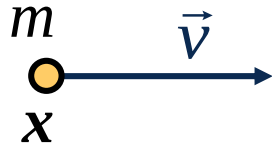


CG3 Part II

Particle Systems

Particle Systems

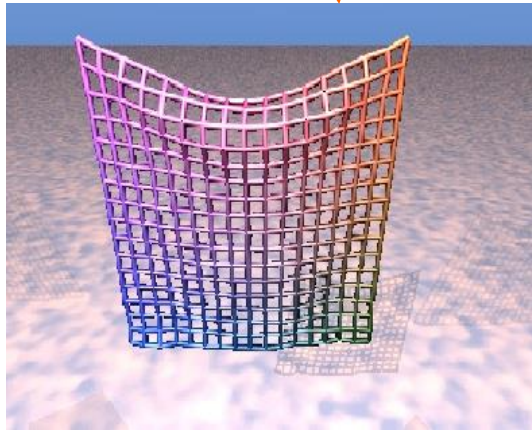
Generalizations of Point Mass



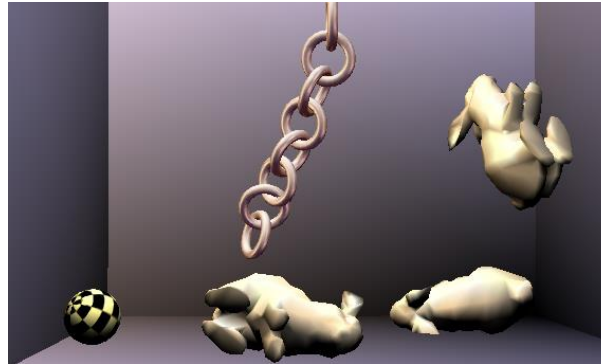
Point mass



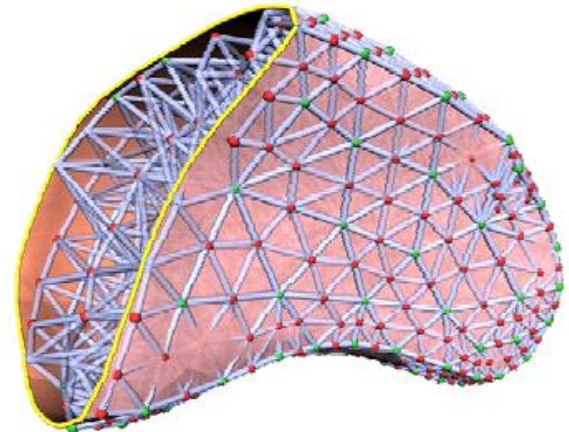
Independent Particles



2d Grid forming Cloth

