Position Based Dynamics – Oriented Particles Dynamics

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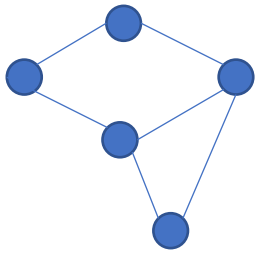
Position based dynamics

Inputs:

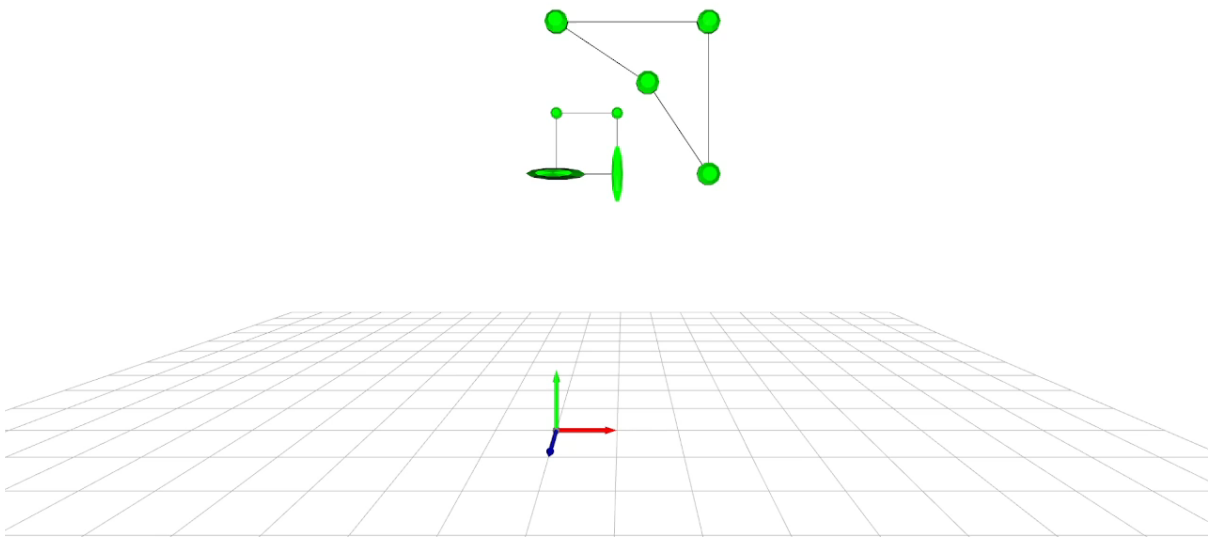


Set of particles (x_i, v_i, m_i).

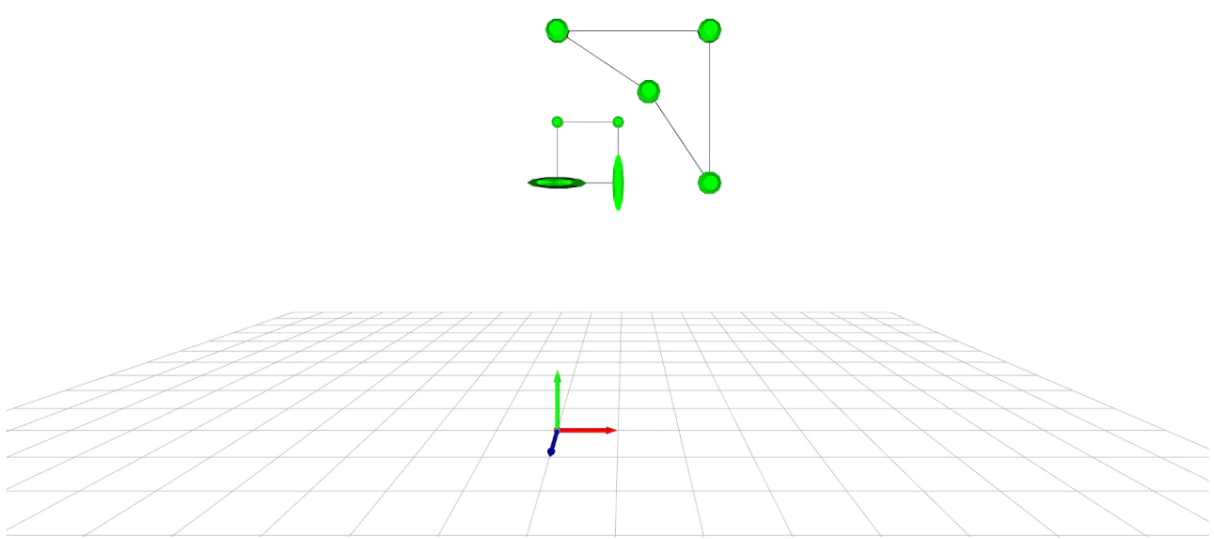
Set of constraints (e.g springs)

- For each time step:
  - Estimate the new velocity (v) and position (p) using stored positions (x) and velocity (v)
    - $v_i(t+dt) = v_i(t) + dt * g$
    - $p_i(t+dt) = x_i(t) + dt * v_i(t+dt)$
  - Damp velocities
  - Correct each position with a corrective term, such that the constraints are satisfied (in a Gauss-Seidel fashion):
    - $p_i(t+dt) = p_i(t) + \Delta p_i$
    - $\Delta p_i \propto abs(p_1 - p_2 - d) * \frac{(p_1 - p_2)}{abs(p_1 - p_2)}$
  - Update the positions and velocities
    - $v_i(t+dt) = \frac{p_i(t+dt) - x_i(t)}{dt}$
    - $x_i(t+dt) = p_i(t+dt)$
  - Perform frictions with ground and particles

Position based dynamics – Damping tests



Simulation without damping



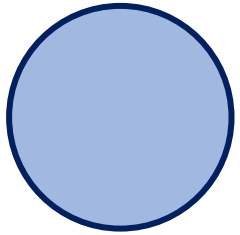
Simulation with damping

Observation: Bodies are stiffer

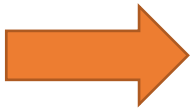
Distant Constraint ON – Shape Matching OFF

