Excercise 1.
Implementing a first Application in RePast: A Rabbits Grass Simulation.

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1 Implementation

1.1 Assumptions

Grass The amount of grass per cell is limited to 1. Grass can also not grow on cells that are occupied by a rabbit at that time.

Rabbits Rabbits will try to move to neighboring cells in the North, East, South or West. If they cannot move because all neighboring cells are occupied by other rabbits already, they will stay at their current cell. However, they still lose the same amount of energy at the end of the simulation step.

Reproduction Giving birth will cost a rabbit 2/3 of the birth threshold[1]. Newly born rabbits will try to eat grass right after they are born - therefore, in case they are born on a cell with grass, they will it the grass instantly. In the very unlikely event, that a new rabbit cannot be born as there couldn't be found a non-occupied cell (also see Subsection 1.2), the rabbit that was supposed to give birth will not be deducted any energy.

1.2 Implementation Remarks

Order of events In every simulation step, the following steps are undergone: (1) Grow grass, (2) try to bear new rabbits, (3) move rabbits to a new position and (4) let rabbits without enough energy die. The placement of grass will happen randomly among the non-occupied cells (i.e. on cells without grass and rabbits). For the placement of rabbits, a random cell is chosen, and if it is not occupied (i.e. if there is no other rabbit), the rabbit will be born there.

Performance considerations In order to achieve random placements among non-occupied cells, a list of non-occupied cells will be (re)generated for grass cells at the beginning of each step. We decided for this kind of implementation, as it seemed to be most consistent and efficient given the variety of possible parameters. We ruled out the alternative of randomly determining a cell and checking whether it's occupied for the case of grass growth. With infinite retries this would lead to infinite loops when all cells are occupied. As this is the case for many parameters, this is not a suitable implementation design. When using only finite retries, grass might not grow despite the fact that not all cells are occupied.

In contrast, for rabbits, we are doing a loop as shown in Algorithm 1. We do this, as the frequency of rabbits being born is comparably low and the probability of a cell being occupied is low as well (only cells with other rabbits are seen as occupied). Therefore, this should on average allow for a more efficient placement of new rabbits, compared to keeping track of the empty cells.

Edge cases Due to our implementation, there is a small probability that a new rabbit might not be

[1] Amount of energy required to give birth

Algorithm 1 Place a new born rabbit

$n \Leftarrow 10 * gridSize_X * gridSize_Y$
while $n > 0$ **do**
  Generate random coordinates x,y
  if (x, y) contains no rabbit and no grass **then**
    Place rabbit
    break
  else
    $n \Leftarrow n - 1$
  end if
end while

born due to the random determination of a new cell. This probability increases if the initial energy level and/ or the energy that a rabbit earns by eating a unit of grass is extremely high, thus causing a slightly lower population of rabbits overall.

2 Results

2.1 Experiment 1

2.1.1 Setting

Birth threshold: 15, Grass rate: 10, Number of rabbits: 30, Grid Size: 20 $\times$ 20

2.1.2 Observations

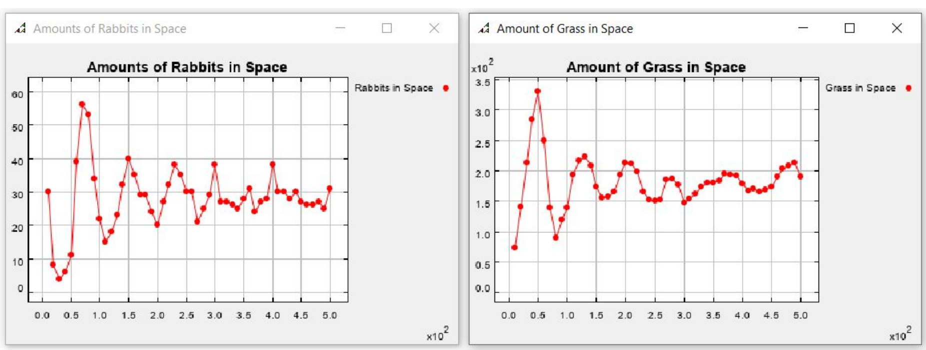

Figure 1: Development of rabbits and grass units over time in experiment 1

The rabbit population plot oscillates around a value of 30 rabbits. The rabbit population seems to be an opposing force to the grass volume, which oscillates around approximately 170 grass units.
The oscillations are particularly high at the beginning of the simulation, and decrease in their amplitude after around 200 simulation steps. This can be explained because the initial grass volume is set to 10, which does not seem to be enough to maintain the population at 30 rabbits. As the initial rabbit population cannot eat enough grass to survive, the population decreases at first. On the other hand, this allows for an increase in grass units on the field because fewer rabbits consume grass. This, in turn, allows for the rabbit population to grow again.

2.2 Experiment 2

2.2.1 Setting

Birth threshold: 25, Grass rate: 10, Number of rabbits: 30, Grid Size: 20 $\times$ 20

2.2.2 Observations

The observations are similar to the first experiment, however the amplitudes decrease more slowly, compared to the first experiment. This can be easily explained: As only the birth threshold increased, but the grass rate maintained constant, the rabbit population still oscillates around 30, and the grass rate at around 170.
However, through the higher birth threshold, the oscillation decreases more slowly, because rabbits require a higher energy level to give birth to new rabbits. Therefore, the reaction to changing grass volumes requires more time to result in a changing rabbit population.

2.3 Experiment 3

2.3.1 Setting

Birth threshold: 15, Grass rate: 15, Number of rabbits: 30, Grid Size: 20×20

2.3.2 Observations

The increase in the grass rate results in a larger rabbit population. Therefore, the rabbit population now oscillates around a value of approximately 40 rabbits. The grass volume oscillates around 170 again, which can explained through the higher rabbit population that compensates the higher grass rate, so that the resulting volume remains the same.

2.4 Experiment 4

2.4.1 Setting

Birth threshold: 15, Grass rate: 10, Number of rabbits: 10, Grid Size: 20×20

2.4.2 Observations

Through the initially lower number of rabbits, the population is close to 0 at the beginning, because the existing grass is spread over the entire grid and rabbits have low chances of finding enough grass to survive. The grass volume however increases during this initial period, thus allowing a heavy reverse of this trend, where the remaining, small, population can eat grass with almost every movement. Therefore, the initial oscillations are very high, however, in the long term, we can see similar outcomes as in experiment 1.

2.5 Experiment 5

2.5.1 Setting

Birth threshold: 15, Grass rate: 6, Number of rabbits: 10, Grid Size: 20×20

2.5.2 Observations

In this last experiment we tried to find a reasonable threshold for the grass rate below which all the rabbits will eventually die (keeping the other parameters as those of experiment 4). After many trials (of course the outcomes are random), we found that by manually tuning the grass rate, the value 6 is a good approximation of such value. Indeed, starting from 9 and keeping decreasing the grass rate, this was the first value that made all the rabbits die for 5 consecutive simulations. The reason is that the smaller the initial number of rabbits, the lower is the probability for them (or just a fraction of them) to randomly encounter cells with grass so they don't live enough to give birth other rabbits that, in the future, will find the grid full of grass and will keep the population alive.