Cloth Simulation & Collisions

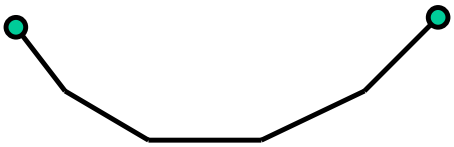
Last Time?

Today

- Mass Spring Systems
  - String
  - Hair
  - Cloth
- Stretch/Stiffness
- Discretization
- Collisions
- Implicit Integration

How would you simulate a string?

- Each particle is linked to two particles
- Forces try to keep the distance between particles constant
- What force?

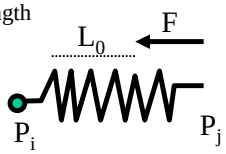


Spring forces

- Force in the direction of the spring and proportional to difference with rest length

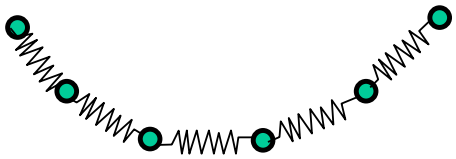
$$F(P_i, P_j) = K(L_0 - ||\vec{P_iP_j}||)\frac{\vec{P_iP_j}}{||\vec{P_iP_j}||}$$

- K is the stiffness of the spring
  - When K gets bigger, the spring really wants to keep its rest length



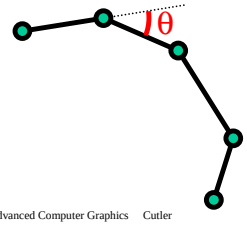
How would you simulate a string?

- Springs link the particles
- Springs try to keep their rest lengths and preserve the length of the string
- Problems?
  - Stretch, actual length will be greater than rest length
  - Numerical oscillation



How would you simulate hair?

- Similar to string…
- Deformation forces proportional to the angle between segments



Mass-spring

- Interaction between particles
- Create a network of spring forces that link pairs of particles
- Used for string, hair, cloth

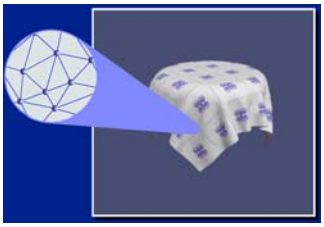


Image by
Baraff, Witkin, Kass

Questions?

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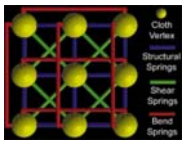
Three types of forces

- Structural forces
  - Try to enforce invariant properties of the system
  - E.g. force the distance between two particles to be constant
  - Ideally, these should be constraints, not forces
- Internal Deformation forces
  - E.g. a string deforms, a spring board tries to remain flat
- External forces
  - Gravity, etc.

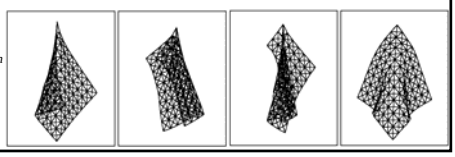
Cloth modeled with Mass-Spring

- Network of masses and springs
- Structural springs:
  - link (i, j) & (i+1, j) and (i, j) & (i, j+1)
- Shear springs
  - link (i, j) & (i+1, j+1)
- Flexion springs
  - link (i,j) & (i+2,j) and (i,j) & (i,j+2)



From Lander
http://www.darwin3d.com/gamedev/articles/col0599.pdf

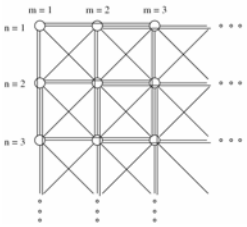
Interactive Animation of Structured Deformable Objects
Desbrun, Schröder, & Barr 1999



Cloth

External forces

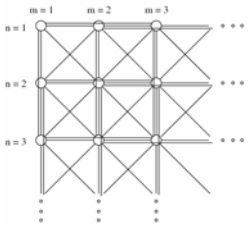
- Gravity Gm
- Viscous damping Cv
- Wind, etc.



From Provost 95

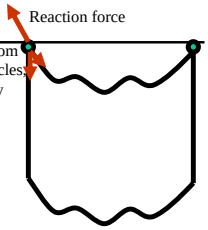
Cloth simulation

- Then, the all trick is to set the stiffness of all springs to get realistic motion!
- Remember that forces depend on other particles (coupled system)
- But it is sparse (only neighbors)



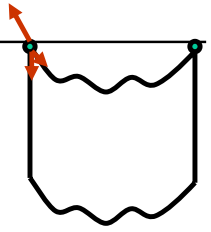
From Provost 95

Contact forces



- Hanging curtain:
- 2 contact points stay fixed
- What does it mean?
  - Sum of the forces is zero
- How so?
  - Because those point undergo an external force that balances the system
- What is the force at the contact?
  - Depends on all other forces in the system
  - Gravity, wind, etc.

Contact forces



- How can we compute the external contact force?
  - Inverse dynamics!
  - Sum all other forces applied to point
  - Take negative
- Do we really need to compute this force?
  - Not really, just ignore the other forces applied to this point!

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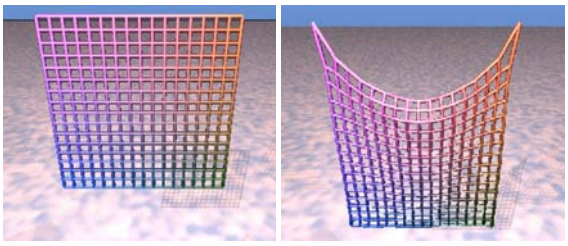
Implementing Cloth

- Excessive deformation:
  the springs are not stiff enough



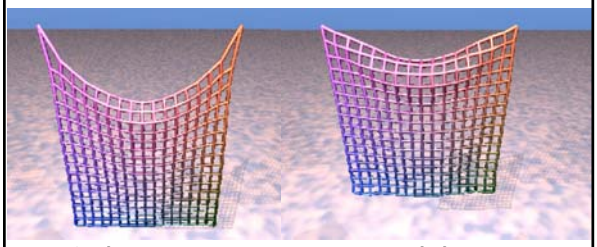
Initial position After 200 iterations

The Stiffness Issue

- Cloth is only a bit elastic, shouldn't stretch so much
- We use springs where we really want a *constraint*
  - What relative stiffness do we want for the the different springs in the network?
- Inverse relationship between stiffness & Δt
- Many numerical solutions
  - reduce Δt
  - use constraints
  - implicit integration
  - …

One Solution

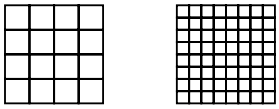
- Constrain length to increase by less than 10%



Simple mass-spring system Improved solution
(see Provot Graphics Interface 1995)

The Discretization Problem

- What happens if we discretize our cloth more finely, or with a different mesh structure?
- Do we get the same behavior?
- Usually not! It takes a lot of effort to design a scheme that does not depend on the discretization.



Questions?