PROJECT 4: MALARIA MODEL

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INTRODUCTION

Malaria is believed to have started from China due to its symptoms that were inscribed in the Chinese Canon of Medicine called, the Nei Ching. It had symptoms of fever and enlarged spleen. It later became noticeable in Greece as a result of frequent fever which killed many Greeks in the 4th Century. In the 6th century, some Hippocrates from Egypt studied the occurrence of fever among a population located near a stagnant pool of water and another studies done by Roman helped to prove that insects from swamp and marshes cause fever, which is a symptom of malaria. Later, famous Indian physician called *Susruta* identified that malaria was caused by the bites of certain insects.

Today, malaria is one of the most rapidly spreading parasitic disease that affects millions of people across the world. This disease is caused by the female anopheles' mosquitoes. They inject into their host (humans) with five different types of malaria parasites; Plasmodium vivax, Plasmodium ovale, Plasmodium malariae, Plasmodium knowlesi, and Plasmodium falciparum. The deadliest among them is the Plasmodium falciparum, which kills millions of children under the age of five and pregnant women in sub-Saharan Africa. Since the discovery of the transmission of the human malaria parasites by Giovanni Batista and his team in 1898, strides have been made by researchers all over the world to combat this dreadful disease.

With the regard to the increasing rate of malaria across the globe, this project presents the goal of creating a malaria model using system dynamic diagrams and Matlab software to investigate the effect of different parameters in the process. The analysis that will be obtained in the form of models, equations and graph will be used to simulate the spread of malaria within a period of time.

EQUATIONS INVOLVED IN THE MOSQUITO MODEL

Mosquito births = Mosquito birth rate * Mosquitoes

Mosquitoes = Uninfected Mosquitoes + Vectors

Uninfected mosquito deaths = Mosquito death rate * Uninfected Mosquitoes

Vector Deaths = Mosquito death rate * Vectors

Prob. vector = Vectors / Mosquitoes

Sub-Model

- $dUIM/dt$

= Mosq Birth rate*Mosq - Mosq Death rate*UIM – Rate Vector conv *UIM Mosquitoes = Uninfected Mosquitoes + Vectors

- $dV\ /dt$

= Rate Vector conv *UIM - Mosq Death rate*V

EQUATIONS AND DIFFERENTIAL EQUATION OF HUMAN SYSTEM.

Uninfected Human:

$$\frac{dUH}{dt} = (Recovery\ rate * \ Human\ host) - (Prob.of\ bitten\ human * Prob.of\ vector * Uninfected\ human)$$

Human Host:

$$\frac{dHH}{dt} = -(Recovery\ rate * \ Human\ host) - (\ Human\ host * Human\ death\ rate) - (Human\ Host * rate\ of\ Immnuity)$$

Immune:

