Report MalariaModel

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1 Introduction

Malaria is an infectious disease spread by mosquitoes. This disease is, if not treated quickly and properly, extremely deadly, and has caused many deaths in the past.

If a female mosquito bites an infected human or animal, the malaria parasite gets transferred to the mosquito. The mosquito then carries the parasite until its next bite, which transfers the parasite to its next victim.

By modelling this procedure, we hope to gain further insights in the spread of malaria, and to discover the effectiveness of mosquito nets as a prevention method.

2 Model definition and implementation

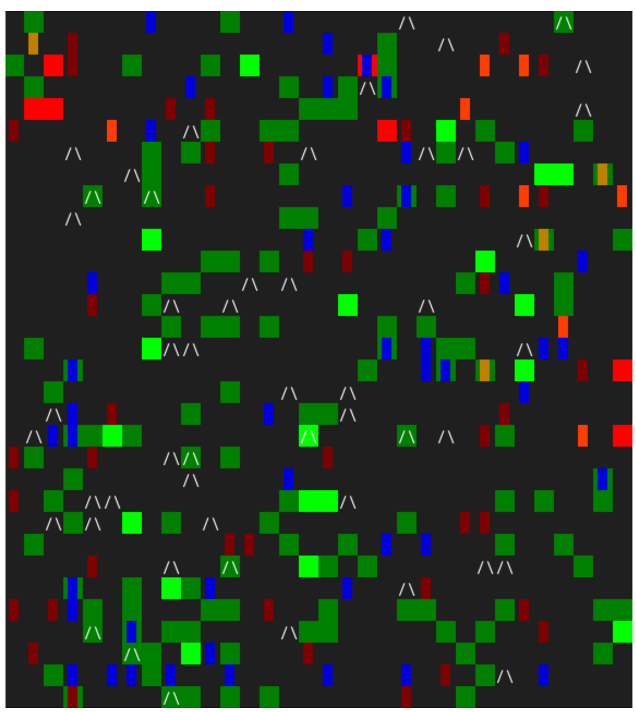

Figure 1: Screenshot of the simulation.

2.1 Parameters

The model has the following parameters:

- `width`: Model width
- `height`: Model height
- `humandens`: The initial density of humans
- `mosquitodens`: The initial density mosquitoes
- `immumepct`: The chance that a human is immune
- `mosqinfpct`: The chance that a mosquito is born infected
- `hm_infpct`: The chance that a human infects a mosquito
- `mh_infpct`: The chance that a mosquito infects a human
- `mhungrypct`: The chance that a mosquito gets hungry
- `hinfdiepct`: The chance that an infected human dies
- `humandiepct`: The chance that an uninfected/immune human dies
- `mosqdiepct`: The chance that a mosquito dies
- `mosqnetdens`: The density of mosquito nets

2.2 Description of model time-step

One step is made up of the following substeps:

1. Kill infected people and people dying of old age.

   A human always has a chance of dying of old age of humandiepct. Additionally, if a human is infected, the chance of dying of malaria is `minfdiepct`.

2. Update the mosquitoes.

   First, for each mosquito, move the mosquito using a random walk algorithm, excluding positions on the grid with a mosquito net.

   Then, if the mosquito is hungry and is on the same cell of a human, bite the human. If the mosquito is not infected and the human is, there is a `hm_infpct` chance of infecting the mosquito. If the mosquito is infected and the human is not, there is a `mh_infpct` chance of infecting the human. If the mosquito is not hungry, there is a `mhungrypct` chance of the mosquito becoming hungry.

   Finally, there is a `mosqdiepct` of the mosquito dying of natural causes.

3. Spawn new humans and mosquitoes.

   For each human and mosquito that died in the previous steps, spawn a new one in a random locations. Humans have a chance of `immumepct` of being born immune. Mosquitoes have a `mosqinfpct` percent chance of being born infected.

3 Fitting the model parameters

The way the default values of our system were chosen was by first filling in the value that seemed the most logical for every variable. By then running the model several amounts of time during testing, some values were corrected to make the simulation appear more logical. The final default values that were used in our model are:

- `width`: 32
- `height`: 32
- `humandens`: 0.15
- `mosquitodens`: 0.10
- `immumepct`: 0.1
- `mosqinfpct`: 0.1
- `hm_infpct`: 0.5
- `mh_infpct`: 0.5
- `mhungrypct`: 0.1
- `hinfdiepct`: 0.01
- `humandiepct`: 10^{-6}
- `mosqdiepct`: 10^{-3}
- `mosqnetdens`: 0.05

4 Experiments and analysis

4.1 States vs. time

While developing the model, it was clear the model began stabilising values after some amount of time. This primarily included the states of humans. That's why this is the first experiment that was tested against the model.

This experiment tests the amount of healthy humans, infected humans, immune humans, infected mosquitoes and hungry mosquitoes against the model time (in steps). The graph below shows the results calculated by the test.