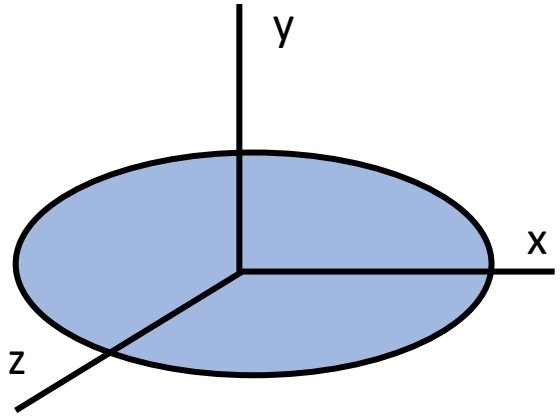
Oriented Particles Dynamics

Particles become ellipsoids:



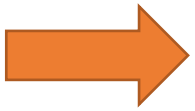
(x_i, v_i)

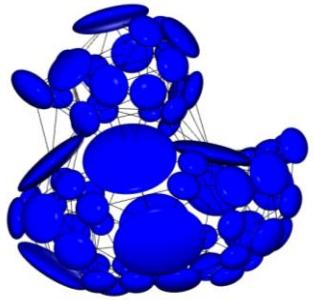




$(x_i, v_i, q_i, \omega_i)$

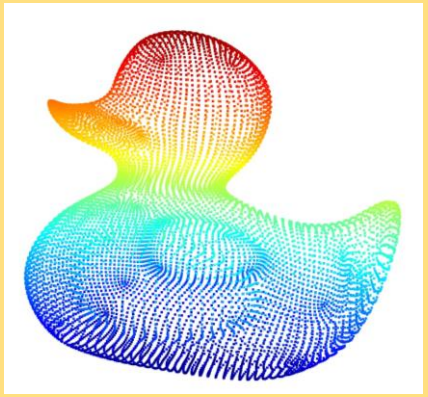
We represent a mesh with a graph of ellipsoids



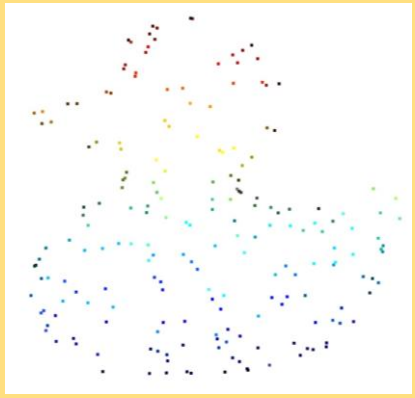


Each ellipsoid describes a local rigid transformation of the mesh, thanks to (x_i, q_i). The inverse transformation will be done with skinning.

Mesh Generator: Inputs, process and outputs



Vertices of the mesh



Candidate centers for ellipsoids (mesh-inferred)

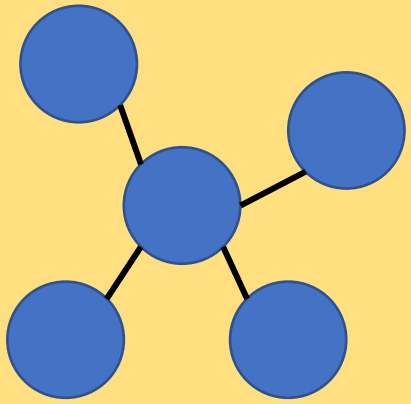
Maximum radius of ellipsoid

KD-Tree of vertices and centers

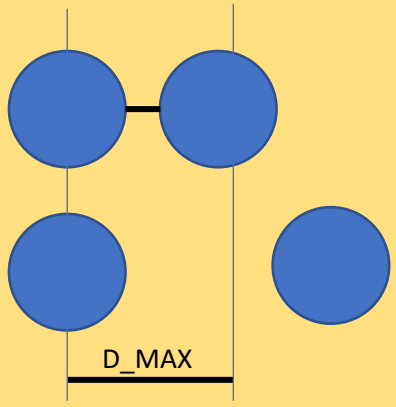
Find neighbor vertices of each center candidate

