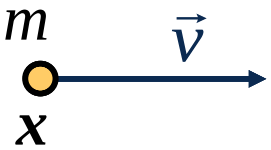
CG3 Part II
Particle Systems

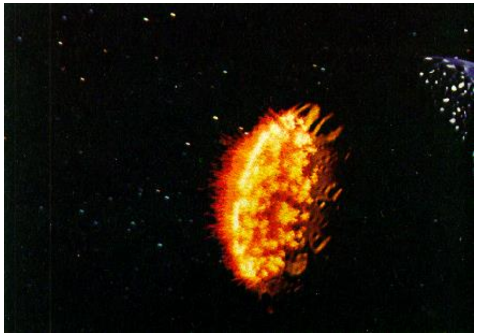
Particle Systems

Motivation

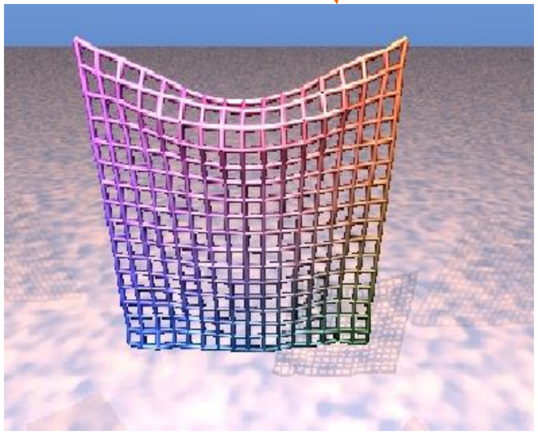
Generalizations of Point Mass



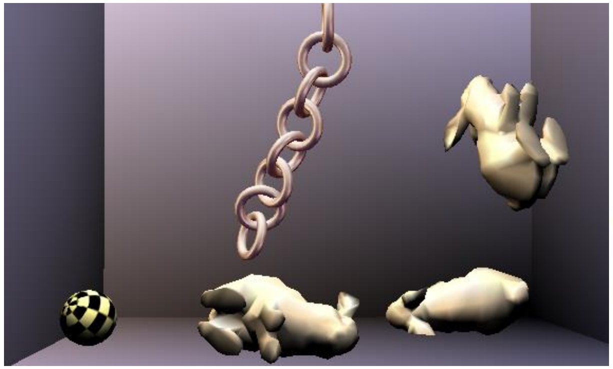
Point mass



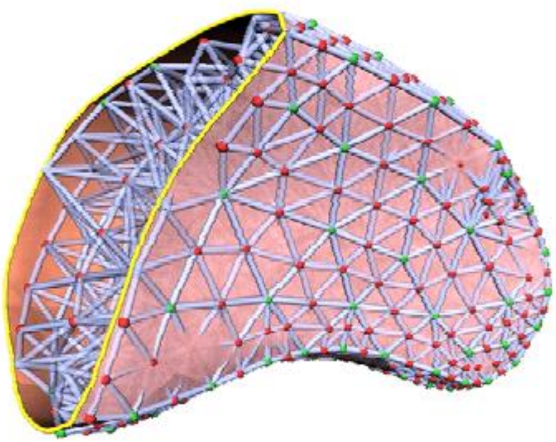
Independent Particles



2d Grid forming Cloth



Rigid Bodies

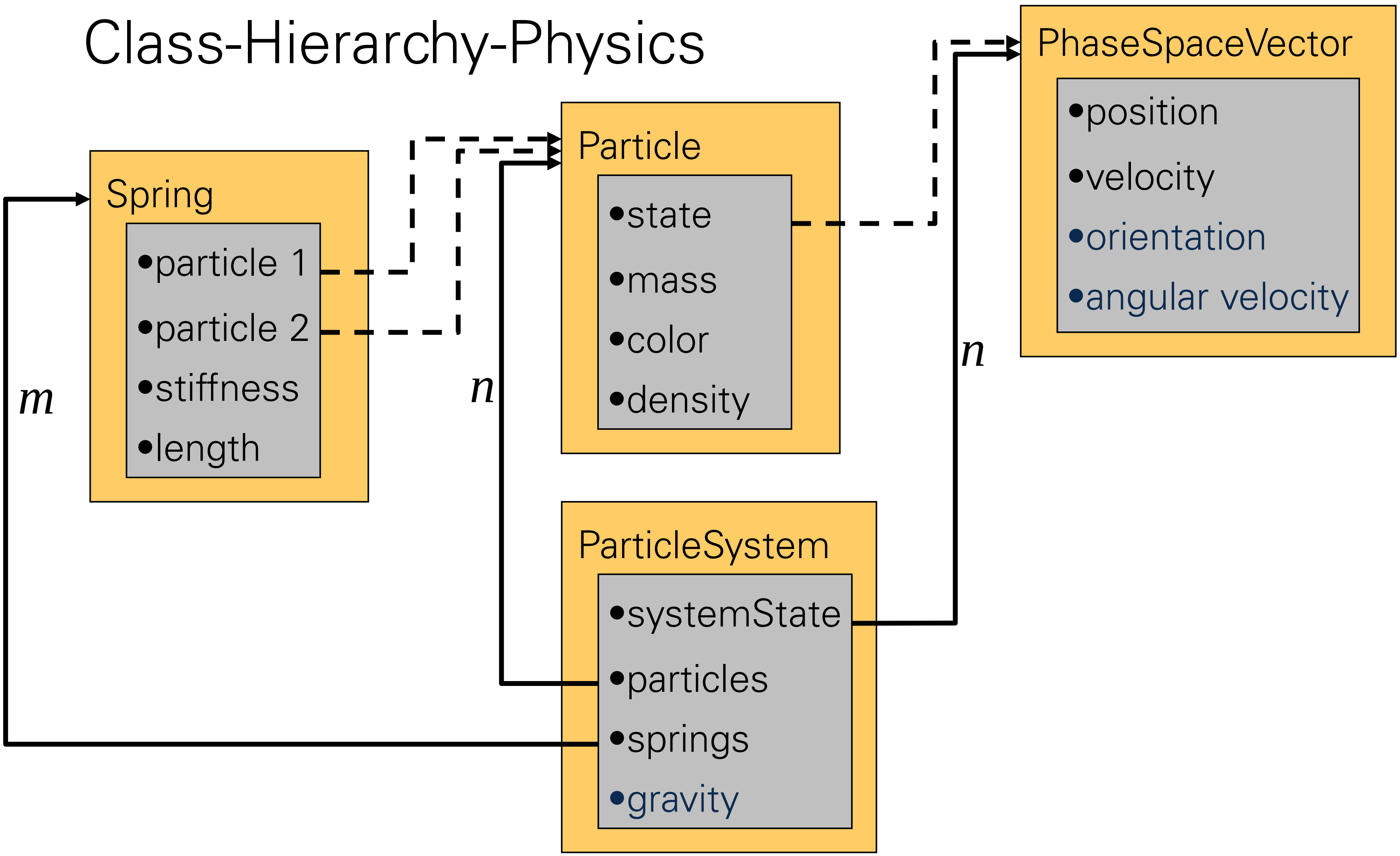


3d Grid for Soft Bodies

Content

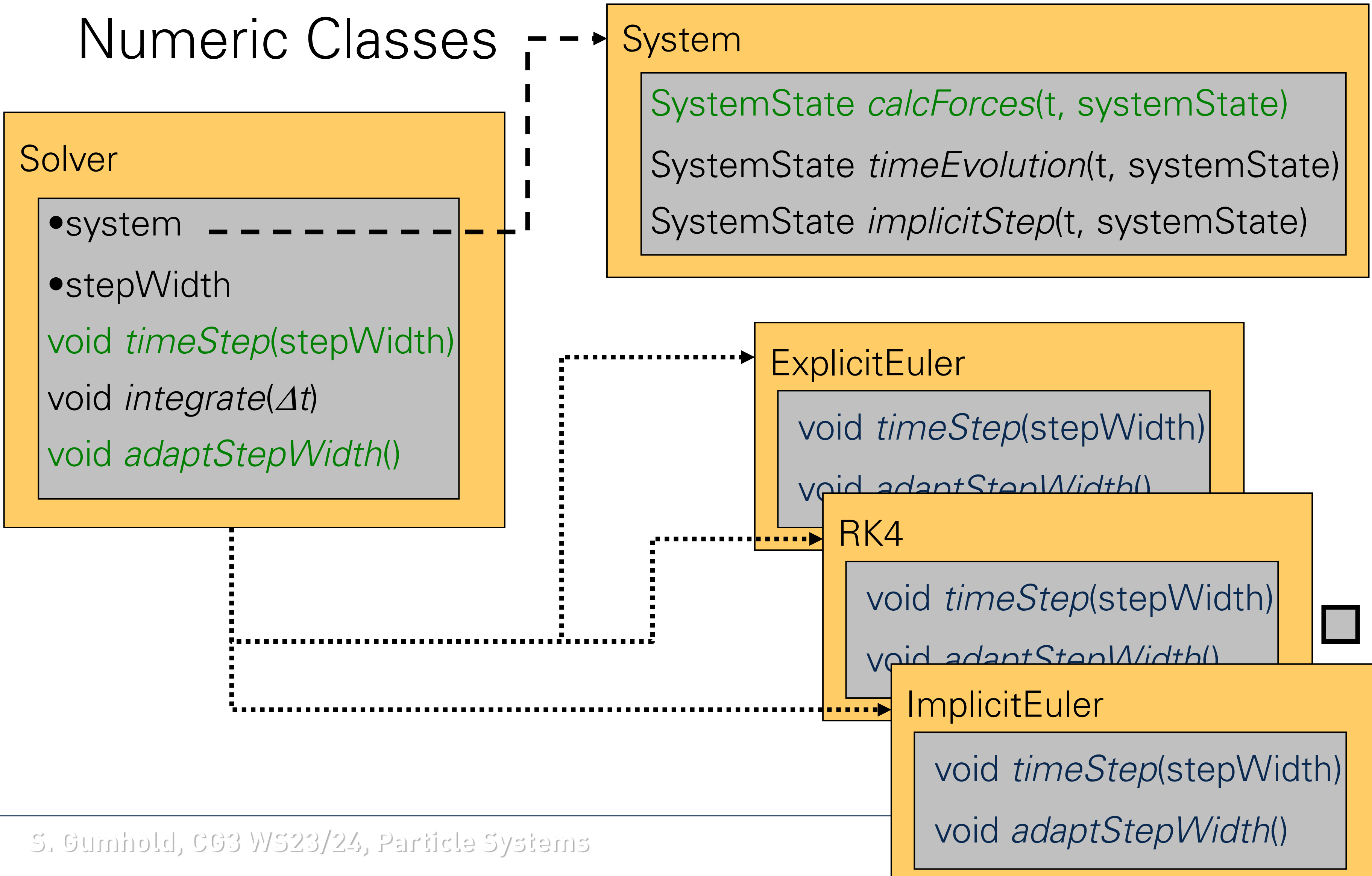
Software Design

