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Project Title: Cloth Deformation Upgrade using Deformation Models

Base Assignment: Programming Assignment 1 (PA1)

Motivation

The mass–spring cloth finished in Assignment 1 is easy to code but difficult to tune:

- Stretch, shear, and bend stiffnesses interact unpredictably.
- Large deformations look rubbery or tear when springs are stiff.
- Numerical damping must be cranked up to hide artifacts.

Triangle-based energy models (co-rotated linear, St. Venant–Kirchhoff, Neo-Hookean) offer a cleaner alternative using the same mathematics already implemented for the 2-D gingerbread simulator. Porting those models to the cloth will give realistic stretching and crisp folding while letting us remove most hand-tuned spring constants.

Goals and Scope

Priority	Goal	High-level Method
Core	Replace spring forces with per-triangle energy forces for three models: 1) co-rotated linear, 2) StVK, 3) Neo-Hookean.	*Each frame*: compute deformation gradient **F** for every triangle → evaluate stress **P(F)** with the chosen model → convert to vertex forces using the lecture 06's five steps.

Core	Keep the existing symplectic-Euler integrator, gravity, damping, and obstacle collisions from Assignment 1.	No integrator changes; simply sum the new forces with gravity and damping.
UI	Add GUI sliders for model ID, Young's modulus **E**, and Poisson ratio **ν**.	Sliders write directly into the global material parameters.
Stretch goal	Add triangle-hinge bending energy (Baraff & Witkin, 1998)	For each interior edge, calculate the hinge angle and apply its simple energy gradient.

Validation

Aspect	Test & Success Criterion
Physical plausibility	When the cloth hangs under gravity, the co-rotated linear model should exhibit a small but noticeable stretch, the St. Venant–Kirchhoff model should appear stiffer, and the Neo-Hookean model should resist volume change.
Stability	128 × 128 cloth, 1 ms timestep, runs 20 s with no exploding velocities.
Collision quality	Sphere-drop scene from Assignment 1: maximum penetration < 1 % cloth thickness.

User control	Changing sliders during runtime updates stiffness smoothly with no reset required.
Stretch goal	With hinge bending enabled, a folded cloth shows similar (maybe sharper) creases.

Performance target: ≥ 60 FPS on GPU Taichi for the 128×128 grid.

Timeline

Week	Milestone
1	Convert cloth quads to triangles; pre-compute rest matrices D_0^{-1} and areas.
2	Implement deformation gradient **F** and energy forces for the co-rotated model; verify on single triangle unit tests.
3	Add StVK and Neo-Hookean options; connect GUI sliders; regression tests on sphere and table scenes.
4	Optimize kernel loops; record validation results; polish demo.
5 (stretch)	Implement hinge bending energy; compare folds; finalize report and video.