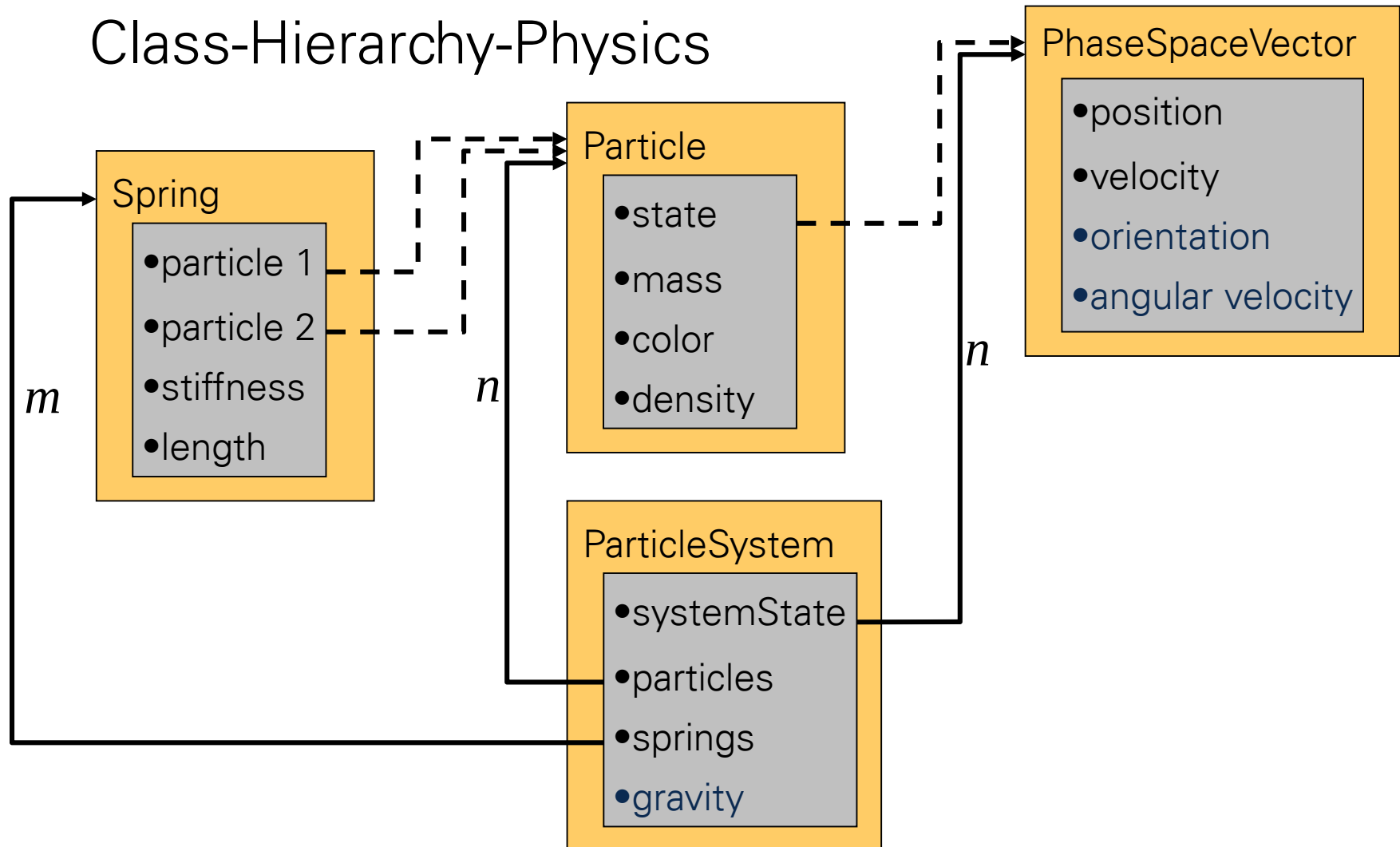


Rigid Bodies

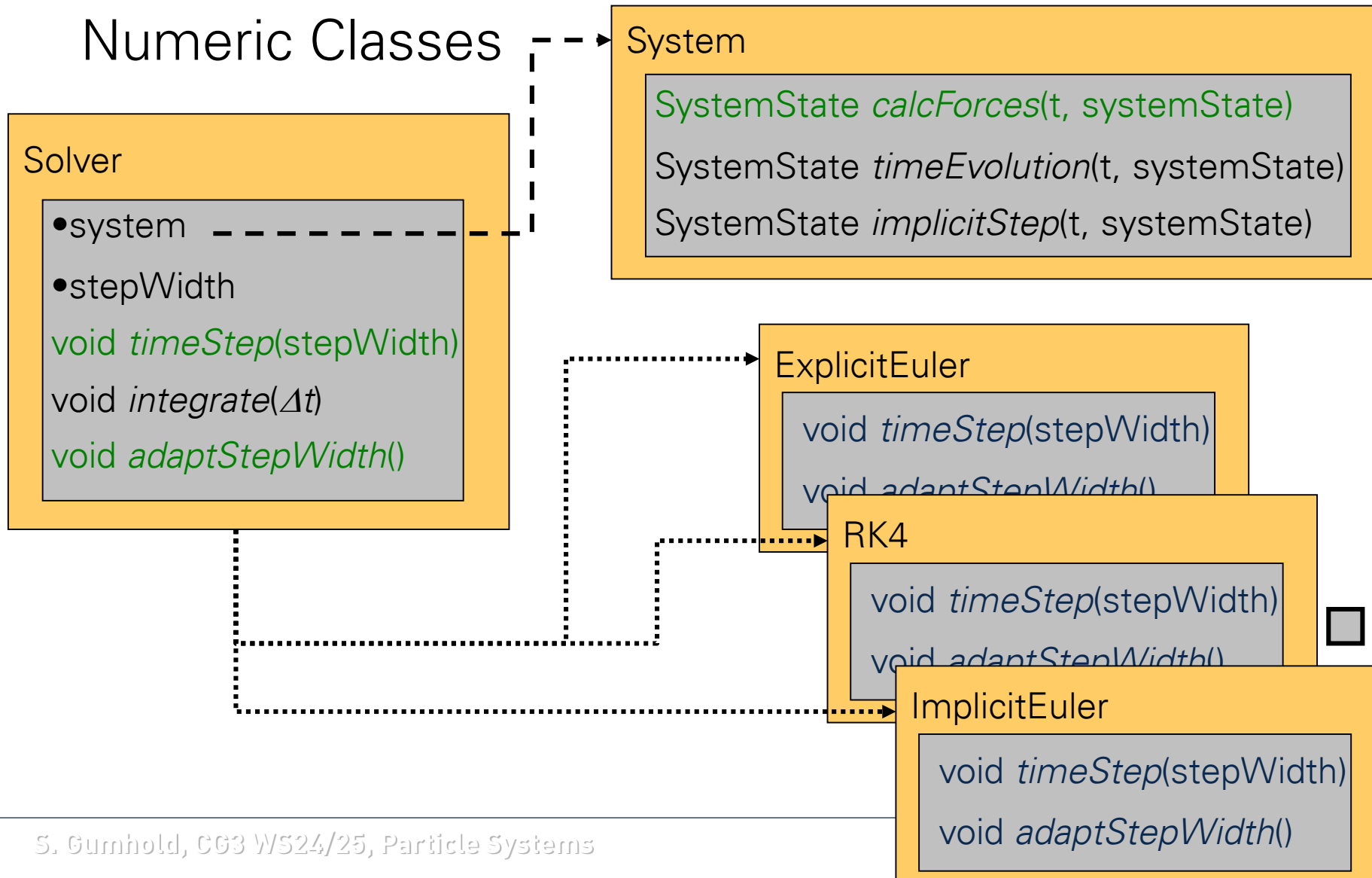


3d Grid for Soft Bodies

- Software Design
- Foundations
- Boids
- Natural Weathering
- Cloth Simulation

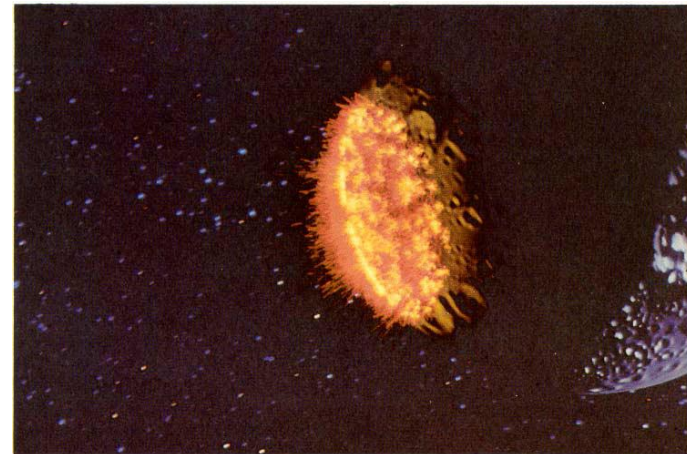
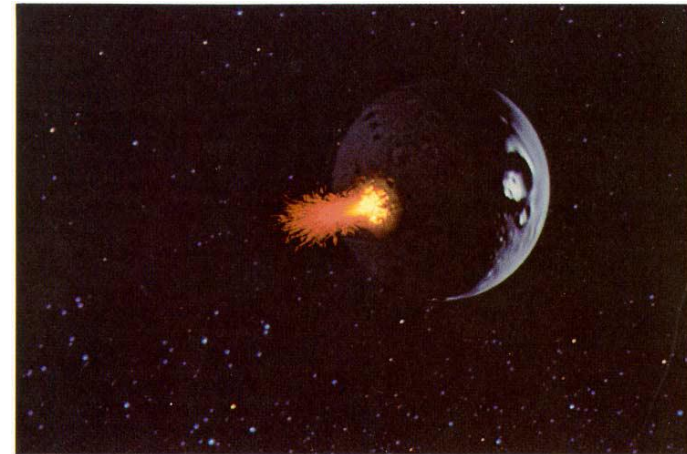


