme. The next section details the consequences of parameters reduction on the underlying equations of motion.

5. CONSEQUENCES ON THE EQUATIONS OF MOTION

We briefly remind of few important elements of the Lagrangian Formalism. A more detail study can be found in [Arnold89].

Let a material system S composed of particles identified by an element $\omega \in \Omega \subset \mathbb{R}^d$. One considers that the system S has $n < 3 \cdot Card(\Omega)$ degrees of freedom. A coherent state of this system can be described by a finite set of parameters corresponding to a given geometric configuration. These real parameters, called system generalised coordinates, are summarised in a vector ε and can be understood as the degrees of freedom of the studied system *S*.

In consequence, we define the position function Φ as a functional which gives, from a configuration vector ε and a particle identifier ω, the spatial position of the corresponding material point.

$$\Phi : \begin{cases} \mathbb{R}^{n+1} \times \Omega \to \mathbb{R}^3 \\ (\varepsilon,\omega) \mapsto \Phi(\varepsilon,\omega) \end{cases}$$

We note $J(\varepsilon,\omega)$ the Jacobian matrix of the position function Φ. It is expressed as:

$$J(\varepsilon,\omega) = \frac{\partial}{\partial \varepsilon}\Phi(\varepsilon,\omega) \in M_{3,n}(\mathbb{R})$$

From now, we restrict our study to material systems of which the Jacobian matrix $J(\varepsilon,\omega)$ is independent of the generalised coordinates ε. This is particularly the case for material systems modelled by d-dimensional splines [Remion00b]. So, we have:

$$J(\omega) = \frac{\partial}{\partial \varepsilon}\Phi(\varepsilon,\omega)$$

Then, with the given parametric mass repartition

$$\mu : \Omega \to \mathbb{R}$$
$$\omega \mapsto \mu(\omega)$$

we are able to express the kinetic energy of a material system:

$$K(\varepsilon,\dot{\varepsilon}) = \tfrac{1}{2}\int_\Omega \mu(\omega)\frac{d\Phi}{dt}(\varepsilon,\omega)^2 d\omega$$

more precisely,

$$K(\varepsilon,\dot{\varepsilon}) = \tfrac{1}{2}\dot{\varepsilon}^T M \dot{\varepsilon} \quad \text{with} \quad M = \int_\Omega \mu(\omega) J(\omega)^T J(\omega)\, d\omega$$

The matrix M is the generalised masses matrix. Since the Jacobian matrix is independent of the generalised coordinates ε, M is a constant matrix.

The Lagrange equations are then equivalent to the following linear system:

$$M\,\ddot{\varepsilon} = Q(\varepsilon,\dot{\varepsilon})$$

where $Q(\varepsilon,\dot{\varepsilon})$ is a vector composed of the power ratings of the given forces in the virtual movement instilled by each ε_i.

We now consider a reduced set of $n\alpha \le n$ parameters noted α and a "parameters reduction" function φ expressed as:

$$\varepsilon = \varphi(\alpha) \quad \text{with} \quad \alpha = \left(\alpha_1 \cdots \alpha_{n\alpha}\right)^T$$

Since these two generalised coordinates vectors ε and α describe the same material system, we should be able to compare the constituent terms of the two corresponding linear systems. According to the previous relation, we have:

$$\dot{\varepsilon} = \nabla(\alpha)\dot{\alpha} \quad \text{where} \quad \nabla(\alpha) = \frac{\partial}{\partial\alpha}\varphi(\alpha)$$

$\nabla(\alpha)$ is the Jacobian matrix of φ,

If we consider the special case of knitted cloth where the "parameters reduction" function is linear, the Jacobian matrix is a constant matrix. So we have:

$$\dot{\varepsilon} = \nabla\dot{\alpha}$$

Like for the initial parameters set ε, the Lagrange equations, expressed in the reduced parameters set α, are equivalent to the following linear equations system:

$$m\,\ddot{\alpha} = Q'(\alpha,\dot{\alpha})$$

This linear system is the actual system to resolve. To complete the definition of this new equations system, we have to detail both the generalised masses matrix *m* and the vector $Q'(\alpha,\dot{\alpha})$ of power ratings.