Check if enough points

Creation of OBB. The edges gives ellipsoid radii

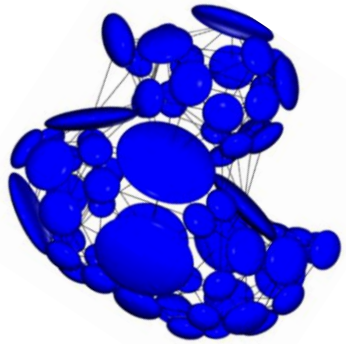


Maximum number of neighbors

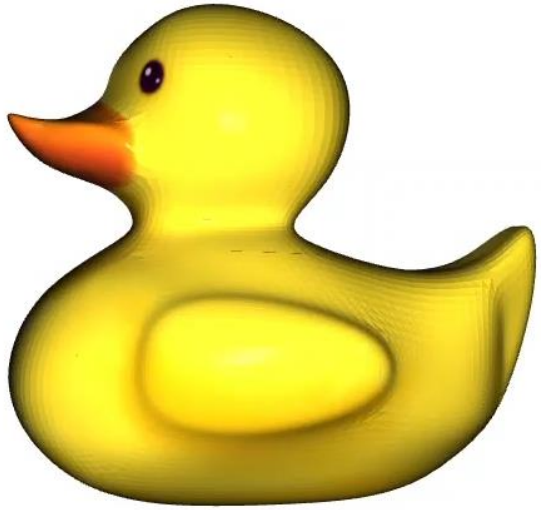


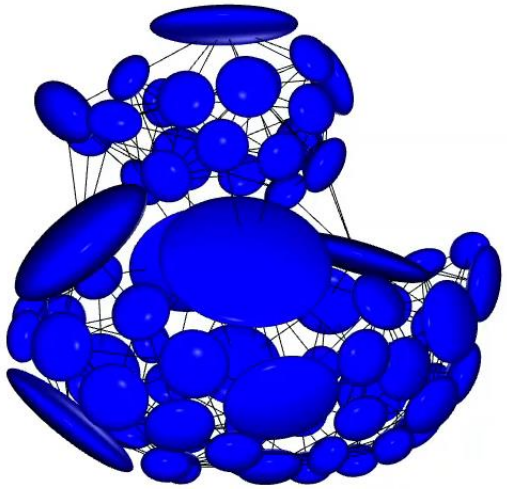
Maximum distance between neighbors

Create ellipsoids. Find connections. Create Particle Graph



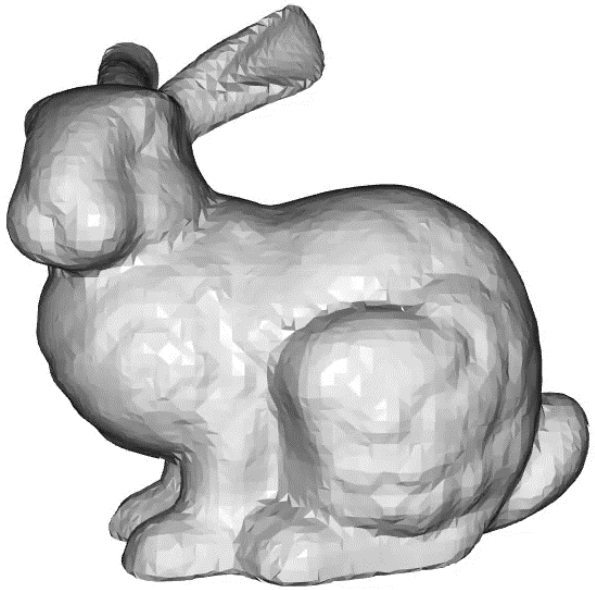
Results of mesh generator

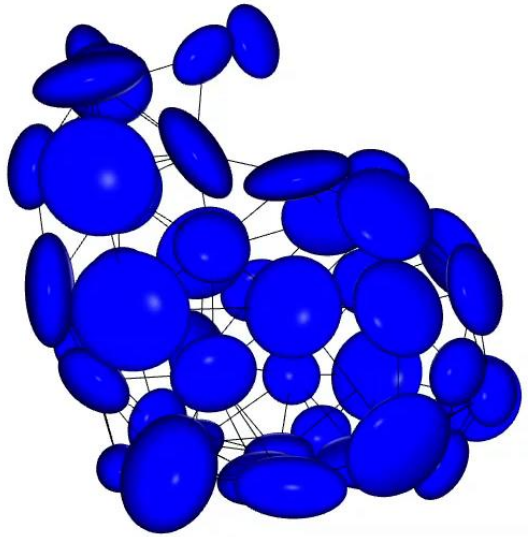




Parameters:

- max_radius = 0.90
- num_candidate_centers = 1500
- max_distance_neighbors = 1.75
- max_num_neighbors = 9

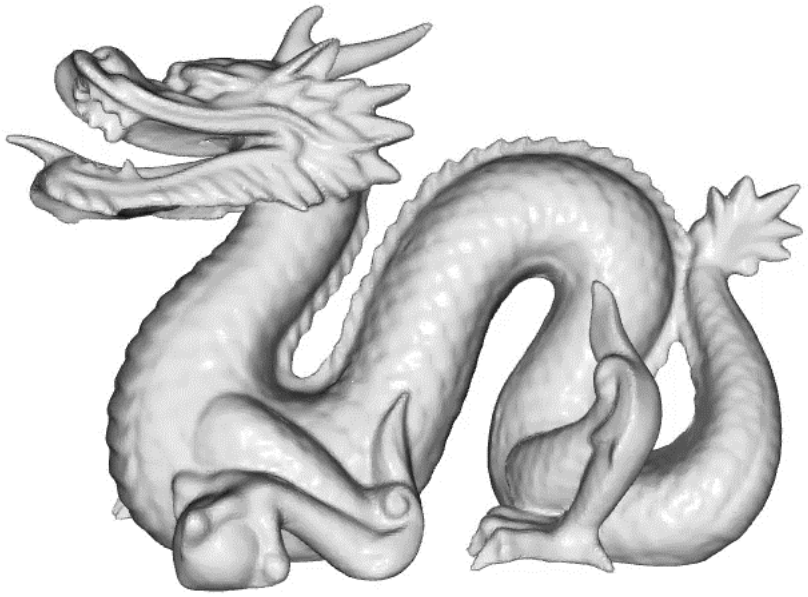


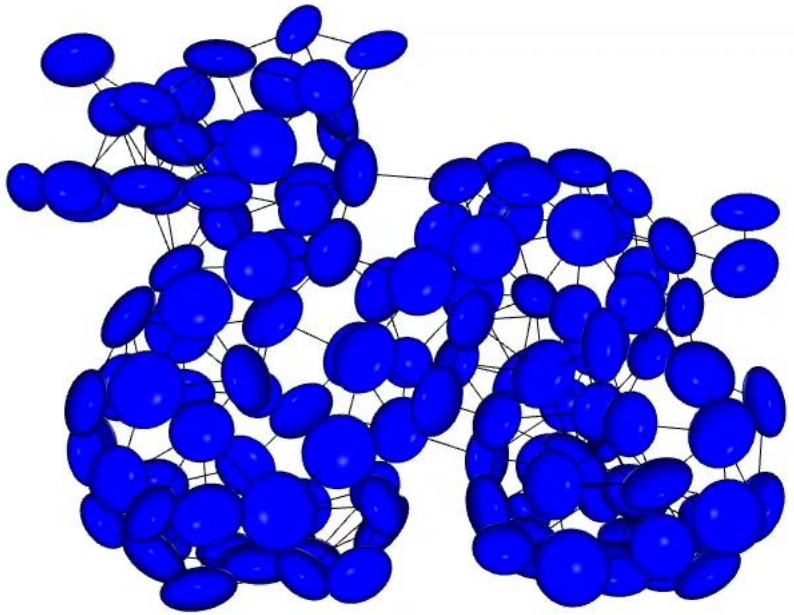


Parameters:

- max_radius = 0.90
- num_candidate_centers = 1500
- max_distance_neighbors = 1.4
- max_num_neighbors = 9