Numeric Classes



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 visual complexity

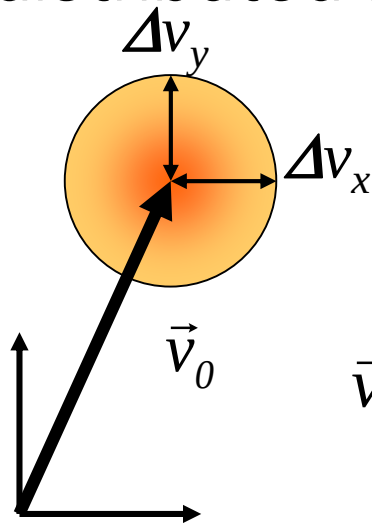


William T. Reeves:
Particle systems - a technique for modeling a class of fuzzy objects. 359-375

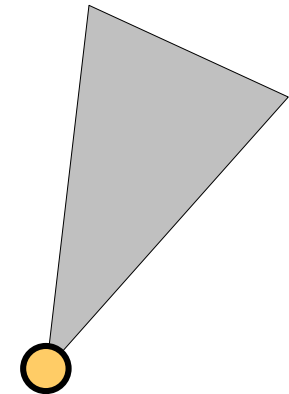
Statistic Sources

<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 $\rho_i \in [0,1]$



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



Boids

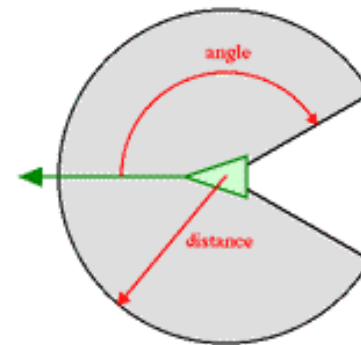
(Reynolds 87)



Computergraphik
und Visualisierung

Flock of Birds, Herds, Schools

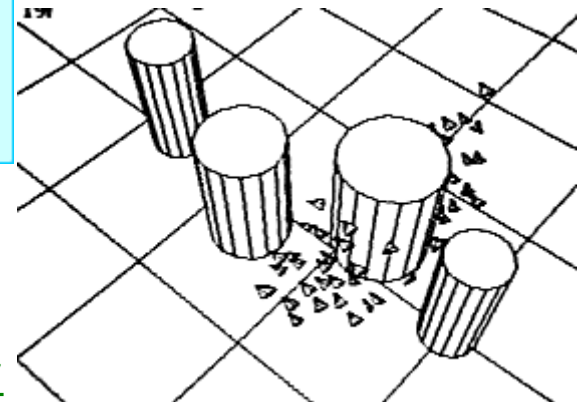
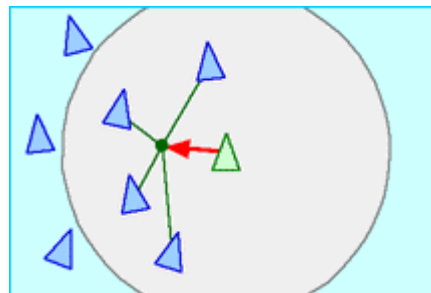
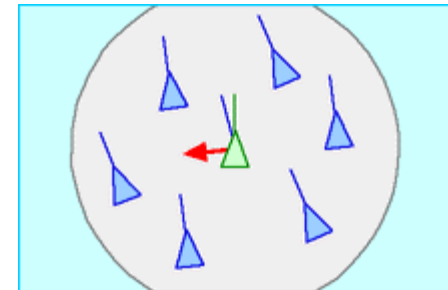
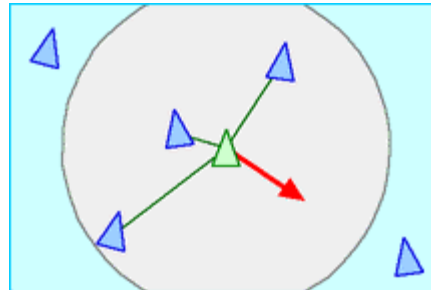
- Extend particles with orientation and 3D modell (e.g. bird, cow, fish, ...)
- Instead of force based models, simulate the behavior of animals that move jointly in swarms, herds, ...
- Evaluate a perceptual model and decide with controlled chance on course change



