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High Performance Computing with GPUs
Exercise No. 4

Outline
For the simulation of particles we can combine visualization and compute capabilities of a GPU by opening a window and coloring pixels according to particle properties (position mapped to pixel in window, velocity, other properties, mapped to color). To represent the particles in 2D, the following data structure can be used:

- Position $\vec{p}$ with x, y in meter m
- Velocity $\vec{v}$ with x, y in m/s
- Acceleration $\vec{a}$ with x, y in m/s^2
- Mass m in kg
- Force $\vec{F}$ with x, y in $kg \cdot m/s^2$ $(= N)$

We start with simulating the behaviour of particles under the influence of gravity. For this the gravity $g = a = 9.81\ m/s^2$ is used, which should take effect in negative y-direction. Additionally the following rules and equations are required for the calculation of the particle simulation:

$$\begin{aligned} \vec{F} &= m\vec{a} \\ \vec{v} &= \vec{v} + \vec{a} \cdot \delta t \\ \vec{p} &= \vec{p} + \vec{v} \cdot \delta t \end{aligned} \tag{0.1}$$

where δt is the time step incremented by the display loop.
You may start from the Framework used for the exercise for the Julia sets.

Part a
Start with a window size of 800x800, distribute particles randomly at the top and let the particles reenter at the top after they left the window. The particles do not interact. Two particles at the same pixel is no problem and the color of the pixel may be determined by one of the particles at the same place.
With these values the simulation looks like rain or snowfall.

Part b
Develop your own particle simulation scenario (explosion, flow or smoke). Color the particles after different criteria.

Part c
Implement a scene there particles are interacting and avoiding each other. Assume the additional internal force

$$F = \frac{m_1 v_1 \cdot m_2 v_2}{r} \cdot const$$

with a properly choosen constant.