Monte Carlo Simulation for detecting probability of Malaria

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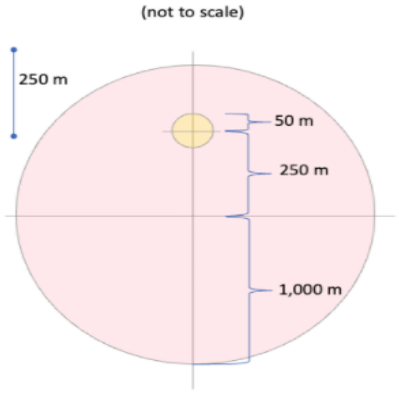
Problem Statement:

This report attempts to show the probability of a mosquito attacking a host within a radius of 1000 meter in a duration of 10 days. The location of host is fixed at co-ordinate (0,250).
The mosquito is assumed to have a life span of 10 days and the start location is (0,0). Each day for 10 days the mosquito will smell the host within a radius of 50m. If success, then the search ends. If failure, it turns off its sense of smell and travel to 250m in any direction. The next day it repeats the same.



In this period, we want to find out:
1) What are the chances of the mosquito attacking the host?
2) What are the chances of the mosquito dying on its last day outside of the zone of 1000m radius?

Solution 1:

Initial estimation: Since there is only one host fixed at a particular location (0,250), the probability of finding the host would be very low as the mosquito can go in any direction. And most likely the chance to cross in the same zone as the host persist would be low.

Next, we want to see if our initial estimation of the problem holds true.

To find out the probability of finding the host in 10-day period, we run simulations to find the rate of success.

Step1: To simulate this, every run is considered a new case which means mosquitoes' initial location is at (0,0) at start of the run.

Step2: From the current location, we first want to find out if we can detect the presence of the host. We can do this by taking the Euclidean distance between host's location and current location. If it's less than 50, then it's a "Success"! So, increase the count of the success state.

Step3: If failed to find host, since the mosquito can travel in any direction, then for that day, we randomly sample an angle between 0 to 360 degrees from a uniform distribution. Considering the current location of the mosquito as the origin, we want to locate any point that is on the circumference of this circle with a radius of 250m. Therefore, the next location of the mosquito is found out using below equation:

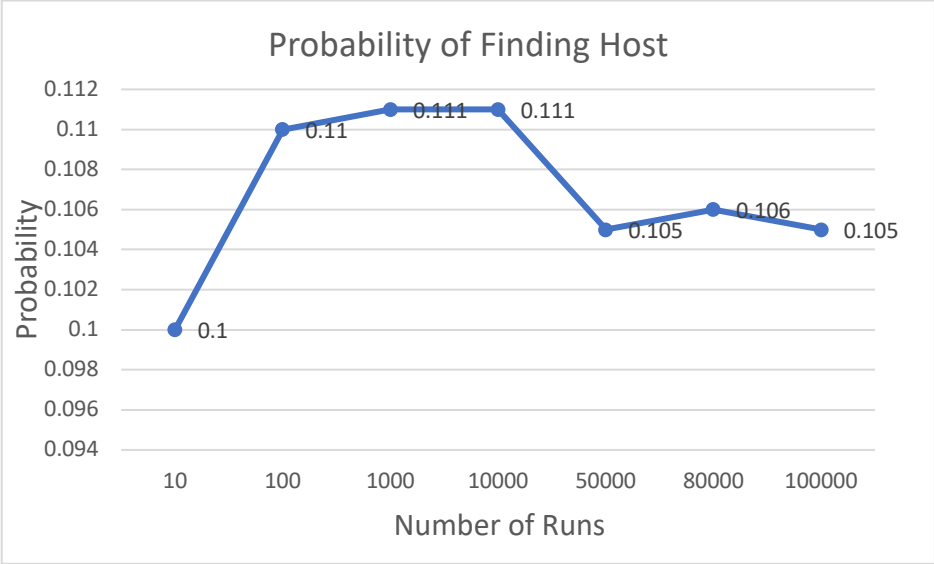
$$x_{new} = x_{old} + (250 * \sin\theta)$$
$$y_{new} = y_{old} + (250 * \cos\theta)$$

Step 4: Repeat the steps 2 and 3 for every run.
Step 5: At the end of the simulation, we find out the probability of finding the host by dividing no. of times success occurred with total no. of runs.

