Lab # 4a – A more realistic population growth


1) Life Science model – the origins: a fast simulation of a rabbit population growth.

The unit is a couple of rabbits and the time step is of a month. We consider that a couple of young rabbits become adult in one month, when the female rabbit becomes pregnant, it takes one month to produce 2 baby rabbits considered as new young rabbits (kittens) that will wait for another month to become adult etc… (see figure 1). If we suppose that rabbits do not die, we obtain the diagram hereafter (observation made by Leonardo of Pizza). For this first question, you will propose a short program simulating the evolution of the number of couples like in the figure below. See the course slides dealing with the model proposed by Leonardo of Pizza. Don't waste your time with this, the 2nd part of the labs necessitates much more energy (more info on this web site: https://r-knott.surrey.ac.uk/Fibonacci/fibnat.html).

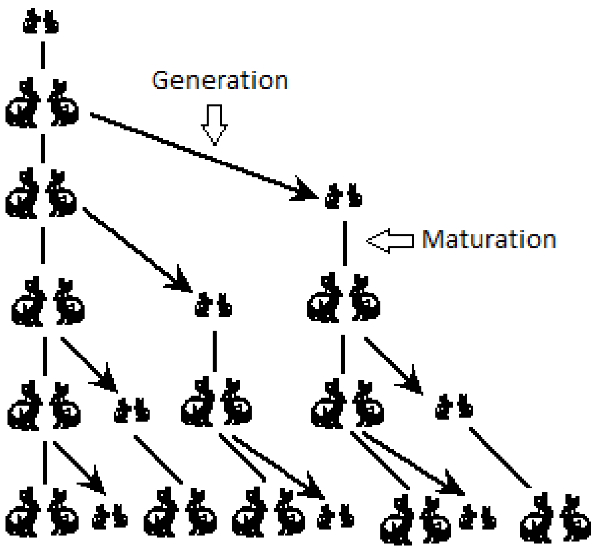

Figure 1: Rabbit population growth (empty spot for a young couple and a filled spot for a couple of adults)

2) More realistic population growth <u>where you will have to make your own modeling choices. Use the C or Java language (C++ accepted).</u>

In this lab you will propose a stochastic discrete event simulation of the growth of a rabbit population which will be more realistic than the previous equations. The mortality rates can take into account diseases and predators. Aging will also be accounted; this supposes that we take into account the birth and death of rabbits. The simulation is said to be 'individual based' and this approach is known as individual based modeling since each rabbit has its own parameters that are taken into account in the simulation. It may seem simple, and you should start with a simple implementation, but simulating many years will take time the coding is not optimized or the programming language not adapted.

A female rabbit can give birth approximately every month, they give 3 to 9 litters per year, but this is not uniform, there is more chance to have 5,6 or 7 litters. For each litter you have an equal chance to obtain 3 to 6 kittens (baby rabbits). A random drawing can determine if such baby rabbits are males or females; the natural probability being approximately around 50%. Unfortunately, in some countries this probability has been changed for humans when girls are killed (before or after birth) if the parents preferred males (up to 100 million women missing in a big country, a eugenic approach which leads to a drama). Sexual maturity is reached between 5 to 8 months after the birth of kittens, but you can simplify and retain an annual time step for the simulation. We can also simulate the probability of death according to the rabbit age; this can be given by proposing simple rules about survival. For adults (rabbits at sexual maturity), the survival rate is 60%, for little rabbits it is only 35%. When a rabbit reaches 10 years old, its survival rate is diminished by 10% every year, reaching 0% at the end of year 15 (death of an old venerable rabbit). This model is more realistic than a Fibonacci growth, it can be simulated with the input parameters and probability laws that you will decide. In the past labs everything was guided, now such choices are part of your lab as a modeling activity, it is a new step in difficulty. You can find more realistic values using the Internet or Wikipedia depending on the rabbit species.

Considering limited resources, predators or rabbit pandemics is out of the scope of this lab (though fast students can tackle this). In the same way, parallel programming could be interesting for running large numbers of experiments but we will leave parallel stochastic approaches for next year.

You can decide to simulate for a few years, try to reach 20 years maximum – this can be tough depending on your coding choices (and on the programming language). First see the impact of the initial conditions, starting with a single **adult couple**, the going to much more couple (the initial population may die due to high mortality of young rabbits). Observe the number of rabbits you have during the simulation and at the end, the growth can be fast for we do not have predators. This simulation can require important computing time on a regular PC. Remember that what you obtain after a simulation is just the result of a single stochastic experiment. The stochastic variability can be high. You should try different experiments and present proper stochastic simulation results as seen in Lab 3. Prepare a written report describing the development and your experiments.