Particle Methods
Spring Semester 2023

Homework 2

Due date: 29.03.2023

Write a program using language of your choice (C, C++, Matlab, python, ..) implementing variation of prey and predator model in 2D with the following conditions:

- Assume the habitat is a 2D square, $L = 10$ units in size, periodic in all directions.
- Each animal is represented by an agent. There are two types of agents: rabbits and wolves.
- The simulations start with agents randomly distributed in the domain: $N_r = 900$ rabbits and $N_w = 100$ wolves.
- Each rabbit behaves according to the following rules:
  - Each time step it chooses random direction and makes a step of length sampled from the normal distribution with mean parameter $\mu = 0$ and standard deviation parameter σ
  - Each time step it replicates with probability $p_r^r = 0.02$ (one more rabbit is created at the same position)
  - Each rabbit dies at the age of t_d^r time steps. At the simulation start, rabbits are created with the age (integer number) uniformly sampled from the interval $[1, t_d^r)$.
- Each wolf behaves according to the following rules:
  - Each time step it chooses random direction and makes a step of length sampled from the normal distribution with mean parameter $\mu = 0$ and standard deviation parameter σ
  - It eats a rabbit with probability $p_e^w = 0.02$ every time the rabbit gets within distance $r_c = 0.5$ of the wolf (each time step the wolf can eat as many rabbits as there are in its vicinity)
  - It replicates with probability $p_r^w = 0.02$ every time it eats a rabbit (it can replicate multiple times during single time step if it eats multiple rabbits)
  - It dies from hunger if it does not eat for $t_d^w = 50$ time steps

a) Initialize the system with random distribution of rabbits and wolves in the domain. Set step size parameter σ equal to 0.5 both for rabbits and wolves. Assume rabbits die at the age of $t_d^r = 100$ time steps. Run simulations and look at the evolution of the number of rabbits and wolves in time. You may want to run simulations for few thousand steps. Consider the Lotka-Volterra equations (https://en.wikipedia.org/wiki/Lotka-Volterra_equations). Our model does not exactly corresponds to these equations, nevertheless what are the similarities between your simulations and solution of these equations?
b) Repeat simulations with the same parameters as in case a), but now set the age for each rabbit to die to $t_d^r = 50$ time steps. What kind of results do you get and why?
c) Repeat simulations with the same parameters as in case a), but now set step size parameter σ equal to 0.05 both for rabbits and wolves. Again, run simulations for few thousand steps. If your simulations take too long, you can reduce the size of the domain to $L = 8$ units. Look at the dynamics of agents in the domain, is it different from case a)? Do you think something like Lotka-Volterra equations can be a good approximation? What makes the difference in this case?
Please submit your code together with the report.