Boids

Flock of Birds, Herds, Schools

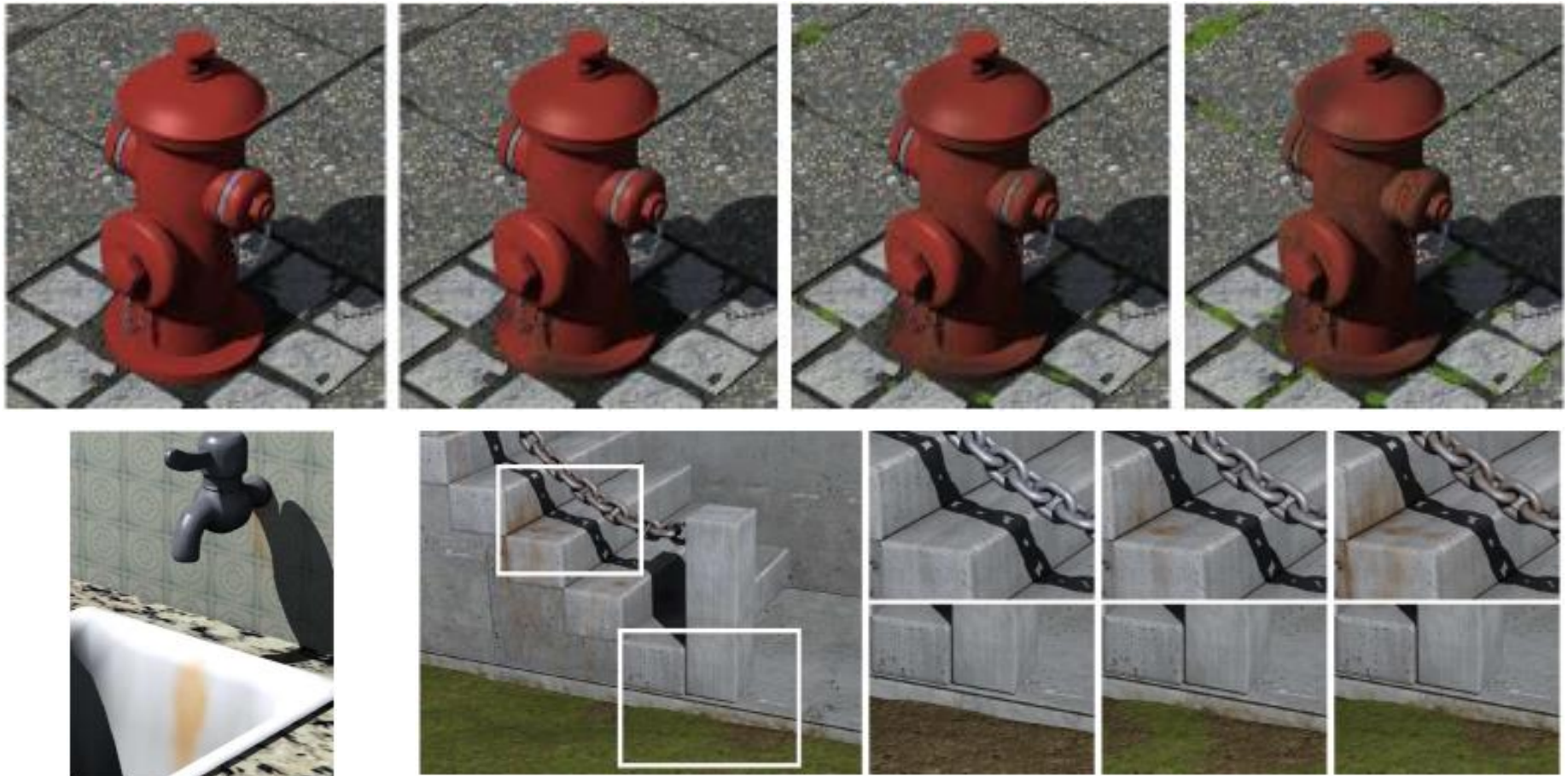
- avoid collisions with others (separation)
- synchronize directions (alignment)
- stay close to others (cohesion)
- avoid obstacles



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

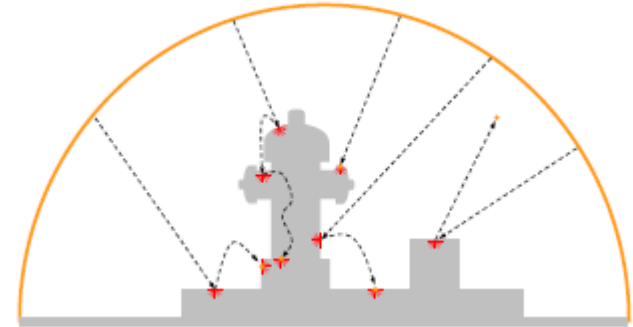
Visual Simulation of Weathering By γ -ton Tracing

(Chen, Xia, Wong, Tong Bao, Guo, Shum Siggraph 05)