Class-Hierarchy-Physics



Software Design

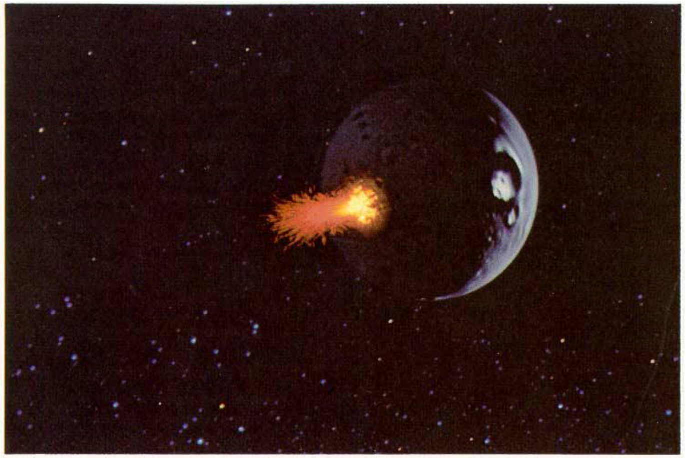
Numeric Classes

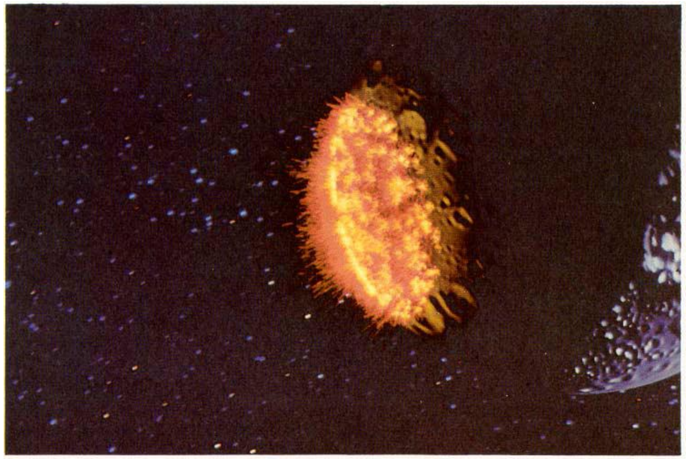


Foundations

Reeves Siggraph 1983/85

- consider independent particles with several properties for phase state and appearance:
  - Position
  - Velocity
  - Mass (typically equal for all particles)
  - Radius
  - Emission Color
  - Transparency
  - Age (used to destruct and re-birth old particles)
- restriction to simple physical model
- stochastic particle sources add complexity