Results of mesh generator

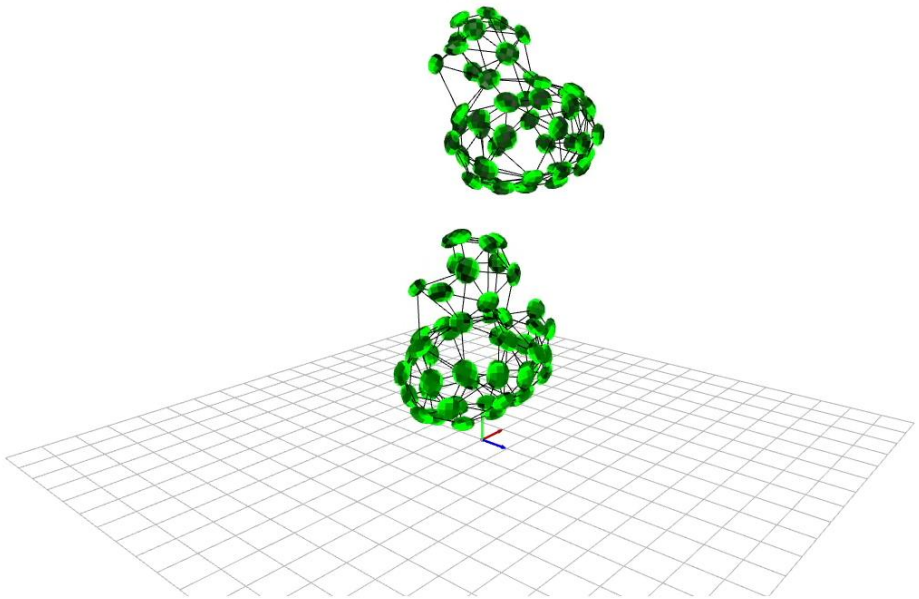




Parameters:

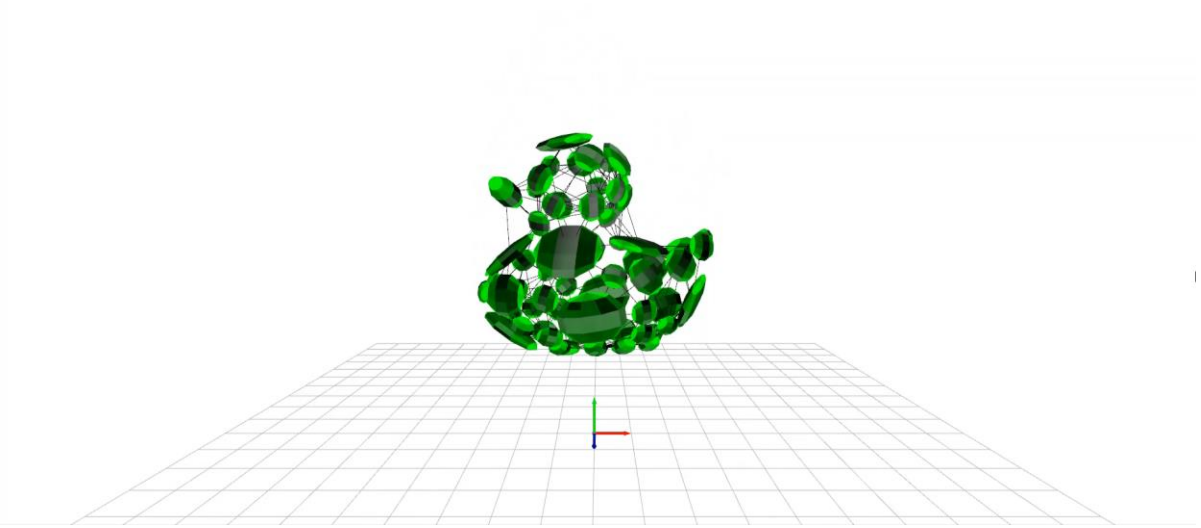
- max_radius = 0.4
- num_candidate_centers = 1000
- max_distance_neighbors = 1.3
- max_num_neighbors = 9

Results of mesh generator



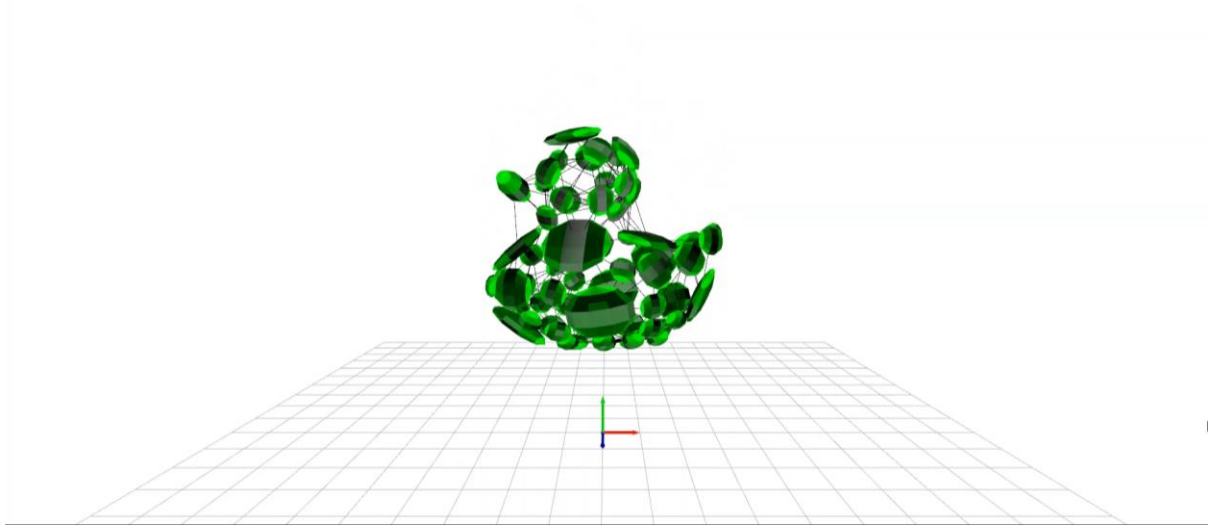
Observation: A graph with small particles can lead to entanglement