Running the above experiments for different number of simulations concludes the following:

For runs of 100000 the maximum probability of finding host reaches at 0.105 (rounded to 3 decimal places), which is extremely low and coincides with our initial estimation.

Below is the plot that shoes how the probability of finding the host increases as number of runs increase.

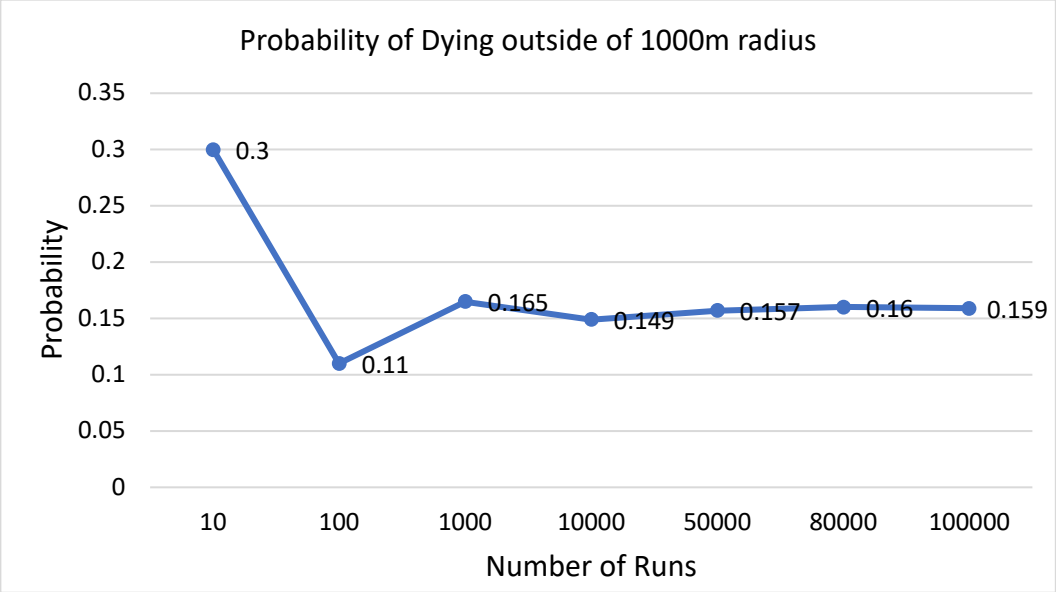


Solution 2: To find out probability of the mosquito dying outside the region of 1000m radius.

Initial estimation: Since the red region has a radius of 1000m, if we assume a mosquito usually goes ahead and doesn't return in the same path so, there is a higher probability of it to go outside of the red region as soon as 5th day. Let's see if this assumption holds true.