$$\frac{dI}{dt} = Human\ host * Rate\ of\ immunity$$

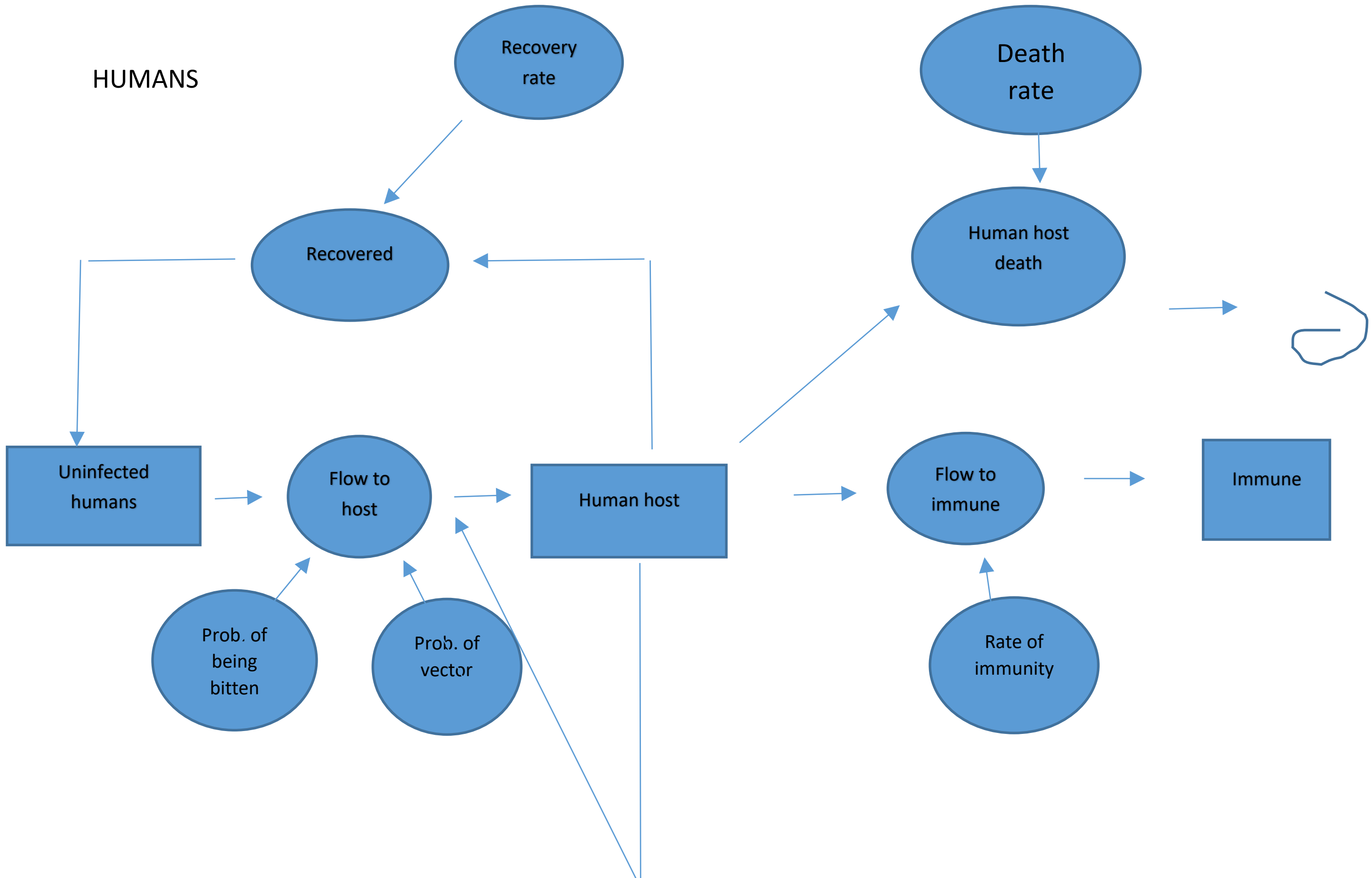
MATLAB CODE:

```
% A model of mosquito infections

function dy = mosquitoModel2()

function dydt = fxn(t, y)

    V = y(1);    % Vectors
    UM = y(2);   % Uninfected mosquitoes
    UH = y(3);   % Uninfected humans
    HH = y(4);   % Human hosts
    I = y(5);    % Infected humans
```