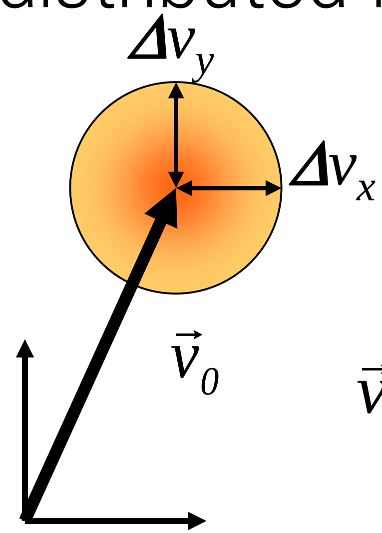
William T. Reeves:
Particle systems - a technique for modeling a class of fuzzy objects. 359-375

Foundations

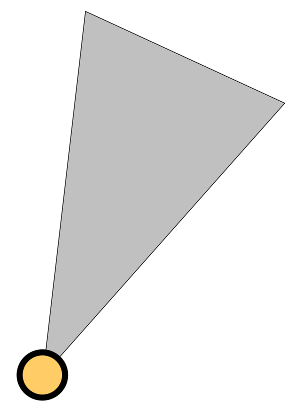
Statistic Sources

https://gpfault.net/posts/webgl2-particles.txt.html

- For each particle property, the user can specify a probability distribution
- One can use transformation sampling to generate random particle from uniformly distributed random variables $\rho_i \in [0,1]$



$$\vec{v}_{rand} = \vec{v}_0 + \rho_1 \begin{pmatrix} \Delta v_x \cos(2\pi\rho_2) \\ \Delta v_y \sin(2\pi\rho_2) \end{pmatrix}$$

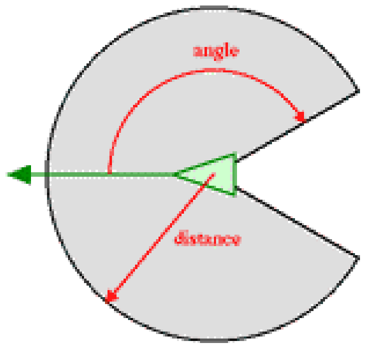


https://webglsamples.org/aquarium/aquarium.html

Boids (Reynolds 87)

Flock of Birds, Herds, Schools

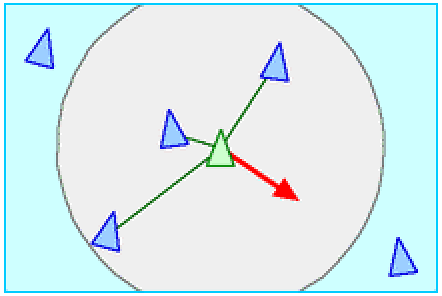
- Extend particles with orientation and 3D modell (e.g. bird, cow, fish, ...)
- Instead of force based models, simulate the behavior of animals that move jointly in swarms, herds, ...
- Evaluate a perceptual model and decide with controlled chance on course change

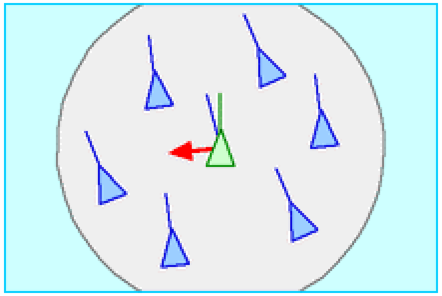


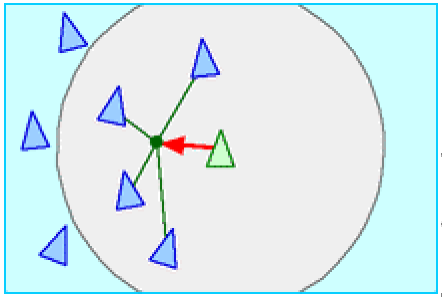
Boids

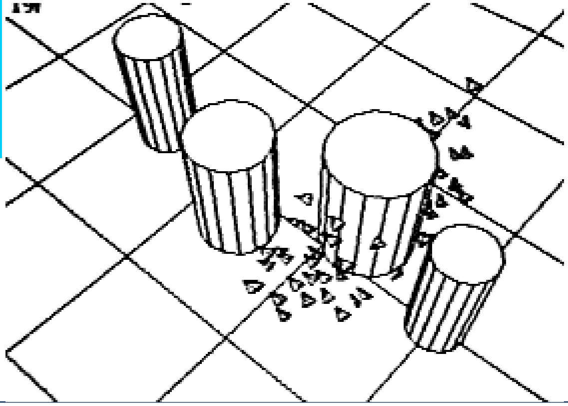
Flock of Birds, Herds, Schools

- avoid collisions with others (separation)
- synchronize directions (alignment)
- stay close to others (cohesion)
- avoid obsticles