We begin to compare kinematics energy expressions:

$$K(\varepsilon,\dot{\varepsilon}) = \tfrac{1}{2}\dot{\varepsilon}^T \cdot M \cdot \dot{\varepsilon} = \tfrac{1}{2}\left(\nabla\cdot\dot{\alpha}\right)^T \cdot M \cdot \left(\nabla\cdot\dot{\alpha}\right) = \tfrac{1}{2}\dot{\alpha}^T \cdot \left(\nabla^T \cdot M \cdot \nabla\right) \cdot \dot{\alpha}$$

$$K(\alpha,\dot{\alpha}) = \tfrac{1}{2}\dot{\alpha}^T \cdot m \cdot \dot{\alpha}$$

We deduce the following important relation:

$$m = \nabla^T \cdot M \cdot \nabla$$

Using this theoretical result, we are able to express the reduced generalised masses matrix for the special case of knitted cloth. For that, we give the expression of M^f $\left(1 \le f \le r\right)$, the generalised masses matrix corresponding to the yarn number *f*. The intrinsic properties of the matrix M^f are detailed in [Remion00a].

$$M^f \in M_{3.n_f}\left(\mathbb{R}\right) \quad ; \quad M^f = \begin{pmatrix} m^f & & \\ & m^f & \\ & & m^f \end{pmatrix}$$

Then, if M is the generalised masses matrix associated to the vector ε which is the concatenation of yarns generalised coordinates ε^f $\left(1 \le f \le r\right)$, we have the following expression:

$$M \in M_{3.\sum_f n_f}\left(\mathbb{R}\right) \quad ; \quad M = \begin{pmatrix} m & & \\ & m & \\ & & m \end{pmatrix}$$

$$\text{with} \quad m \in M_{\sum_f n_f}\left(\mathbb{R}\right) \quad ; \quad m = \begin{pmatrix} m^1 & & \\ & \ddots & \\ & & m^r \end{pmatrix}$$

According to the theoretical development, the matrix M^V is finally expressed as:

$$M^V \in M_{3n}\left(\mathbb{R}\right) \quad ; \quad M^V = \Gamma^T M \Gamma$$

More precisely,

$$M^V = \begin{pmatrix} \sum_{i=1}^{r} \tilde{\Gamma}^{i^T} m^i \tilde{\Gamma}^i & & \\ & \sum_{i=1}^{r} \tilde{\Gamma}^{i^T} m^i \tilde{\Gamma}^i & \\ & & \sum_{i=1}^{r} \tilde{\Gamma}^{i^T} m^i \tilde{\Gamma}^i \end{pmatrix}$$

It is important to notice the matrix M^V is also a constant matrix, allowing us to compute its LU decomposition [Press88] during the initialisation step in order to speed up the temporal resolution process.

Finally, we give the expression of Q^V, power ratings of the given forces in the virtual movements compatible with the reduced generalised coordinates α.

$$Q^V = \Gamma^T Q \quad \text{with} \quad Q = \left(Q^1 \quad \cdots \quad Q^r\right)^T$$

$$Q^V = \sum_{f=1}^{r} \Gamma^{f^T} Q^f$$

The vector Q^f corresponds to power ratings of given forces applied on the yarn number *f*, expressed in the initial parameters set ε.

We mention that considered forces are exactly the same for generalised coordinates ε and α. Since evolutions allowed by these set of parameters are different, effects of these given forces measured by their power ratings are obviously different according to the parameters set. If a real motion, expressed in the initial parameters set, is still compatible with the reduced parameters set then its analysis produces exactly the same evolution by using initial or reduced parameters.