Oriented Particles Dynamics – Shape matching tests



Shape matching stiffness of 0.005

Observation : Simulate a soft body

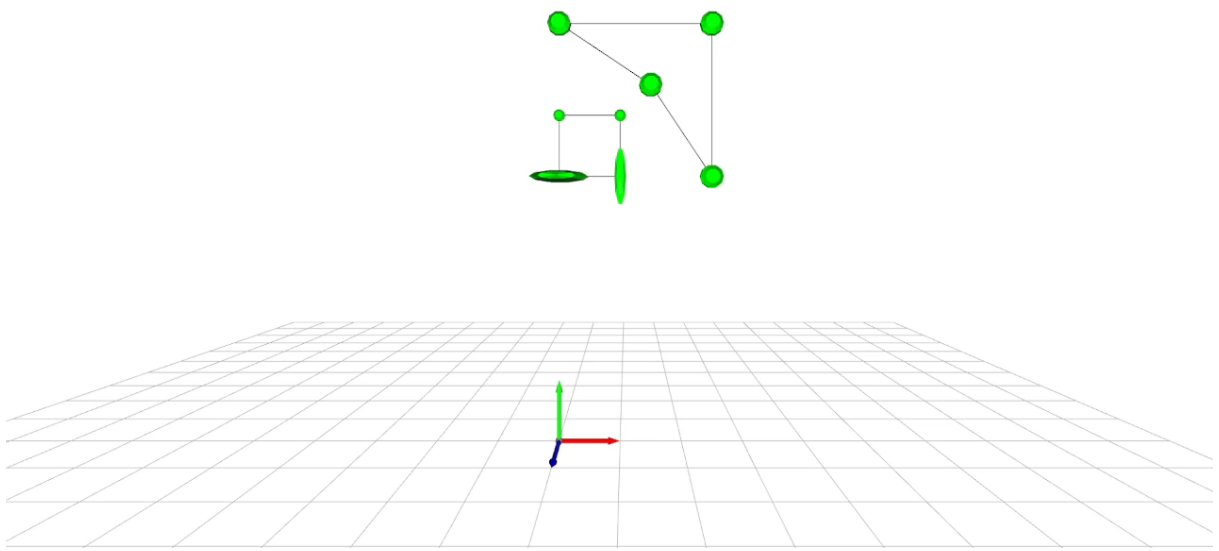


Shape matching stiffness of 1.

Observation : Simulate a rigid body

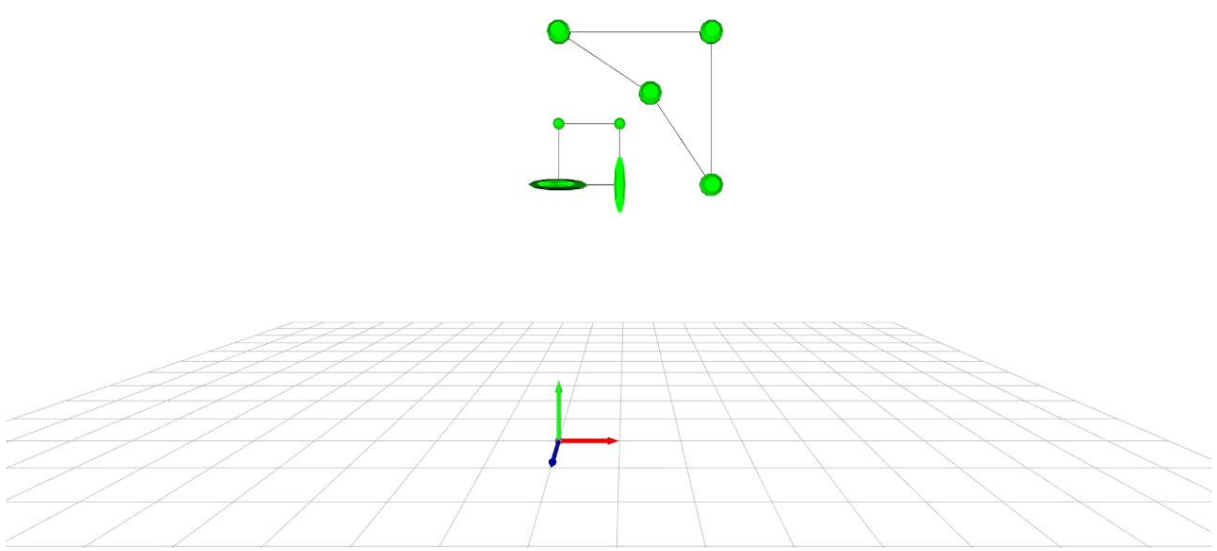
Distant Constraint OFF – Shape Matching ON – dt = 3e-3

Oriented Particles Dynamics – New damping



Simulation with σ = 1000 (weak damping)

Observation: Bodies are flying after impacts

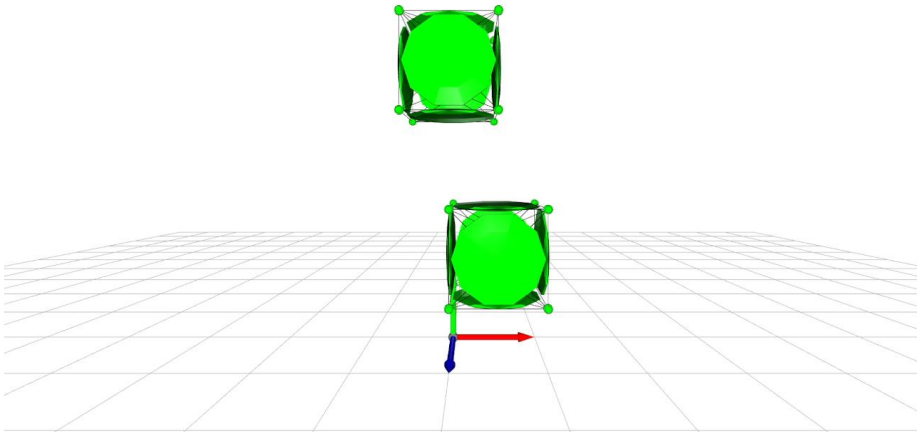


Simulation with σ = 0.01 (strong damping)