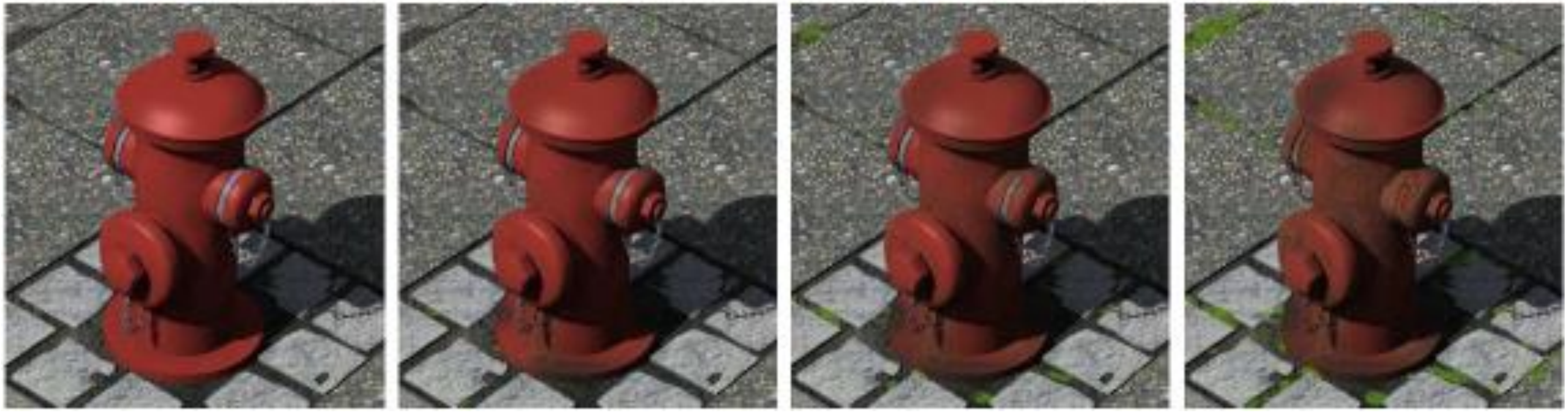




https://threejs.org/examples/#webgl_gpgpu_birds
http://www.red3d.com/cwr/steer/
http://labs.int3ractive.com/javascript/canvas/fish-boids/

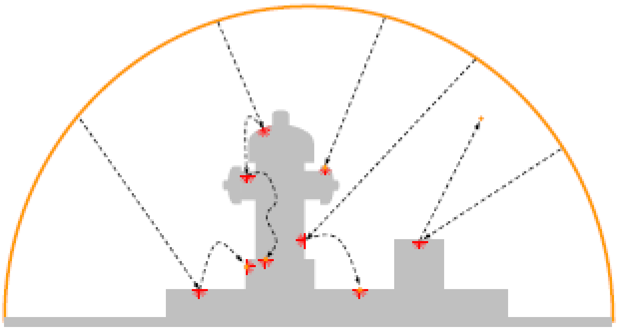
Natural Weathering

Visual Simulation of Weathering By γ-ton Tracing
(Chen, Xia, Wong, Tong Bao, Guo, Shum Siggraph 05)



Natural Weathering

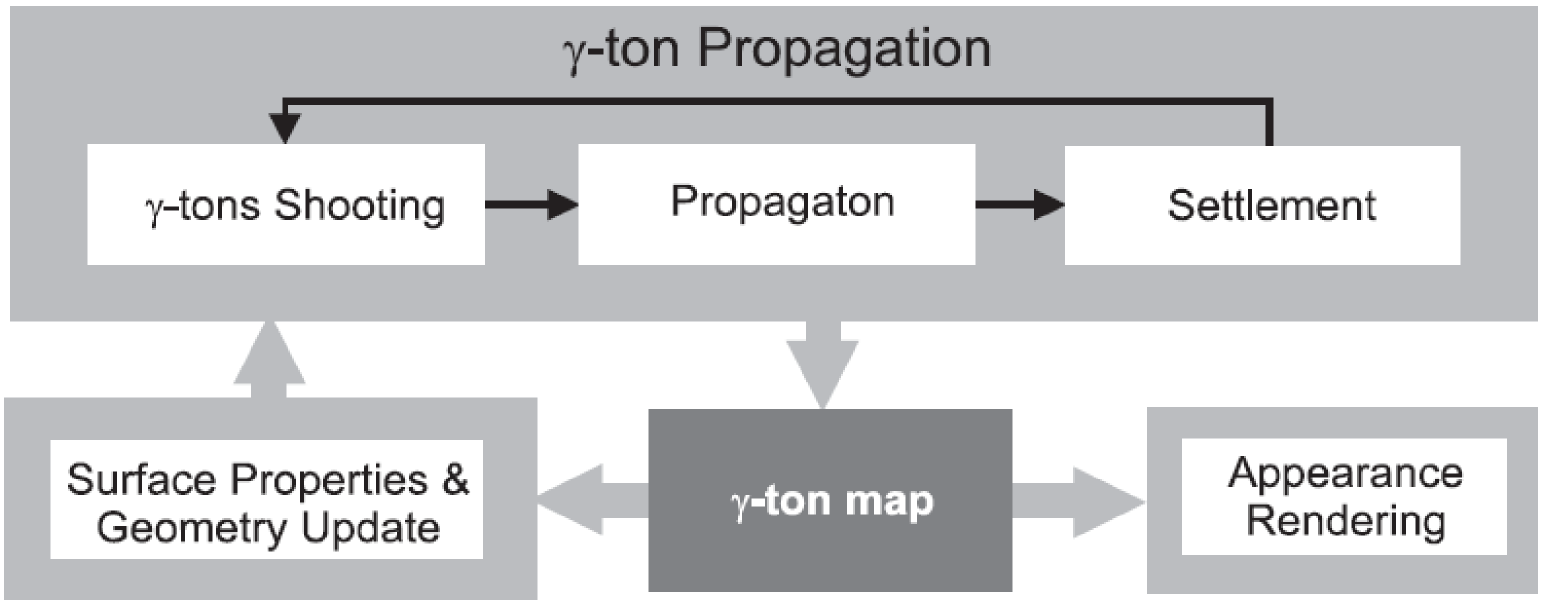
- Gammton from Greek γεροσ or γηραιοσ means old
- γ-tons are generated by sources such as the outer hemisphere of the scene



- Each particle stores movement statistic and weathering influence:
  - humidity, dirt, heat, light
- Deposits and ageing information are stored on the surface of the scene
  - rust, patina, fungus, moss