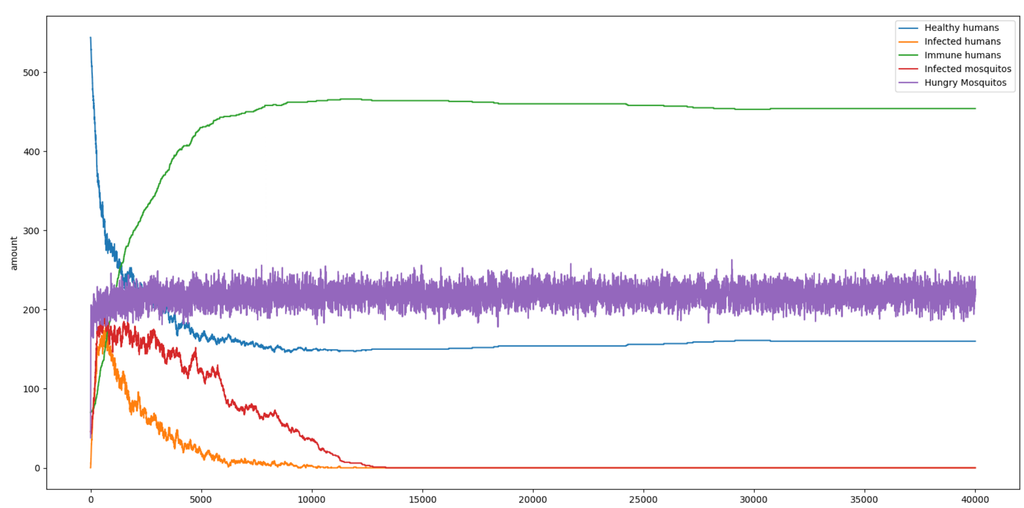

Figure 2: Various states of humans and mosquitoes vs. time

This figure is tested with a 64x64 model and a time range of 1-40000. All other variables used are the default model variables. Around t=14000 all values seem to have stabilized.

The first thing that happens is humans getting infected by the mosquitos. A decrease of healthy and an increase of infected humans can be seen around t=1-1000. Later, this changes in humans getting immune instead of infected. This is caused by humans dying and new healthy or immune people born. Since the Immune people live longer than the other people, they become the majority.

Because of the change described above (less and less humans having malaria), all mosquitos slowly stop being infected. The disease stops getting transferred from people to mosquitos so the disease slowly fades out.

4.2 Mosquito nets vs. immunity

Nowadays, people are more prepared for malaria. Prevention methods like the mosquito net are used in places where malaria spreads. These nets makes it hard or impossible for mosquitos to get to humans inside of them.

This of course reduces the amount of people dying of malaria. But it also brings another effect according to the model. Figure 3 shows 200 different mosquito net densities versus the human immunity after 10000 timesteps on a 16x16 grid.

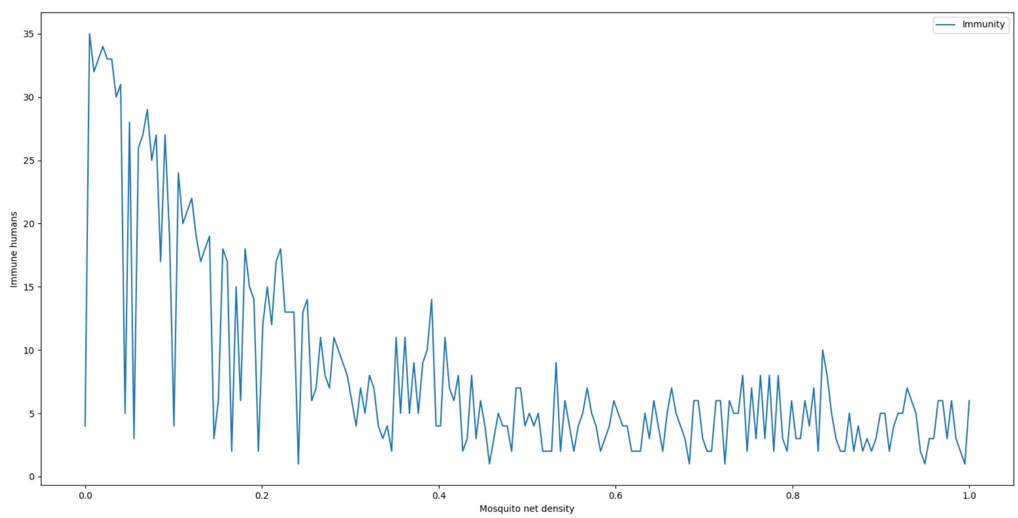

Figure 3: Mosquito net density vs. human immunity after a while

The figure shows that the amount of immune humans is the highest when nobody uses a mosquito net. This can be explained by looking at natural selection. When nobody uses mosquito nets, the situation explained in the subsection above appears: many people that aren't immune get infected and die faster than immune people, which increases the immunity density and fades out the malaria virus. However when many people use mosquito nets, mosquitos can't infect people so the immunity stays low. Which means the malaria virus will keep existing.