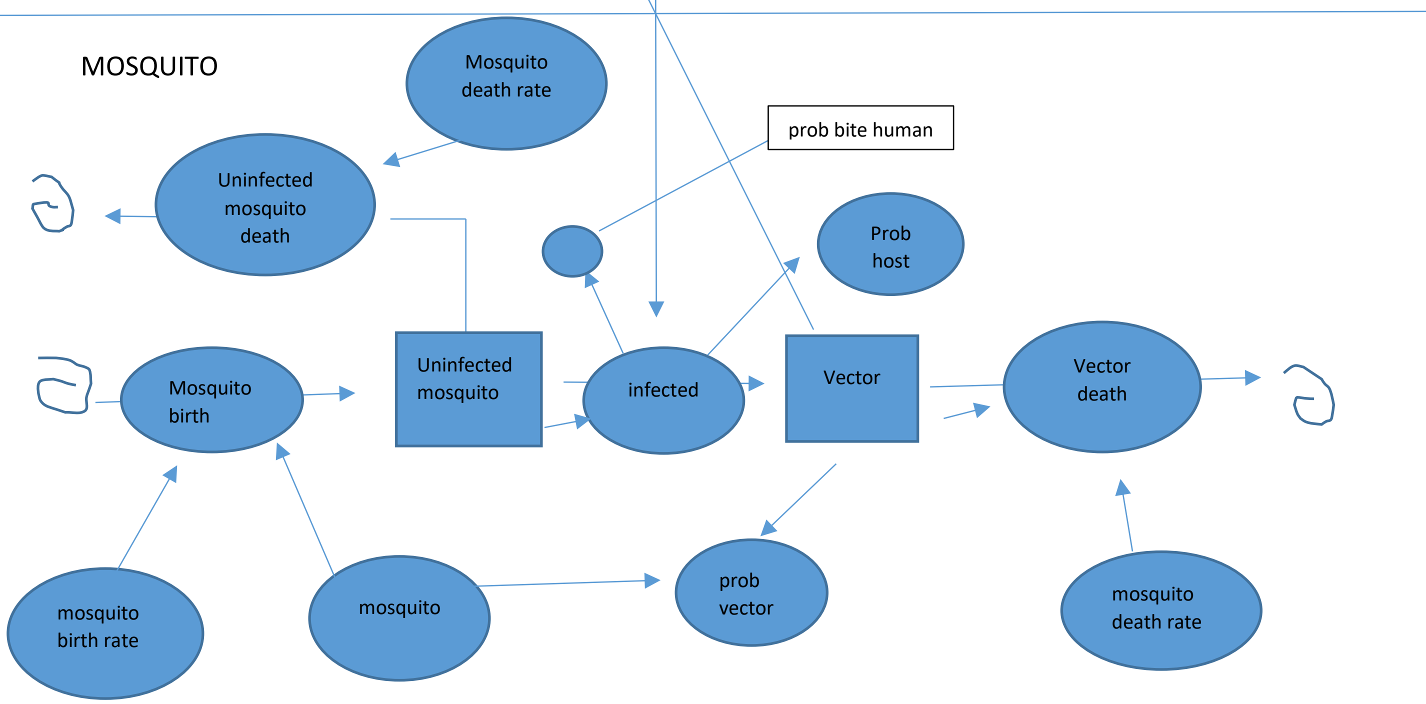
```
    mdr = 0.01;          % mosquito death rate
    mbr = 0.01;          % mosquito birth rate
    pbhu = 0.3;          % probability that mosquito bites a human
    rr = 0.3;            % recvery rate of humans
    hdr = 0.005;         % human death rate due to malaria
    ri = 0.01;           % rate of immunity

    pbho = HH/(HH+I+UH);         % probability of biting a host
    rvc = pbhu*pbho;     % rate of vector conversion
    M = V+UM;            % number of mosquitoes
    pv = V/M;            % probability that a mosquito is a vector

    dVdt = rvc*UM - V*mdr;
    dUMdt = mbr*M - UM*mdr - rvc*UM;
    dUHdt = rr*HH - pbhu*pv*UH;
    dHHdt = pbhu*pv*UH - HH*rr - HH*hdr - HH*ri;
    dIdt = HH*ri;

    dydt = [dVdt; dUMdt; dUHdt; dHHdt; dIdt];
end

    tspan = [0 200];

    UHo = 300;
    UMo = 300;
    HHo = 1;
    Io = 0;
    Vo = 0;

    y0 = [Vo UMo UHo HHo Io];

    [t, y] = ode45(@fxn, tspan, y0);

    plot(t, y)
    xlabel('Time')
    ylabel('Populations')
    title('Model of mosquito infections')
    legend('Vector', 'UMos', 'UHuman', 'HHost', 'Immune')
end
```

SYSTEM DYNAMIC DIAGRAM

HUMANS



MOSQUITO



Explanation of the model

Human Model: An uninfected human stands the chance of being bitten by a mosquito who is a vector. The individual becomes a host which can recover, be immune to the parasite or can eventually die.

Mosquito: A young mosquito is born uninfected and can die uninfected. It can be infected to become a vector which can die or can also stand the chance of being a host.

A GRAPH OF POPULATION OF MOSQUITOES AND HUMANS OVER TIME.