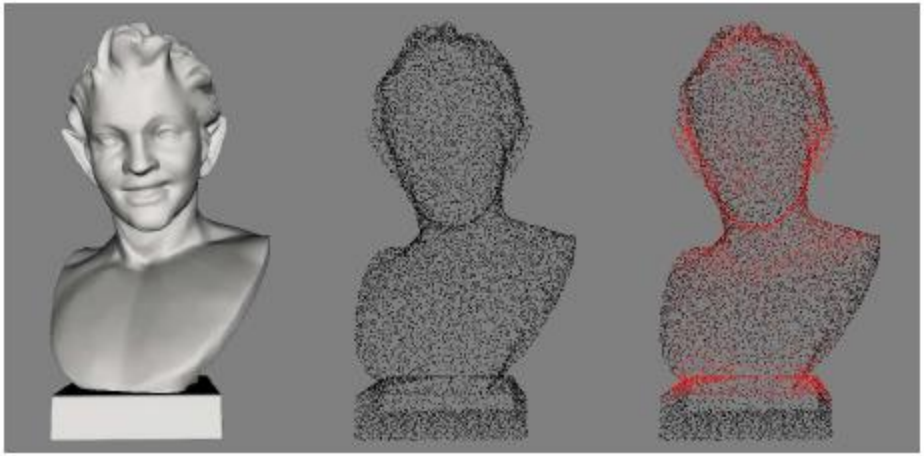
Natural Weathering

Overview of γ-ton Tracing:



Natural Weathering

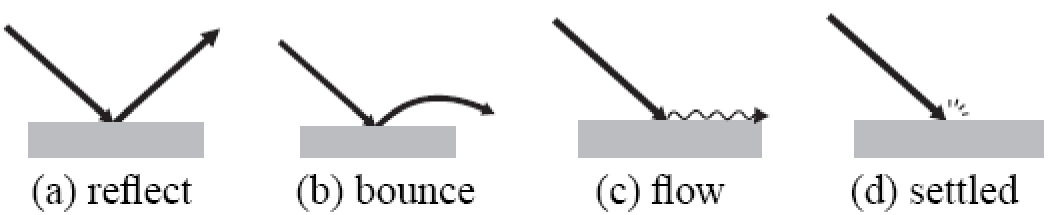
- surfaces are sampled into point clouds; material properties like γ-ton reflectance are stored per point
- γ-tons can deposit, change or pick up materials
- A γ-ton is described through movement statistics, carried materials and weather influences

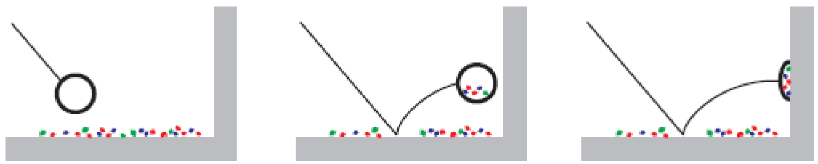


Natural Weathering

Movement Probabilities

- Each particle is assigned propabilities for being in one of the following states:
  - Linear Motion (in case of high energy)
  - Paraboloic Curve (modelling particle with carriers)
  - Flowing along surface (particles with low energy)
  - Settlement (particles with very low energy)
- When particle collides with surface, the movement probabilities change according to surface reflectance



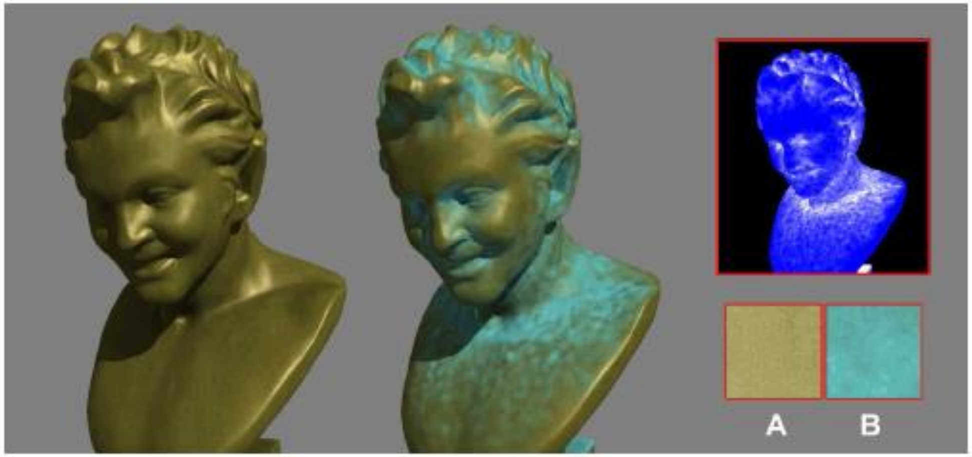


material exchange

Natural Weathering

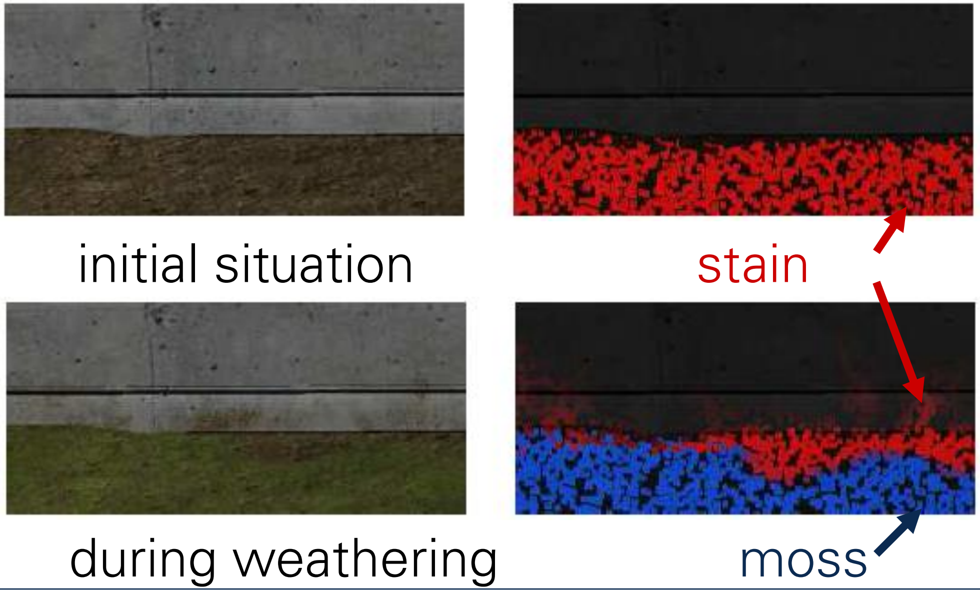
Example Patina:

- γ-tons that carry water increase Patina fraction of surface
- This fraction is used to blend between two materials A and B



Example moss&stain

- γ-tons stimulate moss formation and carry stain



Natural Weathering – Examples

Figure 10: The stain caused by dripping water. This weathering effect is simulated with a point γ-ton source.