	Knitwear (initial parameters)	Bounding volume (reduced parameters)
Control points per yarn	**8×30+3=243**	
Degrees of freedom per yarn	**3×243=729**	
Control points total	**15×243=3645**	**5×5×2=50**
Degrees of freedom total	**3×3645=10935**	**3×50=150**
Vector constraints per yarn	**2×30=60**	
Scalar constraints per yarn	**3×60=180**	
Scalar constraints total	**15×180=2700**	
Scalar unknowns total	**10935+2700=13635**	**150**

Numerical results
Figure 9

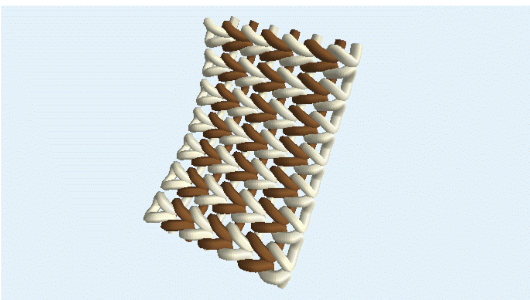
6. NUMERICAL EXAMPLE

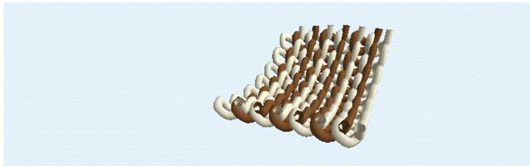
We consider a bounding volume V made of (5,5,2) control points, encompassing a piece of knitted cloth constituted of 15 rows and 30 columns of jersey stitches. Each constituent yarn is composed of $8nc+3$ control points and constrained by $2nc$ contact constraints if nc is the columns number. The number of unknowns for both parameters set are summarised in figure 9.

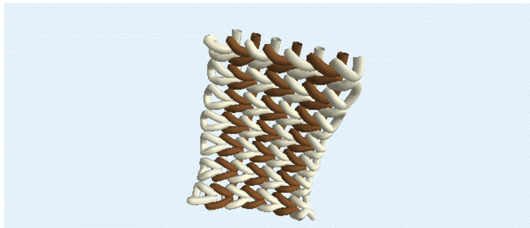
It appears that the "parameters reduction" scheme induces an important data decrease with a ratio equal to 90. This important reduction of the linear system size allows significant accelerations during the temporal resolution step.

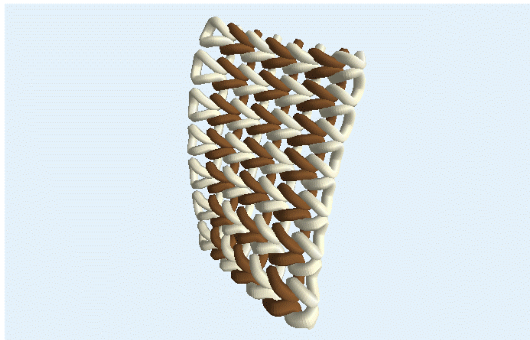
7. FIRST RESULTS IN DYNAMIC ANIMATION

The following images (Figures 10 to 13) are taken from the first dynamic animation of a knitted fabric based on our new method of mechanical level of detail. We used a bounding volume composed of (5,5,2) control points to simulate the behaviour of a knitted cloth made of 7 rows and 7 columns of jersey stitches. The cloth upper side remains immobile using 7 fixed points constraints. Gravity and internal elasticity are the only given forces acting on the material system.









Hanging knitted fabric at time t=0.4, 1, 2, 3 s
Figures 10, 11, 12, 13

8. CONCLUSION

In this paper, we presented the foundations of new mechanical level of detail scheme, compatible with our dynamic continuous model for knitwear. This method does not consist as a refinement or a deterioration of a discreet material points lattice, but rather consists as a degrees of freedom reduction, according to the Lagrangian formalism. The efficiency of this method have been proved for the peculiar case of knitted cloth, where the decrease of the system size significantly accelerate the resolution process. On the other hand, the level of detail scheme dedicated to discreet material systems is usually adaptive, allowing to dynamically vary the number of unknowns to manage. Even if the new method we proposed seems to be static, it is reasonable to consider an adaptive version based on a dynamic adaptation of the number of patches that compose the studied knitted cloth in order to modify local degrees of freedom by adjusting the per patch stitches number.

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