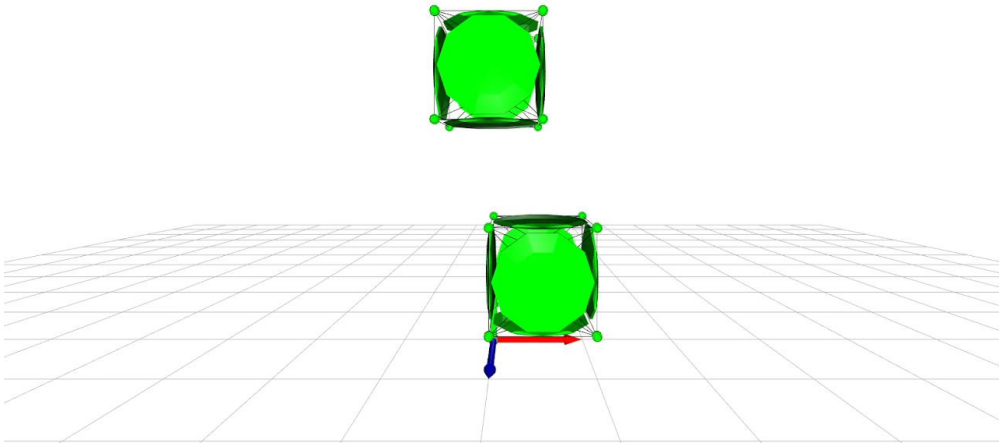
Observation: Bounces are reduced

Distant Constraint OFF – Shape Matching ON

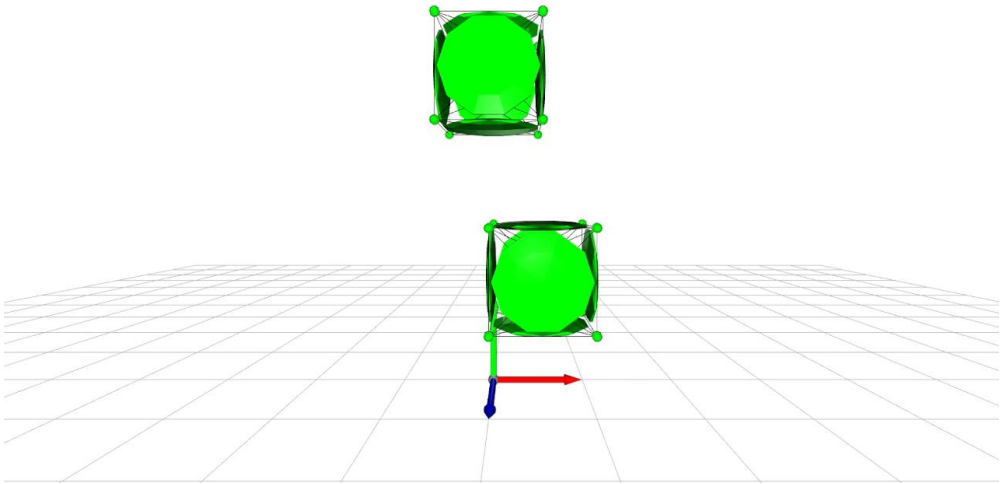
Oriented Particles Dynamics – Friction tests



No friction



Only strong friction with the ground

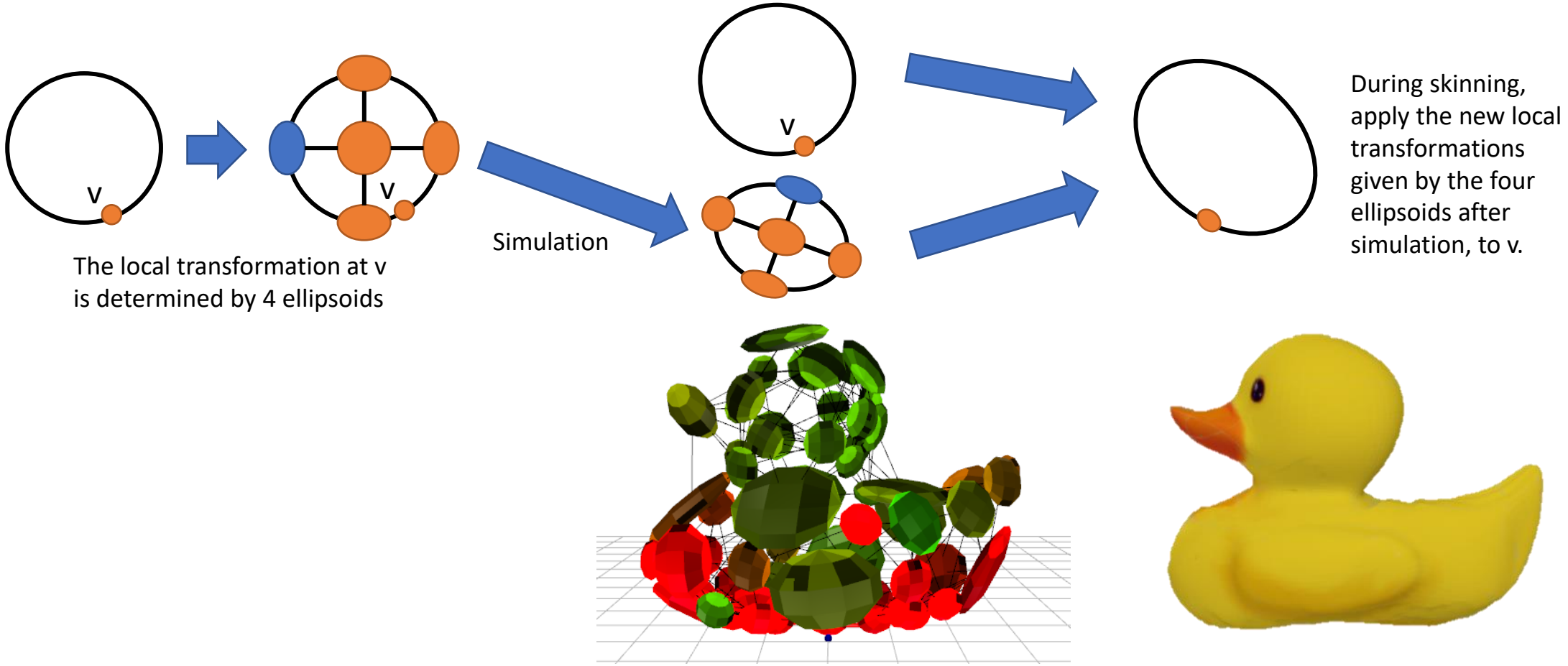


Only friction between particles

Distant Constraint OFF – Shape Matching ON

Oriented Particles Dynamics - Skinning

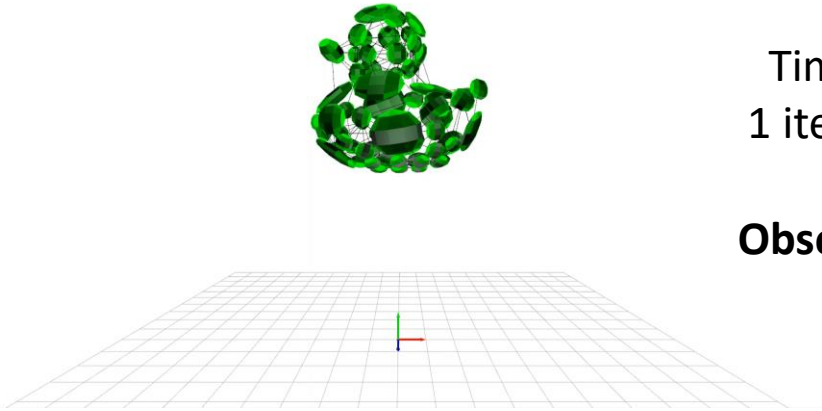
Get the mesh back from the graph: each vertex is transformed according to the weighted local tranformations (rotation+translation) of its neighboring ellipsoids.