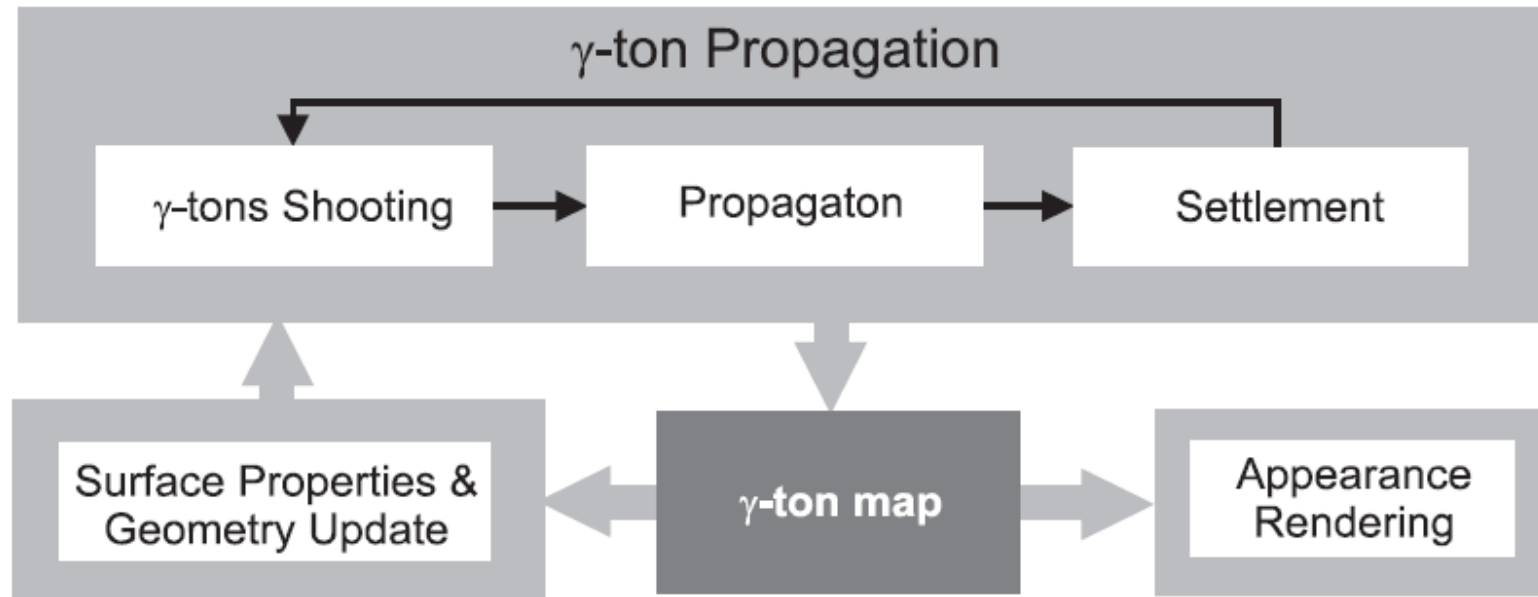


Natural Weathering

- Gammton from Greek γερως 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

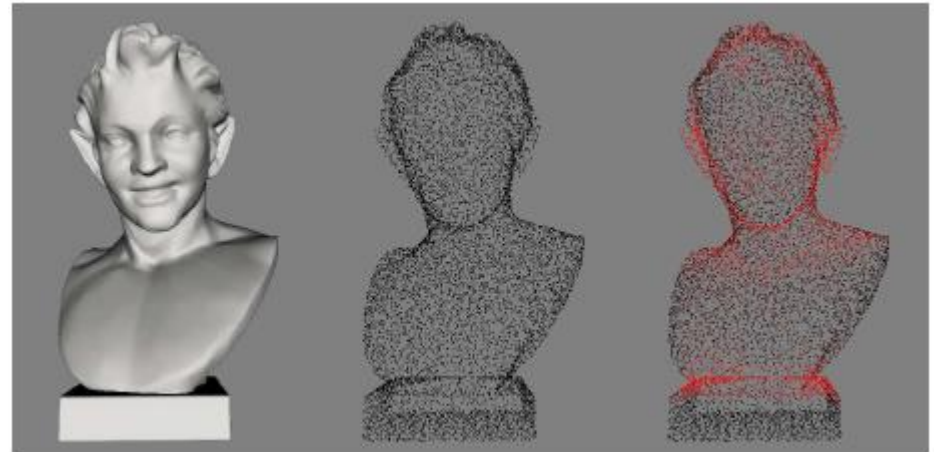


Overview of γ -ton Tracing:



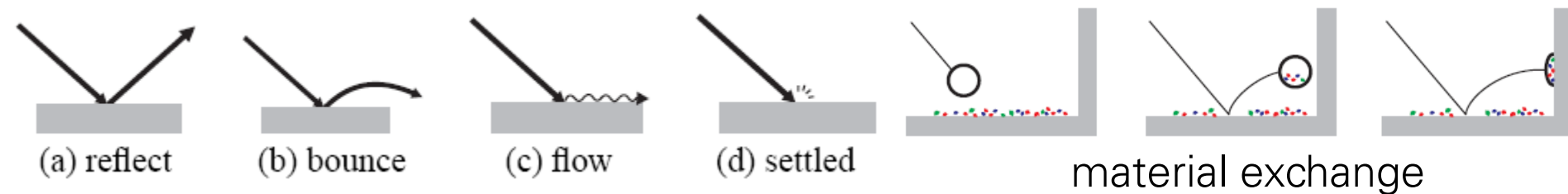
Natural Weathering

- **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



Movement Probabilities

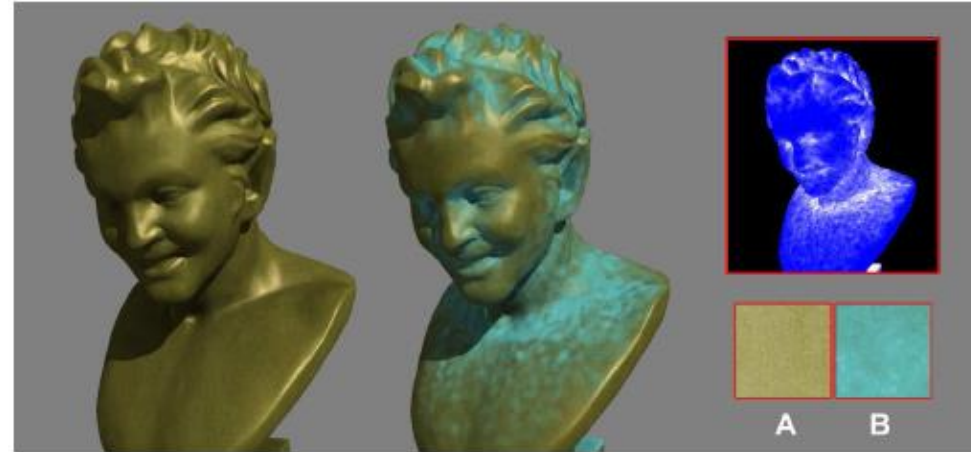
- Each particle is assigned probabilities for being in one of the following states:
 - Linear Motion (in case of high energy)
 - Parabolic Curve (modelling particle with carriers)
 - Flowing along surface (particles with low energy)
 - Settlement (particles with very low energy)
- When particle collides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



