Universiteit van Amsterdam

Report

Modeling and simulating malaria

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1 Model definition and implementation

For the assignment we were asked to create and analyse a model for the spread of malaria disease among a population of humans.
Malaria is a severe disease that is caused by a parasite. The parasite is spread from one infected human to the next by a mosquito. Mosquitoes are born uninfected, but in the course of their lifetime they need to obtain several blood meals. Once they bite an infected person, they become infected themselves and can spread the disease next time they bite.
We implemented the model with a 2D cellular automata in mind. There is a 100 by 100 grid, in each cell of the grid at most one human can be present. Opposite to humans mosquitoes can be co-located. At each step in time mosquitoes move randomly across the grid, human stay in the same cell during their lifetime.
The first step is populating the grid with humans. Humans are represented in a 2D dictionary where the dictionary holds three entries. The first entry is the state of the human in the cell, 0 for not present, 1 for healthy, 2 for sick and 3 for immune, the second entry holds the age for the human and the last entry is for tracking how long a person has been sick. The humans are randomly placed on the grid but humans have a higher change to be placed in a specific cell if neighbouring cells also have humans present. We did this to create a more realistic pattern across our grid where people a located in villages and cities.
After the humans are populated the mosquitoes are created. We chose the number of mosquitoes to be 20% of the size of the grid. Mosquitoes are represented in a 1D dictionary and the dictionary holds four items. The first two items are the x and y coordinates for the mosquito on the grid, the third for whether the mosquito is infected or not and the last for keeping track of the feeding process of the mosquito.

After this is done the simulation can start and the interaction between humans and mosquitoes begins. First mosquitoes are randomly moved. After that is done, for each mosquito is checked whether they moved to a cell with a human in it. If that's the case, and they are hungry, six possible combinations can occur with two different outcomes displayed in the following table:

Tabel 1: Human vs Mosquito outcome

Human State	Mosq State	Human Outcome State	Mosq outcome state
1	0	1	0
1	1	2	1
2	0	2	1
2	1	2	1
3	0	3	0
3	1	3	1

After the interaction is finished, final checks are made. First we check if people are not too old (humans older than 80 will die) then we check if they are not sick for too long (longer than 5 years they will either die or become immune). If humans or mosquitoes die they are immediately replaced. For the rest of the humans their age is increased by one year, if they are sick, sickness is increased by one year as well.

2 Fitting the model parameters

In our model different parameters are present. Of course we have the size of our grid, the chance of humans being located near other humans, the number of mosquitoes, the percentage of humans starting with malaria, the percentage of humans turning immune and for our model we implemented that people can have a mosquito net, preventing them for getting bitten. All of these parameters can be changed.