Stability and Time step

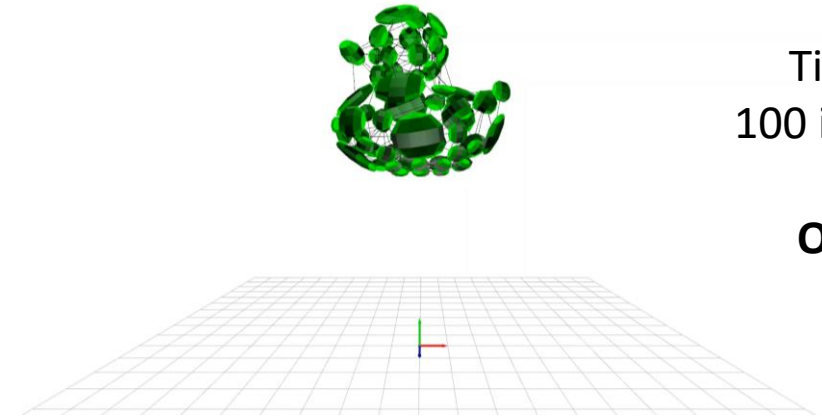
Time step : 3e-3
1 iteration in the solver

Observation: A correct simulation



Time step : 3e-2 (big)
1 iteration in the solver

Observation: Unrealistic deformation

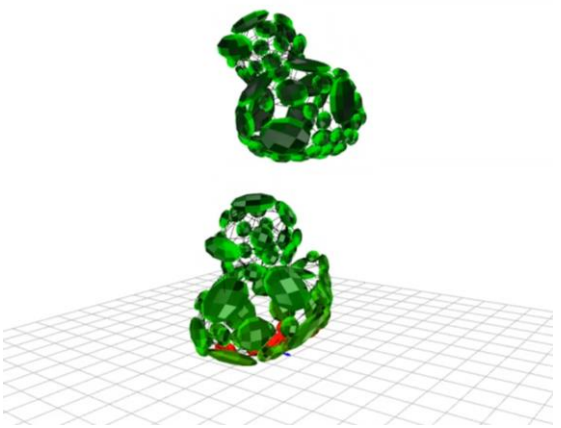


Time step : 3e-2 (big)
100 iterations in the solver

Observation: Sliding artifact

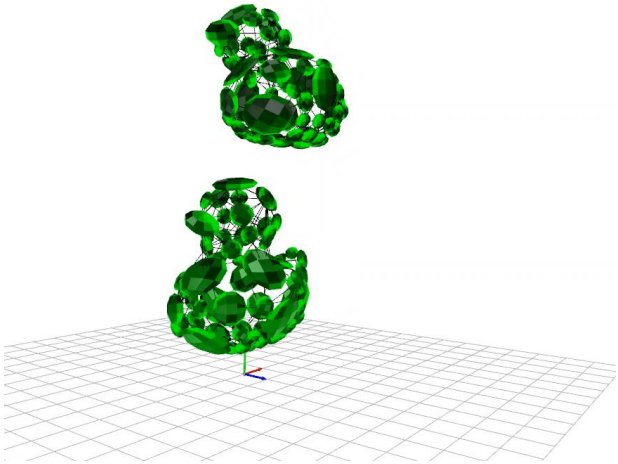
Distant Constraint OFF – Shape Matching ON