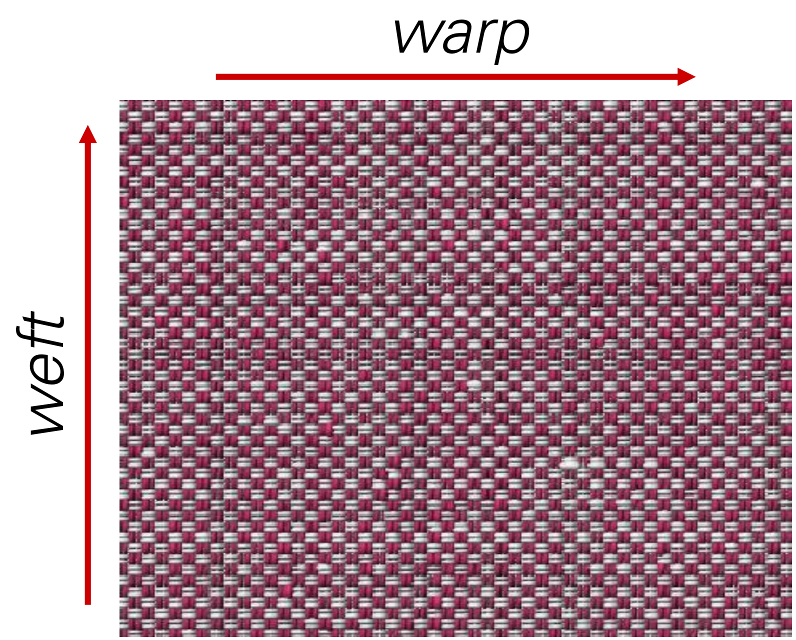
Figure 11: Erosion of Sphinx after thousands of years.

Natural Weathering – Examples

Figure 13: Another scene with “stain-bleeding” effects (in the zoomed areas).

Cloth Simulation

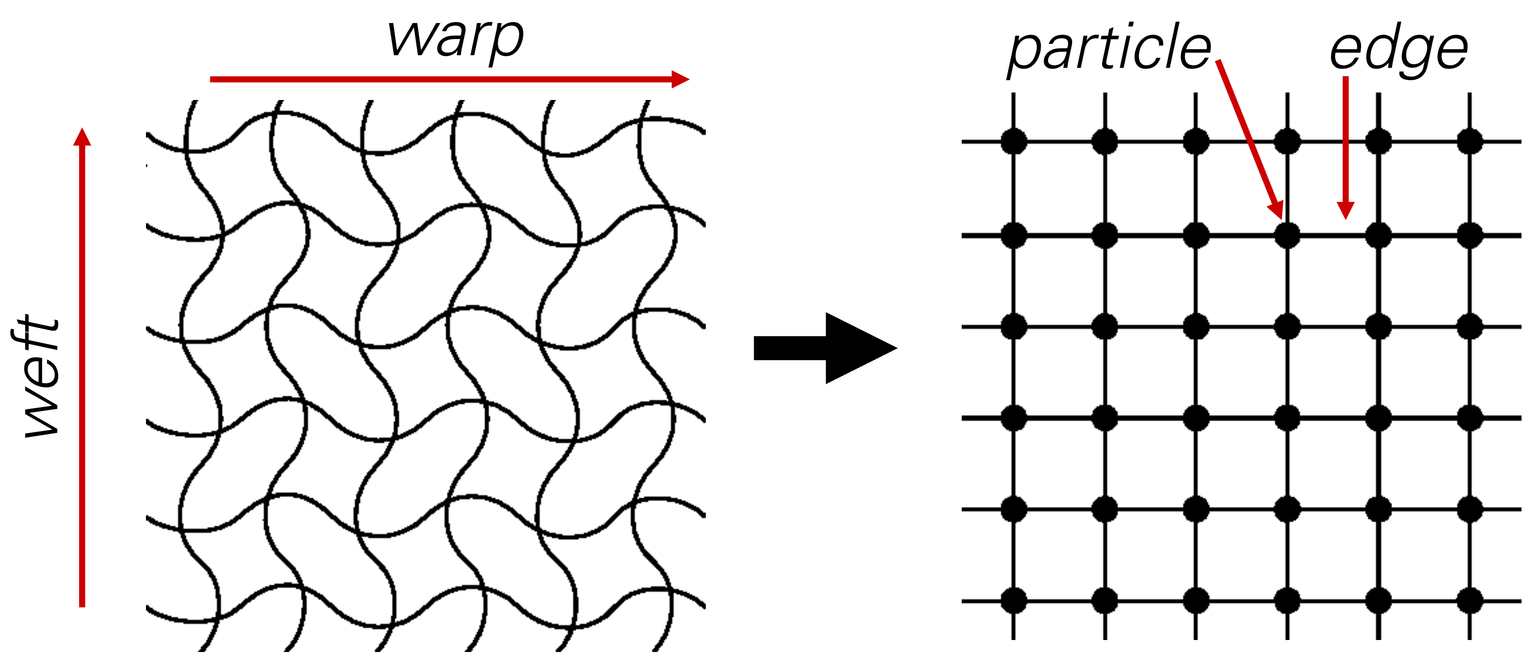
- Woven fabrics typically have two distinguished directions: warp and weft (Kett und Schuss), which significantly influence the physical properties of the fabrics.



© Bernhard Thomaszewski

Cloth Simulation

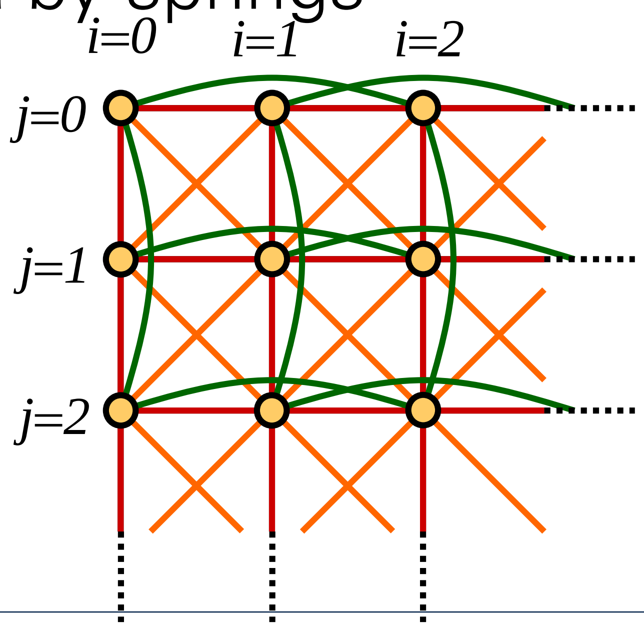
- A discretization of the fabrics should be along the distinguished directions. Therefore, a rectangular grid with vertices where the threads meet is optimal.