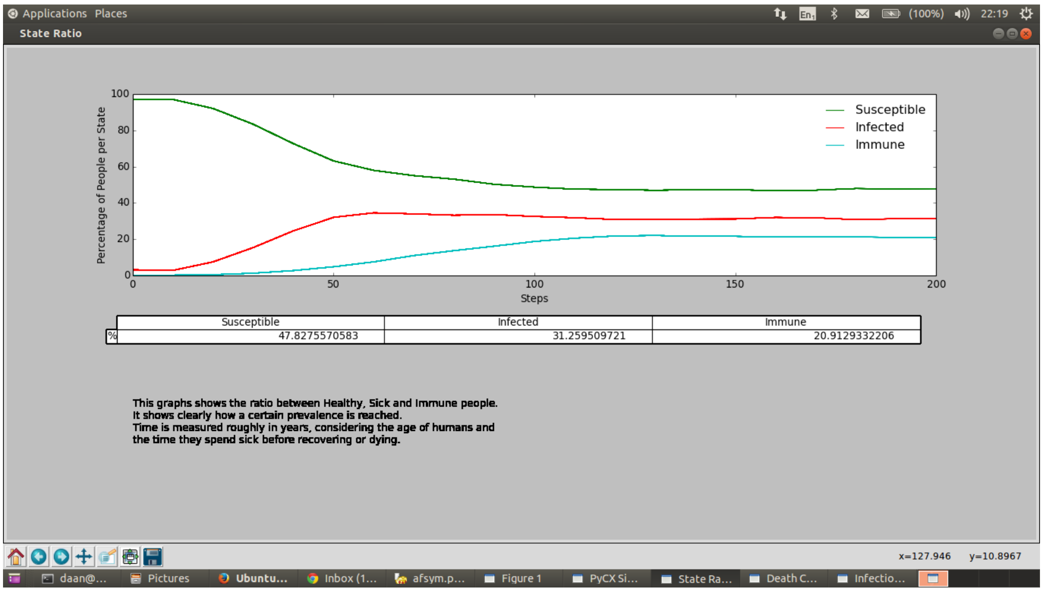
Tabel 2: Parameters

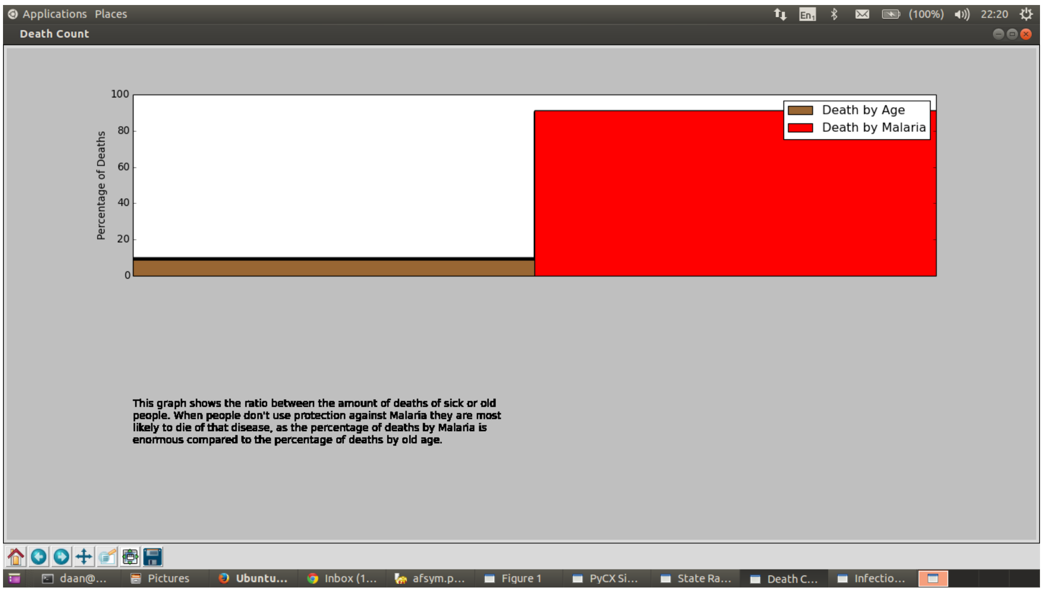
Parameters	Value
Width	100
Height	100
Mosquitoes	20%
Net	0%
Humans density	80%
born infected	3%
immune	5%

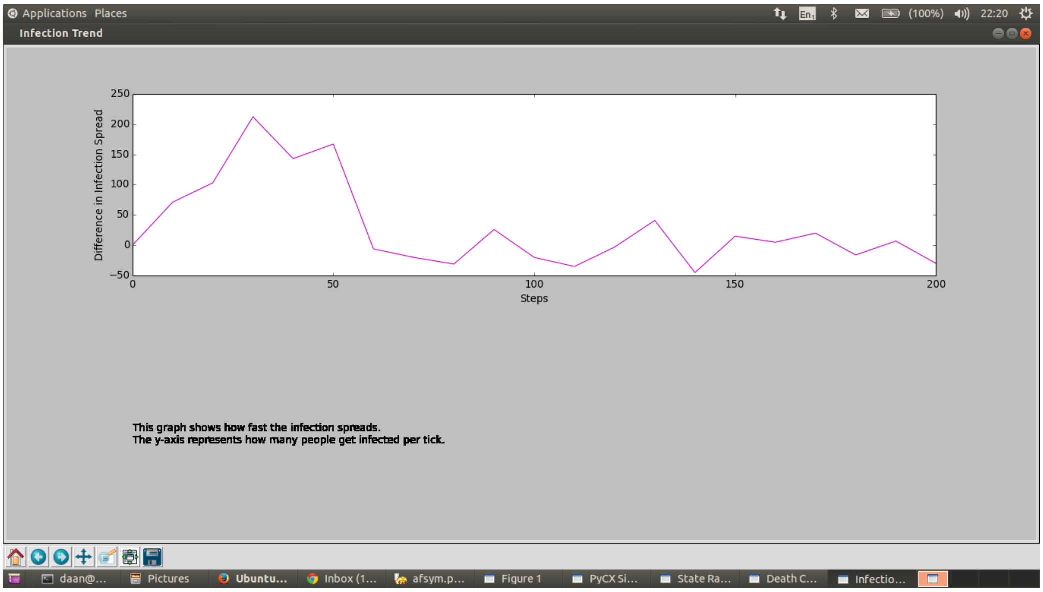
For finding a combination of parameter values we used trial and error. We were looking for a set of parameters that would make the rate of infected humans versus the rate of not infected humans convert to a certain number (between 20% and 40%).