Stability and Time step



Time step : 3e-3
1 iteration in the solver

Observation: A correct simulation



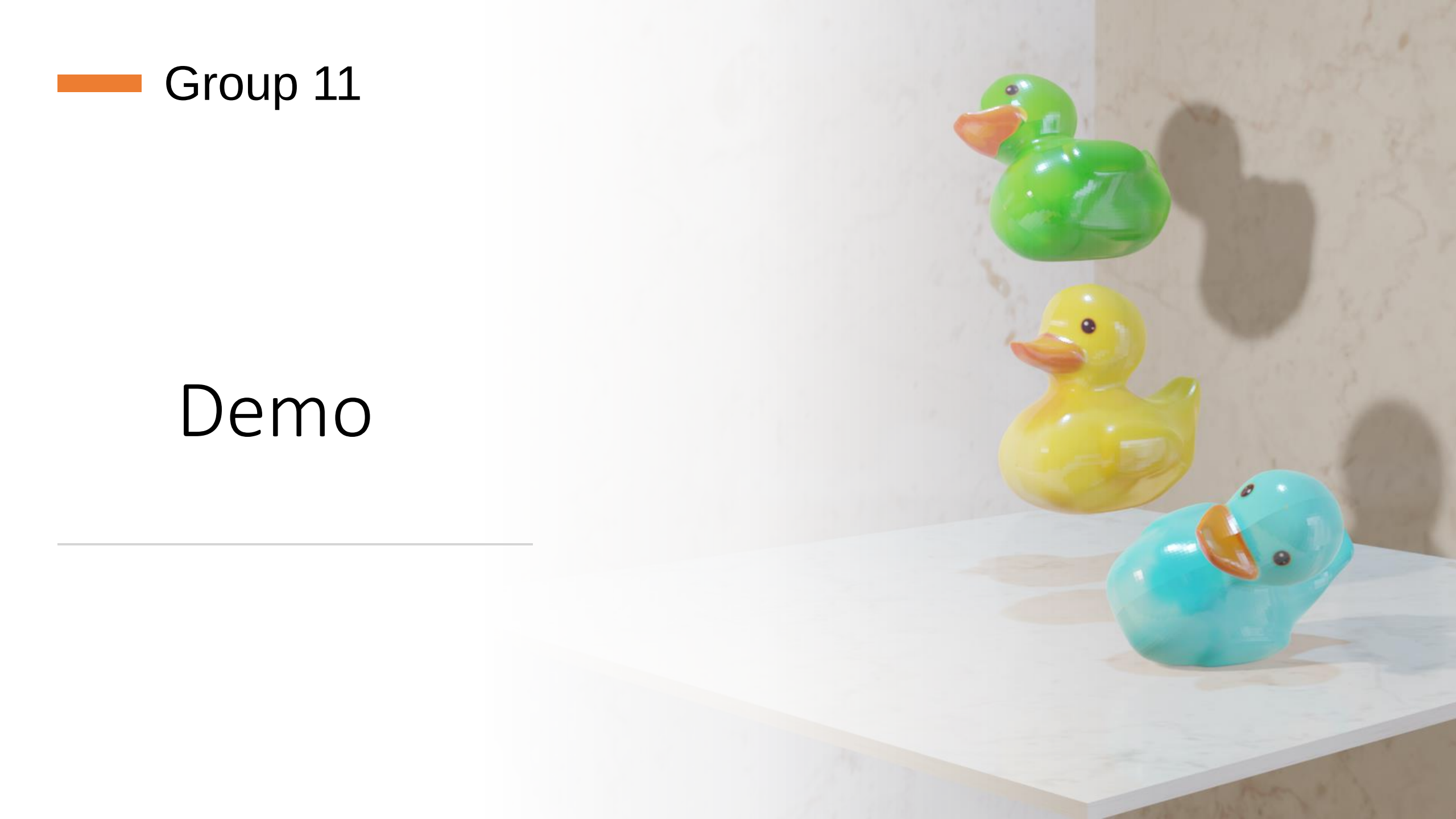
Time step : 3e-2 (big)
100 iterations in the solver

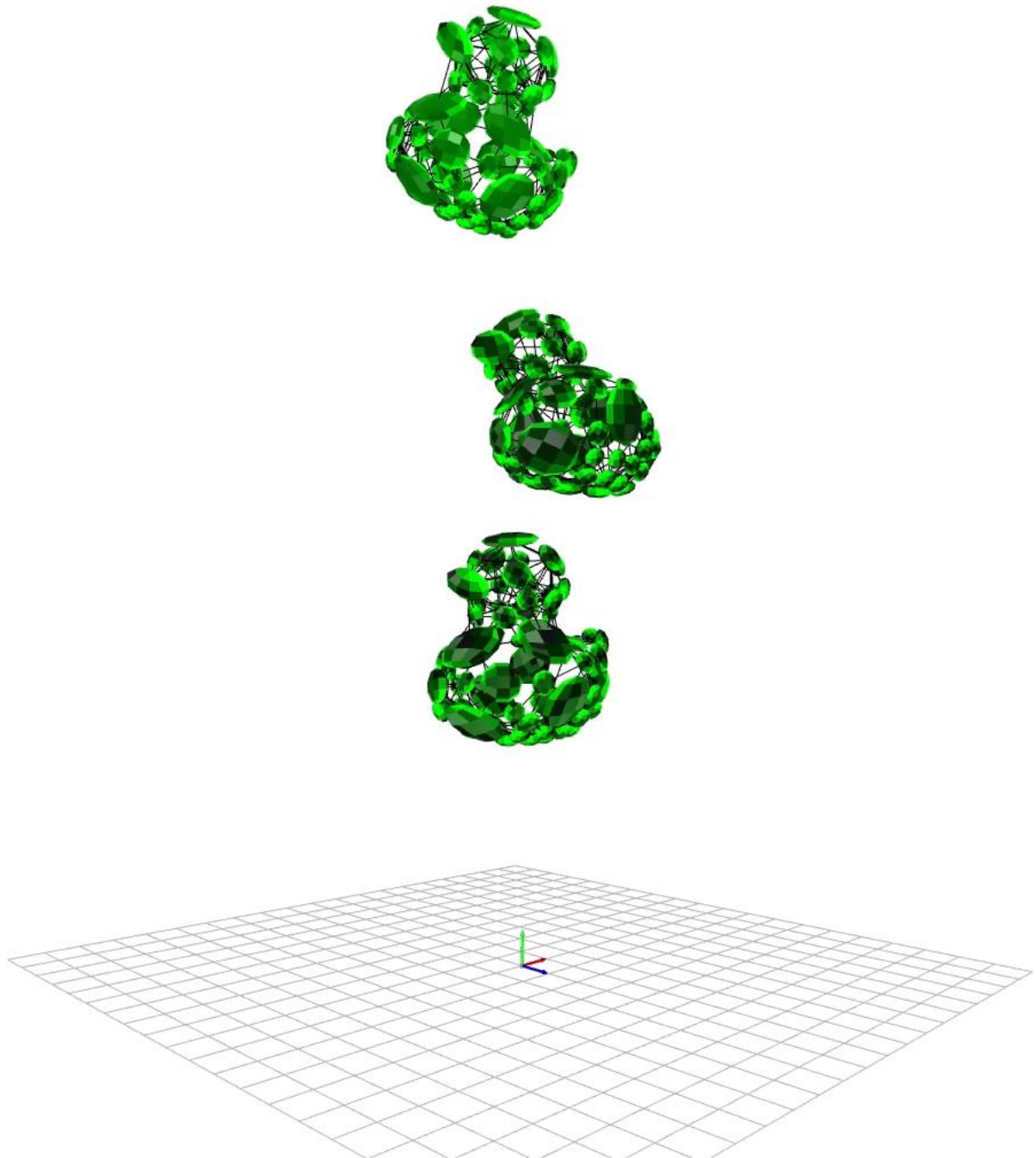
Observation: Some collisions are not detected

Distant Constraint OFF – Shape Matching ON

Group 11

Demo





Group 11

This project is implemented in python using Taichi, open3D and Numpy.
The rendering was performed in Blender.

Dragon and Bunny meshes from:
http://graphics.stanford.edu/data/3Dscanrep/
Textures from:
https://ambientcg.com/
The Duck by Davide Corigliano

Group 11

Questions?