Physikbasierte Modellierung und Simulation
Assignment 11

You may discuss this sheet and ask questions in the exercise on Thursday, January 9, 2017. This exercise is meant to get you started with revising for the exam. Although there are no points for the following tasks, you are strongly encouraged to take your time to re-read the lecture notes so that you can ask any relevant questions in the exercise on Thursday. The following list of topics may guide you during your reading.

11.1 Differential equations

a) Which numerical methods do you know for solving the differential equation $\ddot{x} = \vec{f}(x)$?

b) Imagine you are solving a system of differential equations using the explicit Euler method with time step $h = 0.1 \text{s}$, and you notice that the simulation becomes unstable. Name three ways to modify your approach that may give better results.

c) What are the advantages and disadvantages of implicit solvers when compared to explicit ones?

Solution

a) Euler, Runge-Kutta, Verlet...
b) smaller step size, implicit method, higher-order method
c) more stable for fixed step size, less flexible, more computation per step

11.2 Particle systems

a) How much memory do you need to represent the state of a system of 10000 mass points including their invariant properties? Use four-byte IEEE floats for numbers.

b) Which physical law governs the movement of particles that are connected by a spring?

c) Name four quantities that are conserved in a closed system without external forces. Consider a box of fixed walls that contains moving particles. Which quantities are no longer conserved if the walls reflect the particles, and which one if friction is involved?

Solution

a) $4 \text{ bytes} \times (\text{mass} + 3 \times \text{position} + 3 \times \text{velocity})$
b) Hooke’s law: $\vec{F}_1(\vec{x}_1, \vec{x}_2) = k (||\vec{x}_2 - \vec{x}_1|| - l_0) \frac{\vec{x}_2 - \vec{x}_1}{||\vec{x}_2 - \vec{x}_1||}$
c) momentum, energy, angular momentum, mass; momentum / angular momentum; energy
11.3 Rigid body systems

a) Name two ways to change the angular velocity of a rotating body.

b) Which variables are needed to describe the state of a rigid body including its invariant properties?

c) Two forces with opposite directions are applied to a rigid body. How does this change its velocity and its angular velocity?

Solution

a) apply torque, change inertia tensor

b) position, linear velocity, mass, orientation, angular velocity, inertia tensor

c) velocity does not change, angular velocity depends on where forces are applied

11.4 Collisions

a) Which kinds of bounding volumes do you know?

b) Against how many possible separating planes do you have to check the vertices of two triangles in order to make sure they intersect (in two dimensions)?

c) How does the tangential velocity of a mass point change after it collides elastically (frictionless) with a plane?

Solution

a) AABB, OBB, sphere, convex hull...

b) 6 (the sides of both triangles)

c) not at all

11.5 Fluid simulation

a) What is the difference between Lagrangian and Eulerian fluid simulation methods?

b) Which forces are computed in a smoothed particle hydrodynamics simulation?

c) How can obstacles be included in an Eulerian fluid simulation?

Solution

a) coordinate frame moves with particles / stays fixed

b) pressure, viscosity, surface tension, external forces

c) set velocity to zero

http://graphics.tu-bs.de/teaching/lectures/ws1617/pbm/