Cloth Simulation

Provot 1995

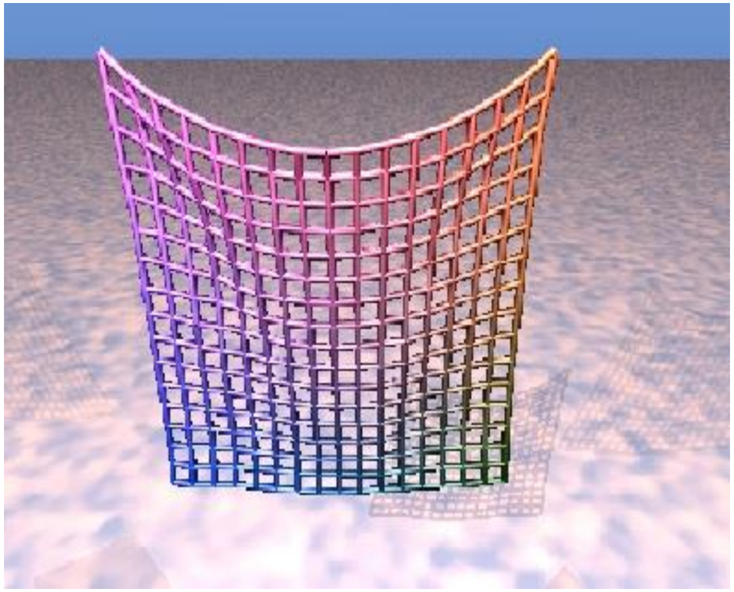
- discretization of a piece of fabrics with a regular grid of particles
- these are enumerated with 2 indices (i,j)
- internal forces are simulated by springs
  - structural springs
  - shear springs
  - flexion springs



Cloth Simulation

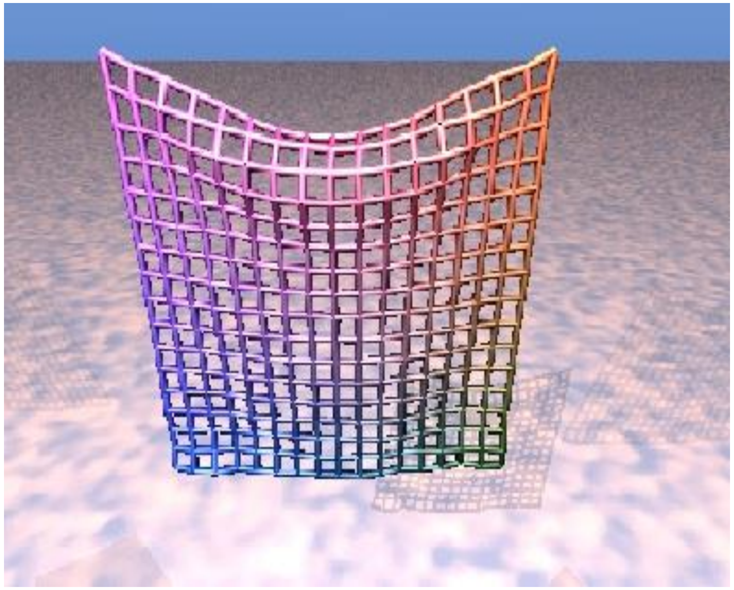
Super Elastic Effect

- If spring constant is chosen too small for easier integration, fabrics become too elastic



What we actually want:

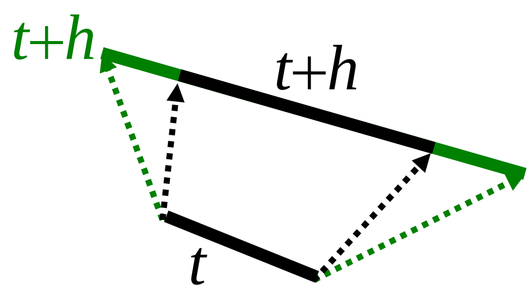
- Structural and shear springs need to be significantly more stiff



https://threejs.org/examples/#physics_ammo_cloth

Solution Strategy

- choose realistically large stiffness k for springs
  - Explicit integration methods need very small stepwidth $h < \pi\sqrt{m/k}$. ➔ use implicit methods
- limit maximum elongation
  - Add constraint on maximum edge length
  - Provot performs simulation step as before and corrects springs that are too long in a random permutation:



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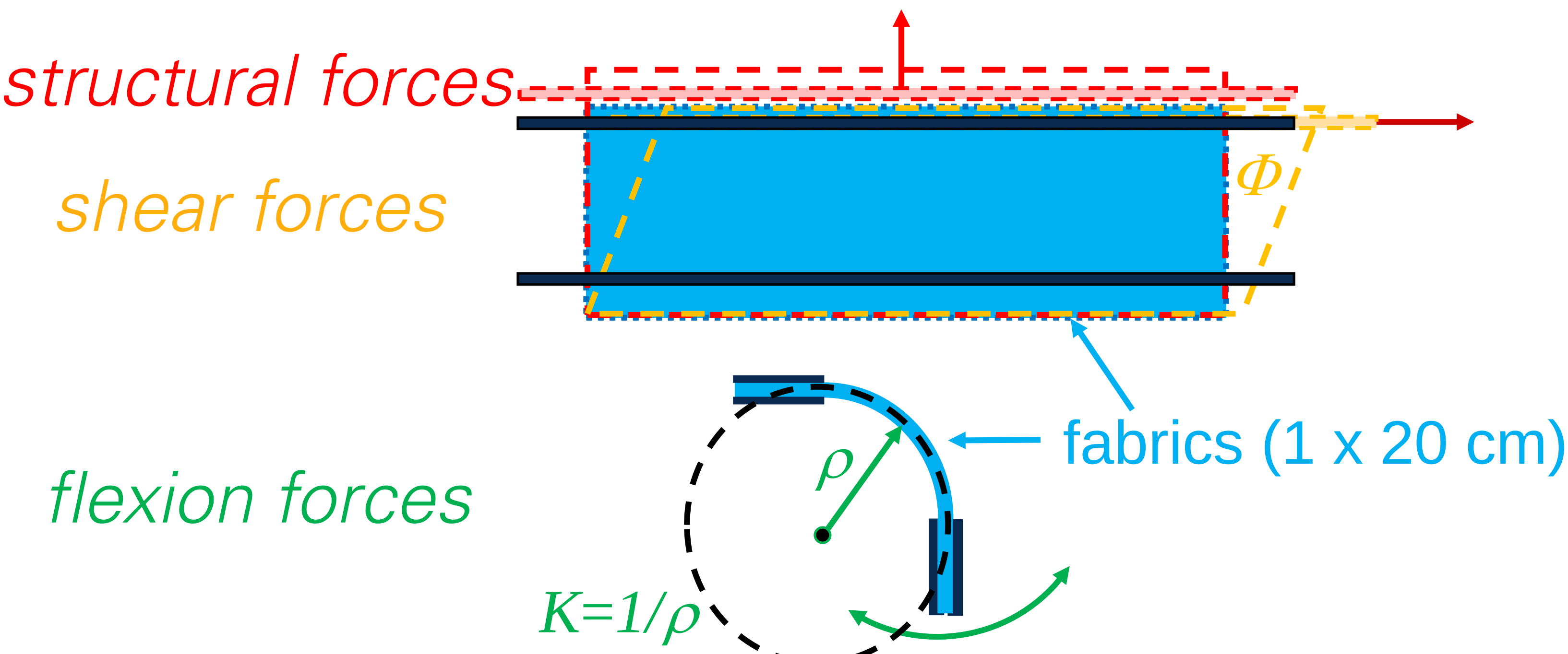
Computergraphik und Visualisierung

Cloth Simulation – Forces

Kawabata-Measurements:

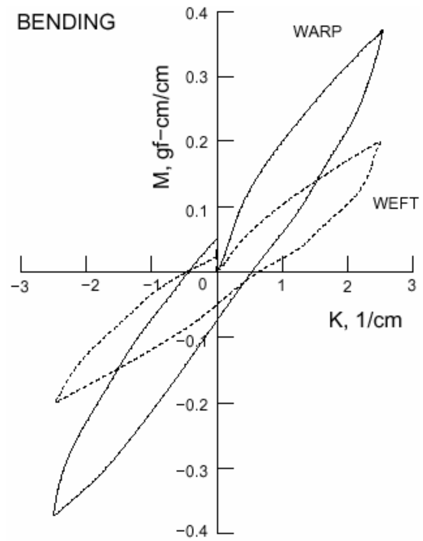
- To simulation real cloth, one measures the three different forces over the elongation with special measurement apparatus:

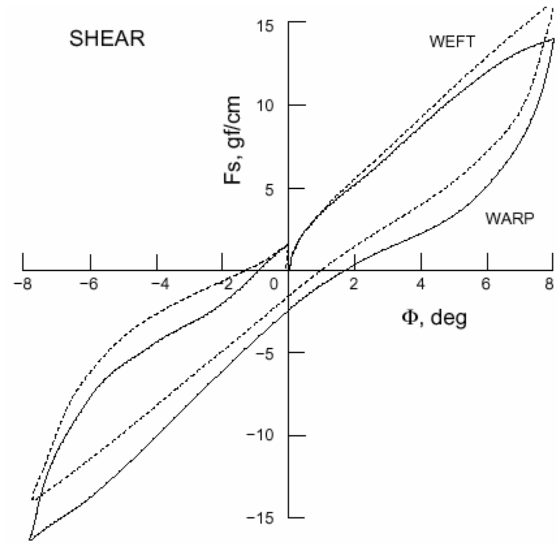


Cloth Simulation – Forces

Hysteresis:

- The measured force curves show the effect of hysteresis, which is due to loss of energy through internal friction of the fabric.
- Therefore one needs to add friction forces that depend on stretching, shearing and bending velocities

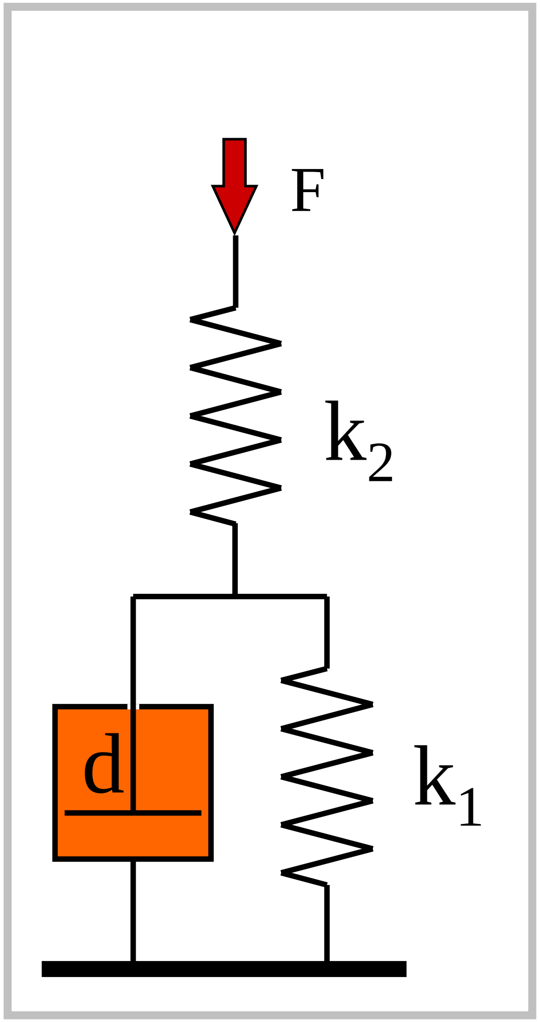




Cloth Simulation – Forces

Hysteresis:

- The Kelvin-Voigt-Spring-Modul allows to model the hysteresis effect by a damper element.
- The damper acts like a memory element that records the history of the movement



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Summary

- Particle systems are the simplest possibility to model a variety of effects like fire, herds and weathering in an adhoc way
- When used for cloth simulation the particles are connected with springs forming a grid like structures with additional connections