3 Experiment and Analysis

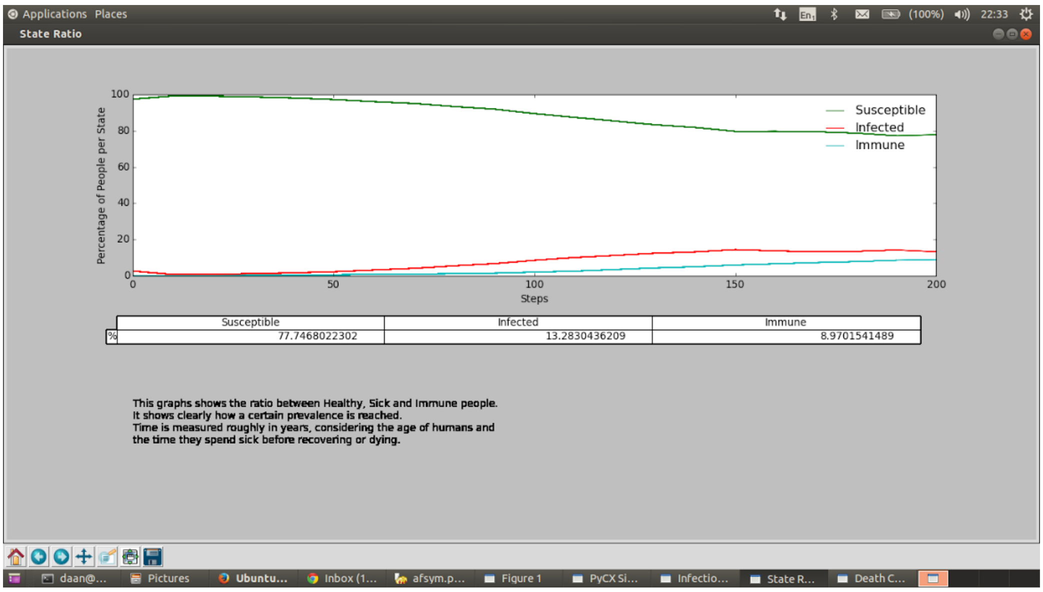
We created some graphs by running the program and using its output data. The first three graphs are the simulation run without using a prevention mosquito net.