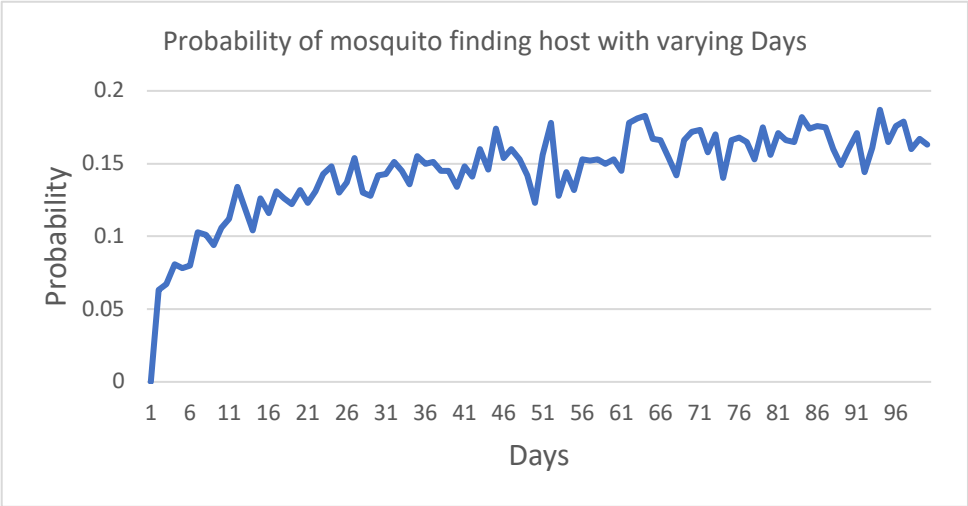
Step1: To find out the probability of the mosquito dying outside of the circle with radius 1000m, follow the same approach as in solution1. But additionally, on 10th day, calculate the Euclidean distance between the final state and the initial state (0,0).
Step2: If the distance is > 1000 then we can conclude that the mosquito dies outside of the 1000m radius. Record this count of throughout the runs.
Step3: Finally, after the end of simulation, find out the probability by dividing no. of times it died outside of red region with total no. of runs.

And from the below figure we can observe that even after running simulation for 100000 runs, the probability of the mosquito dying outside of the red region is very low and around 0.15 which is contrary to the initial estimation.



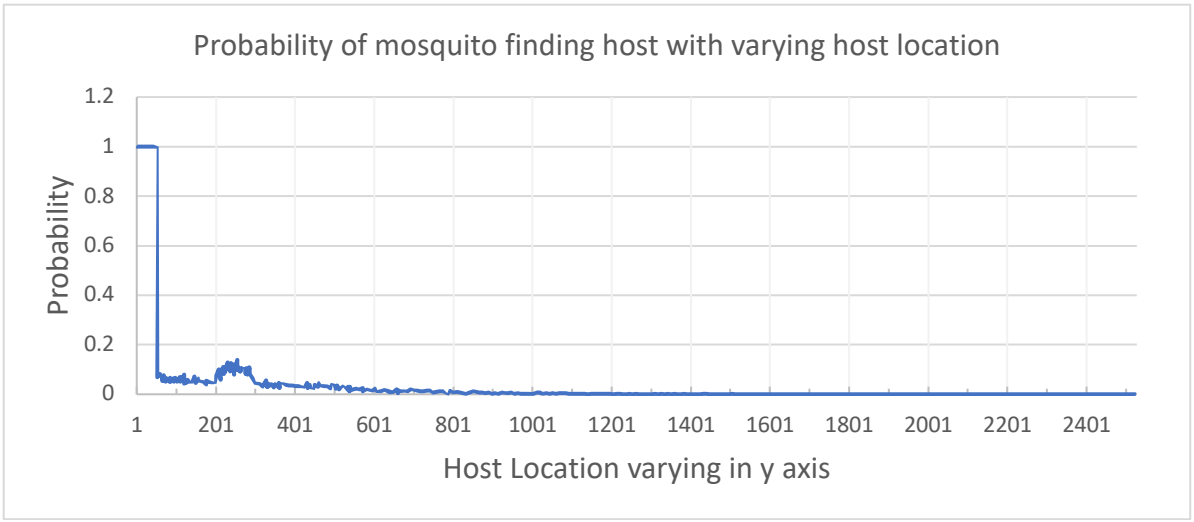
Extra Extra Credit:

Ques. Suppose the mosquito lives for 100 days. Create a plot showing the probably that the insect finds the host by day K.



Simulation run for: 1000 for each scenario

Ques: Suppose that the center of the yellow circle can move along the Y axis, form as little as zero to at most 2,525 m (at which point, the mosquito cannot reach it), Create a plot showing the probability that the (ten day) insect finds the host, as a function of K.



Simulation run for: 1000 for each scenario

The probability decreases to almost zero after host location reaches beyond 1200 with minor fluctuations.