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



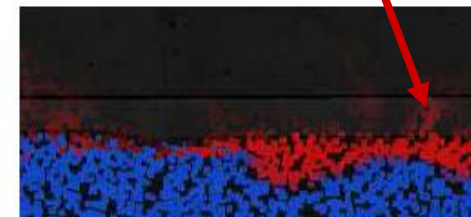
initial situation



during weathering



stain



moss

Natural Weathering – Examples



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



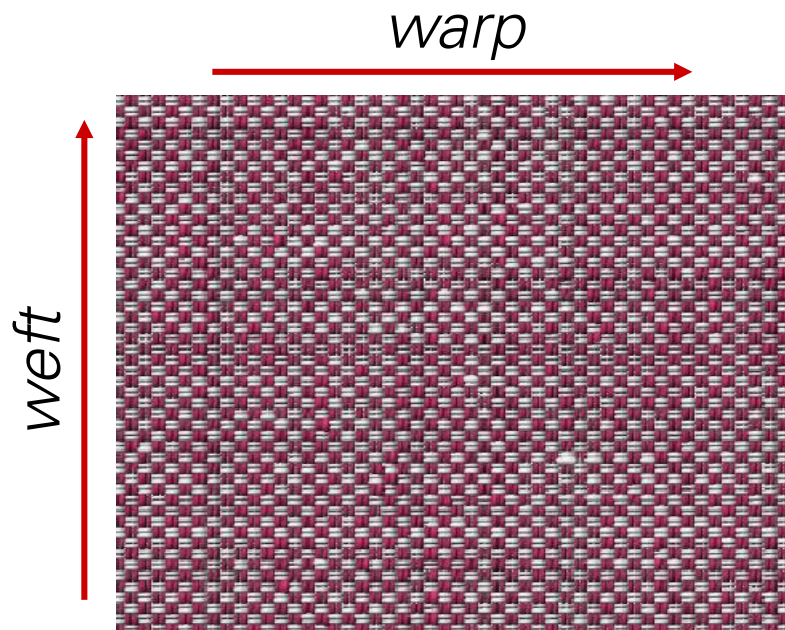
Figure 11: Erosion of Sphinx after thousands of years.

Natural Weathering – Examples



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

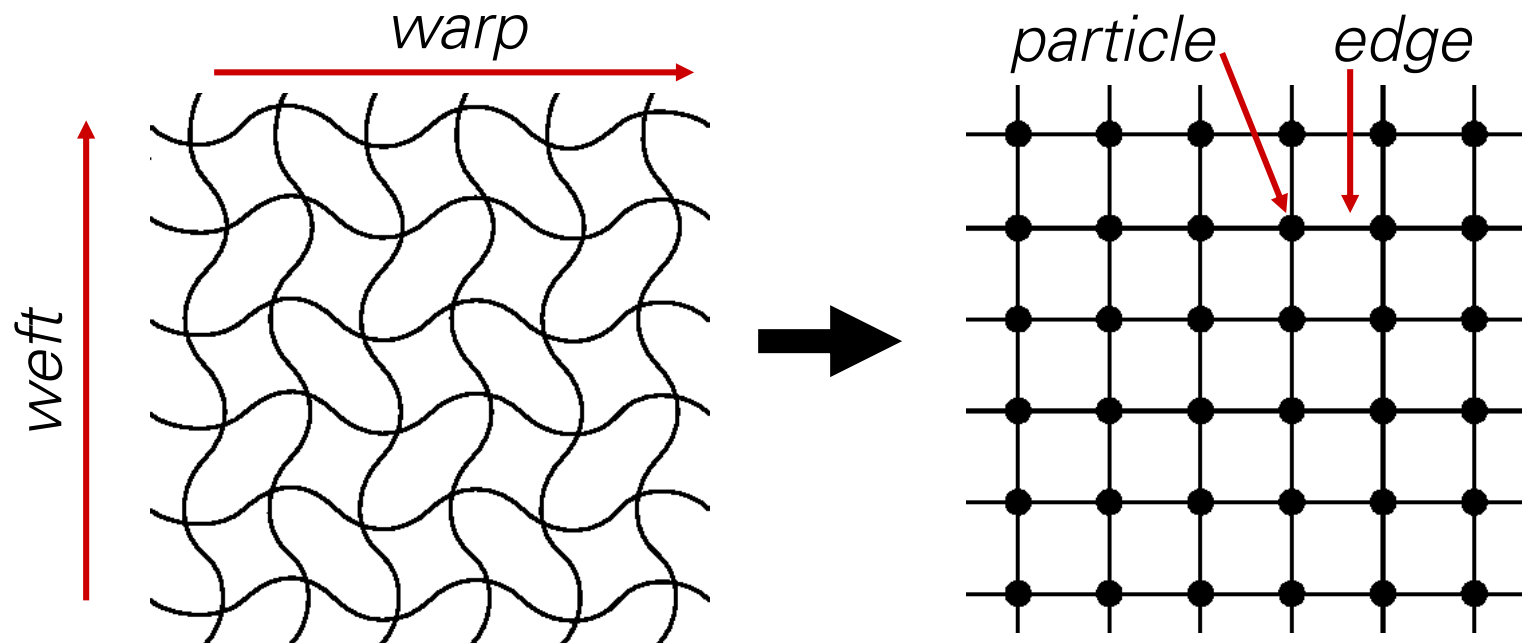
- Woven fabrics typically have two distinguished directions: **warp** and **weft** (**Kett** und **Schuss**), which significantly influence the physical properties of the fabrics.



© [Bernhard Thomaszewski](#)

