Mass spring system and Soft Tissue

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Overview

1. Introduction
2. Our approach
3. Results and discussion
4. Live demo

Introduction[1]

- Mass spring system are one of the simplest and most intuitive of all deformable models.
- Different approach from FEM(assignment 2).
- As the name implies, these models simply consist of point masses connected together by a network of massless springs.

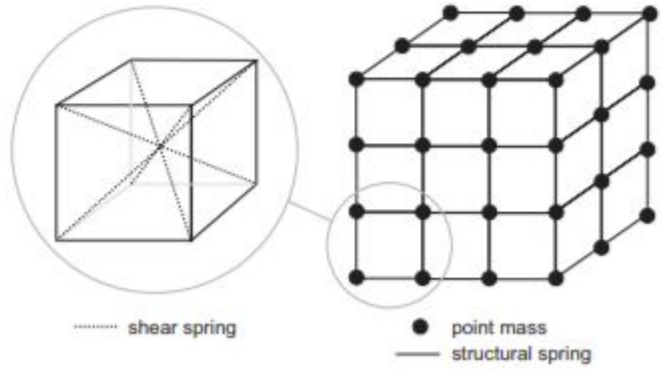

Figure 5: *A mass-spring system.*

Our Approach[1]

- We defined the state of the system, at a given time, by x_i , v_i , f_i .
- The equation of motion for all the particle system is:

$$\mathbf{M}\ddot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{v})$$

- We calculate the the total force of the system and integrate the x_i , v_i accordingly.

Our Approach²

- The force is the sum of internal forces(the forces of the springs) and external forces(like gravity).
- The internal forces are:

$$\mathbf{f}_i = k_s(|\mathbf{x}_{ij}| - l_{ij})\frac{\mathbf{x}_{ij}}{|\mathbf{x}_{ij}|}$$

$$\mathbf{f}_i = k_d\left(\frac{\mathbf{v}_{ij}^T\mathbf{x}_{ij}}{\mathbf{x}_{ij}^T\mathbf{x}_{ij}}\right)\mathbf{x}_{ij}$$

- All of this is really easy to implement in the assignment 2 framework.
- The constants are the tricky part to be able get good results.
- For a good result we got k_s = 200.000 and k_d = 3.000 at first

Our Approach[3]

Calculating the k_s and k_d (soft tissue):

$$k_{(i,j)} = \sum_{t \in \mathcal{T}_{(i,j)}} \frac{2\sqrt{2}}{25} l_t E,$$

$$d_{(i,j)} = \frac{2\sqrt{k_{(i,j)}(m_i + m_j)}}{l_0}.$$

Verlet time integration:

$$\vec{x}(t + \Delta t) = 2\vec{x}(t) - \vec{x}(t - \Delta t) + \vec{a}(t)\Delta t^2$$

$$\vec{v}(t) = \frac{\vec{x}(t + \Delta t) - \vec{x}(t - \Delta t)}{2\Delta t}$$

Our Approach[4]

Additional Distance Constraints for every spring:

1) Over-stretching Compensation

$$C_{stretch}(\boldsymbol{p}_i, \boldsymbol{p}_j) = (1 + \tau_s)l_0 - |\boldsymbol{p}_i - \boldsymbol{p}_j| \geq 0,$$

2) Over-compressing Compensation

$$C_{compress}(\boldsymbol{p}_i, \boldsymbol{p}_j) = |\boldsymbol{p}_i - \boldsymbol{p}_j| - (1 - \tau_c)l_0 \geq 0,$$

Results and Discussion[1]

- Mass spring systems are easy to implement.
- But getting realistic results is hard to achieve because of the k_s and k_d (dependent of the topology of the mesh).

Experimental bad k_s and k_d

Experimental good k_s and k_d

Results and Discussion^2

- Approach not general for every mesh.
- Soft tissue is not that easy to implement because k_s and k_d.
- Additional constraints have to be added.
- Some scenes doesn’t work because of the Young's modulus being to big
- And other because of the topology and the resolution of mesh.

References

1. Nealen, A., Müller, M., Keiser, R., Boxerman, E., & Carlson, M. (2006, December). Physically based deformable models in computer graphics. In *Computer graphics forum* (Vol. 25, No. 4, pp. 809-836). Blackwell Publishing Ltd.
2. Duan, Y., Huang, W., Chang, H., Chen, W., Zhou, J., Teo, S. K., ... & Chang, S. (2016). Volume preserved mass–spring model with novel constraints for soft tissue deformation. *IEEE journal of biomedical and health informatics*, *20*(1), 268-280.

Live Demo

Thank you.