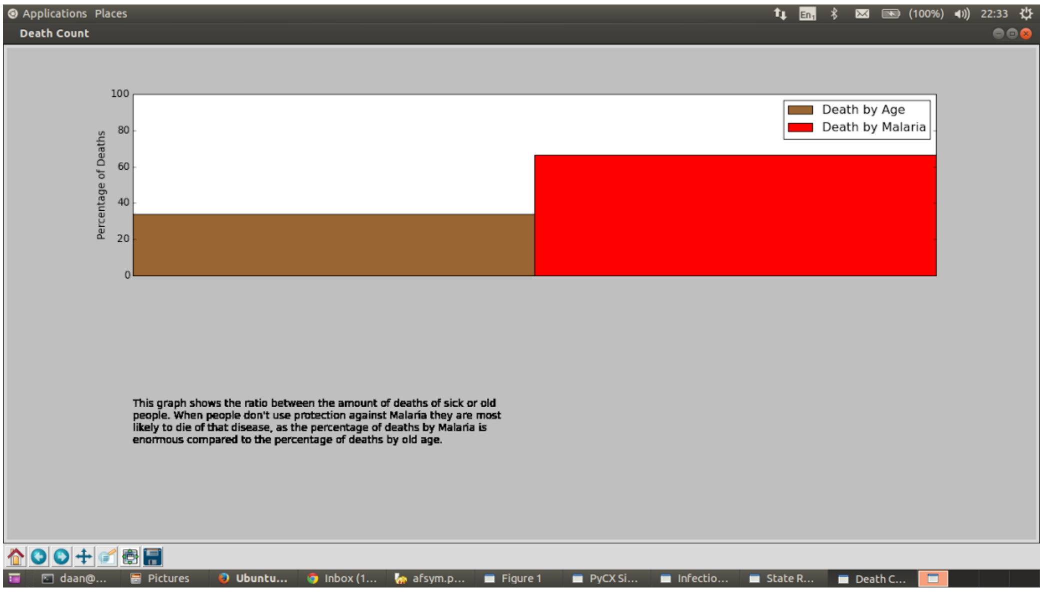


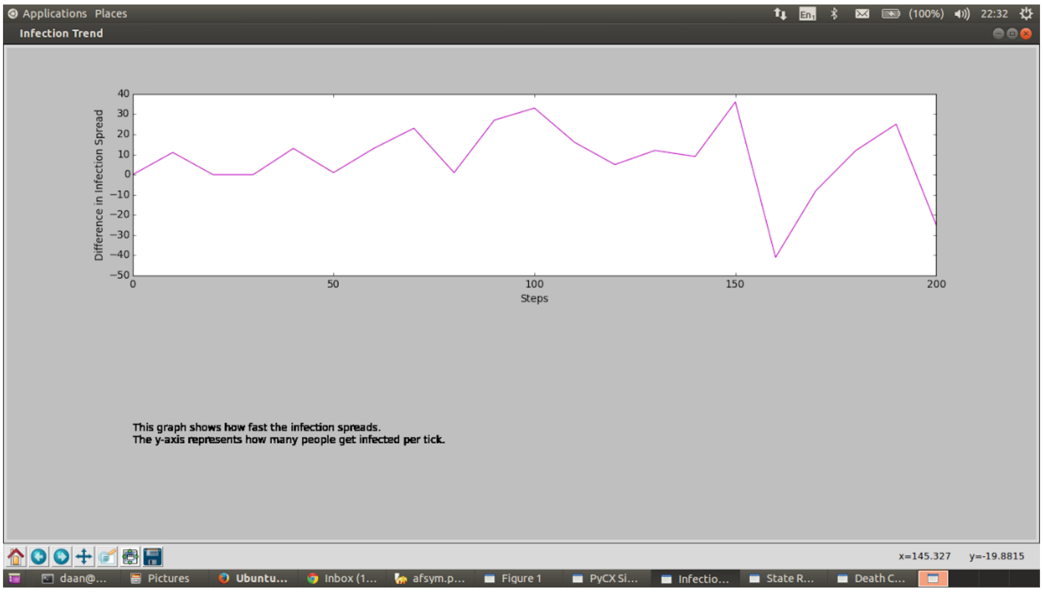




In these graphs is visible that the rate of people that are infected and not infected is 30%. At first a lot of people get infected, which is clearly visible in the third graph (infection trend). After a while this creates some immune people and they stop the upwards motion the infection trend was making. This also visible in the infection trend graph where a big decrease in the number of people that are infected per time step. After a while it settles to a steady rate per time step.In the second graph (Death_count) is visible that most people die from malaria and very few die of natural causes. This changes when some can make use of mosquito nets:




Applications Places
Death Count
Percentage of Deaths
Death by Age
Death by Malaria
This graph shows the ratio between the amount of deaths of sick or old people. When people don't use protection against Malaria they are most likely to die of that disease, as the percentage of deaths by Malaria is enormous compared to the percentage of deaths by old age.


Applications Places
Infection Trend
Difference in Infection Spread
Steps
This graph shows how fast the infection spreads.
The y-axis represents how many people get infected per tick.
x=145.327 y=-19.8815

For these graphs it is made so that 50 percent of the population had a mosquito net. In these graphs is clearly visible that virus is having a much harder time to spread than without any prevention methods. At first the virus is spreading very slowly and not a lot of people get infected per time step. After a while (t = 100 for example) the virus is spreading quick compared to for example t = 20. But as the virus is spreading more people get immune and that slows and eventually kills the progress. This is visible in the last graph (infecting trend) where sometimes the number of people getting the virus decreases. Also in the second graph is visible that a lot more people die of natural cause with the prevention method.
These graphs clearly show that a prevention method works and can kill a virus even if the prevention method is not available to all the humans in the simulation. Of course there might be a lot more variables at play in the real world, but we think this model captures the basic dynamics of real virus spreading.