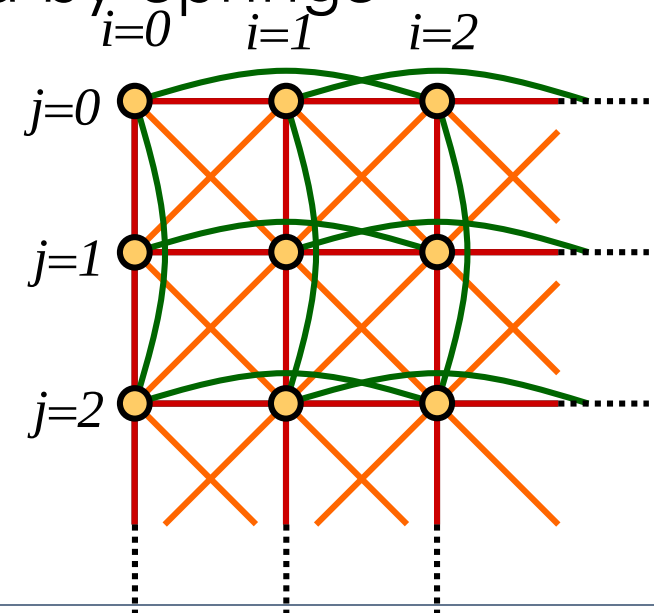
Cloth Simulation

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



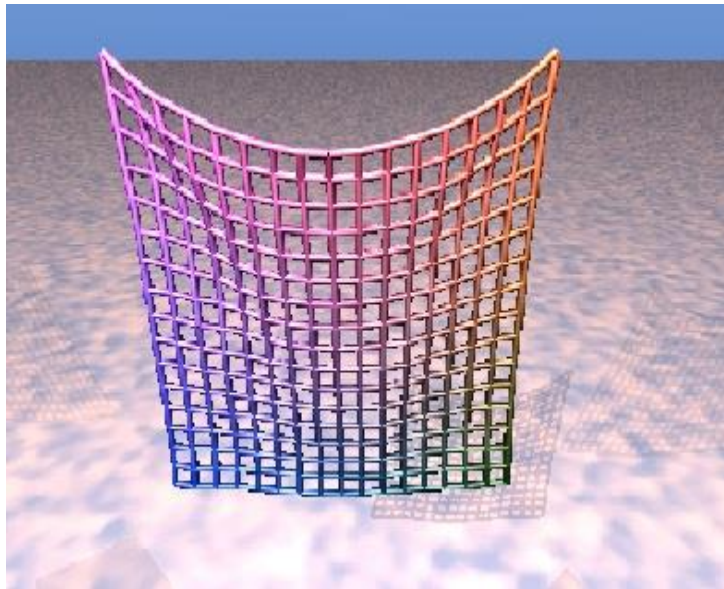
Provot 1995

- 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



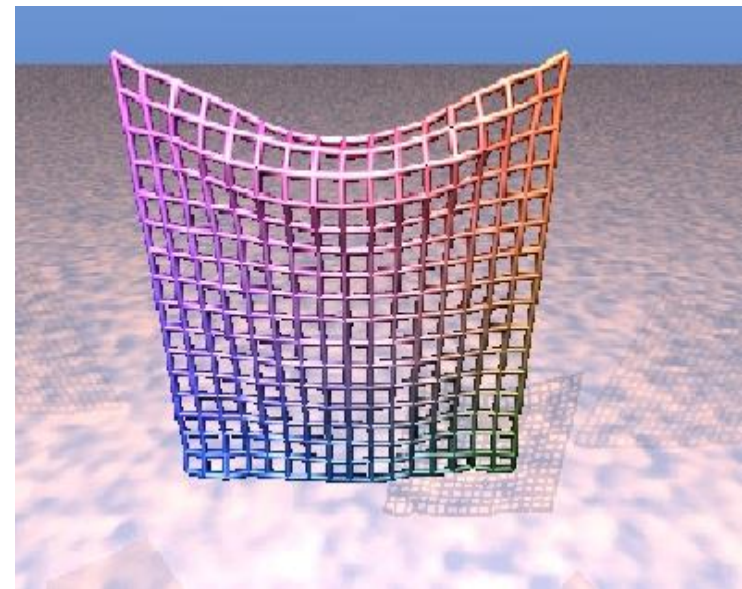
Super Elastic Effect

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



What we actually want:

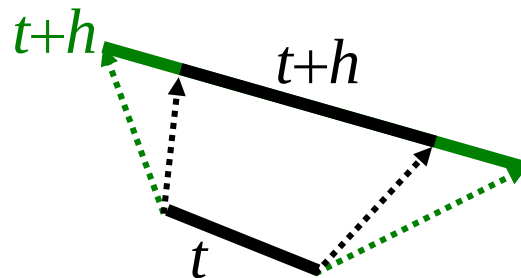
- Structural and shear springs need to be significantly more stiff



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

Solution Strategy

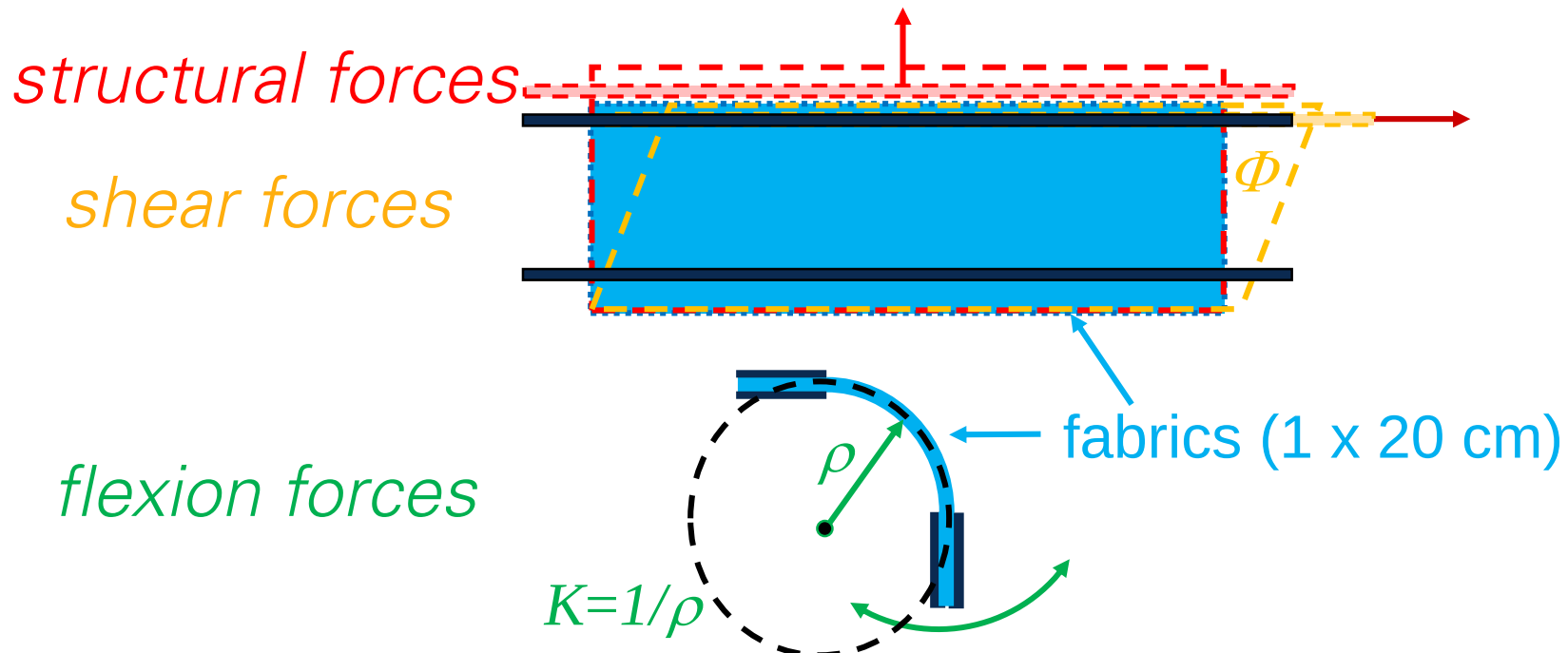
- choose realistically large stiffness k for springs
 - Explicit integration methods need very small stepwidth $h < \pi\sqrt{m/k}$. $\rightarrow$ use implicit methods
- limit maximum elongation
 - Add constraint on maximum edge length
 - Provot performs simulation step as before and corrects springs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



Cloth Simulation – Forces

Kawabata-Measurements:

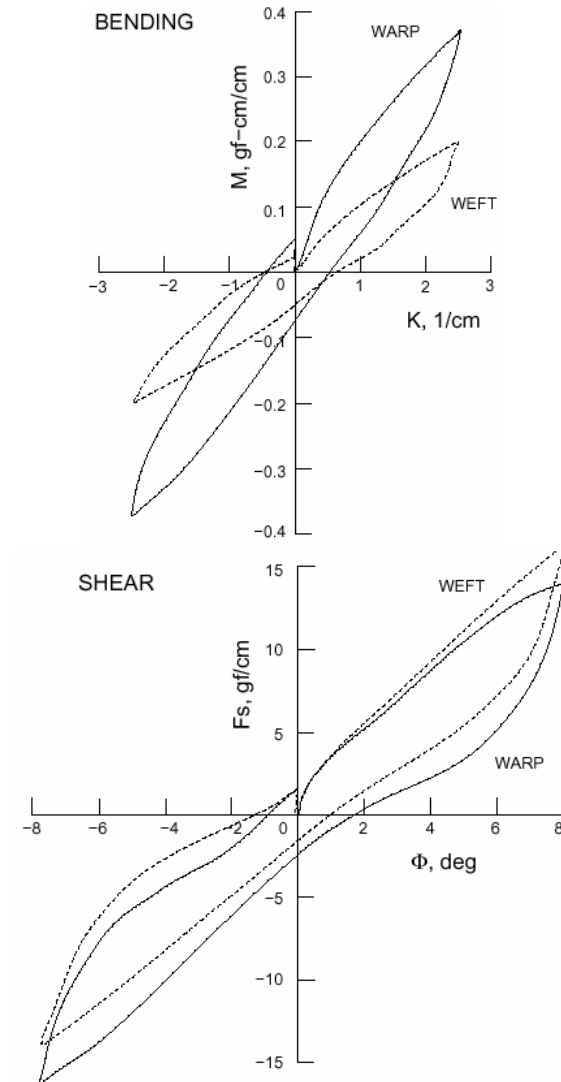
- To simulate real cloth, one measures the three different forces over the elongation with special measurement apparatus:



Cloth Simulation – Forces

Hysteresis:

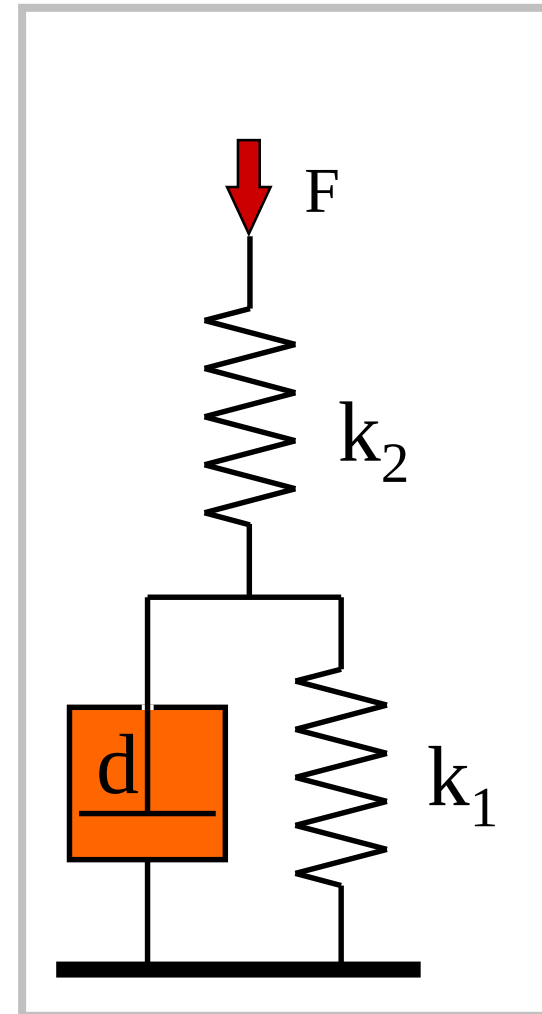
- The measured force curves show the effect of hysteresis, which is due to loss of energy through internal friction of the fabric.
- Therefore one needs to add friction forces that depend on stretching, shearing and bending velocities



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



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