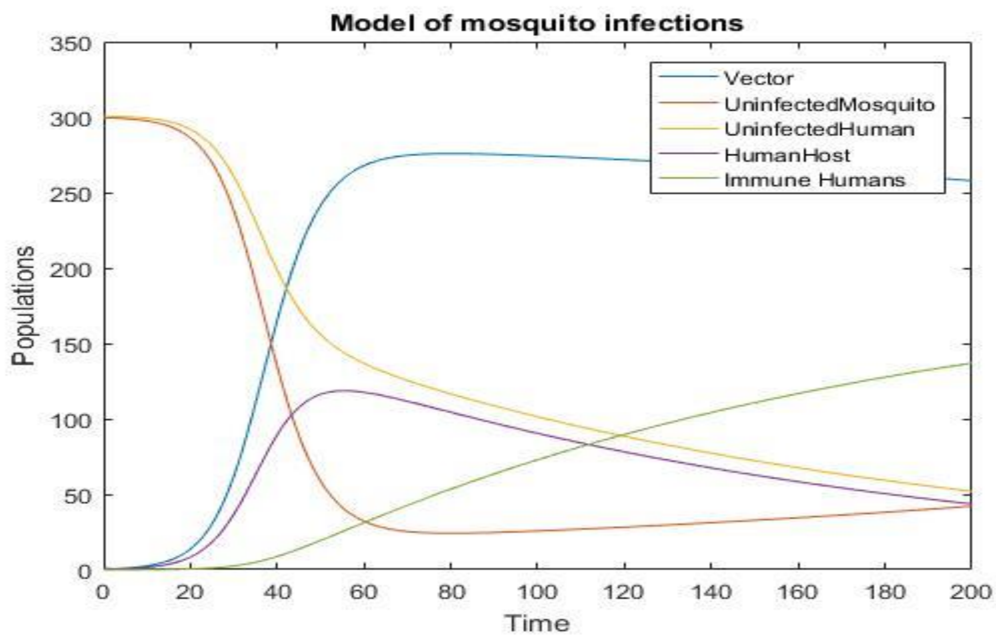
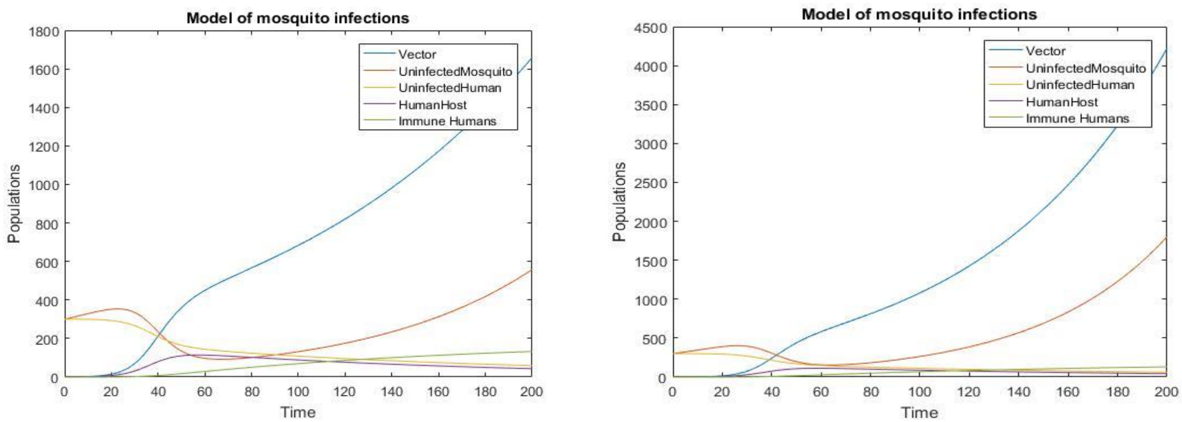


Figure 1. Shows the population of Mosquitoes and humans over time.

Slightly higher birth rate than death rate of mosquitoes.

A slight increase in the birth rate caused both populations of vector and uninfected mosquitoes to increase exponentially over time. But the populations of the uninfected human, human host and immune humans decrease along with time. This implies that the more humans die as the mosquito population increases, leading to a decrease in the human population. The graphs below give show what happens to the population over time.

Graphs of population versus time



The figure. 2 shows the population of mosquitoes and human when the birth rates were 0.02 and 0.025, and the death rate was 0.01

No human host and one vector

There is no observable difference when no human host and one vector is implemented in the code.

A graph of population versus time

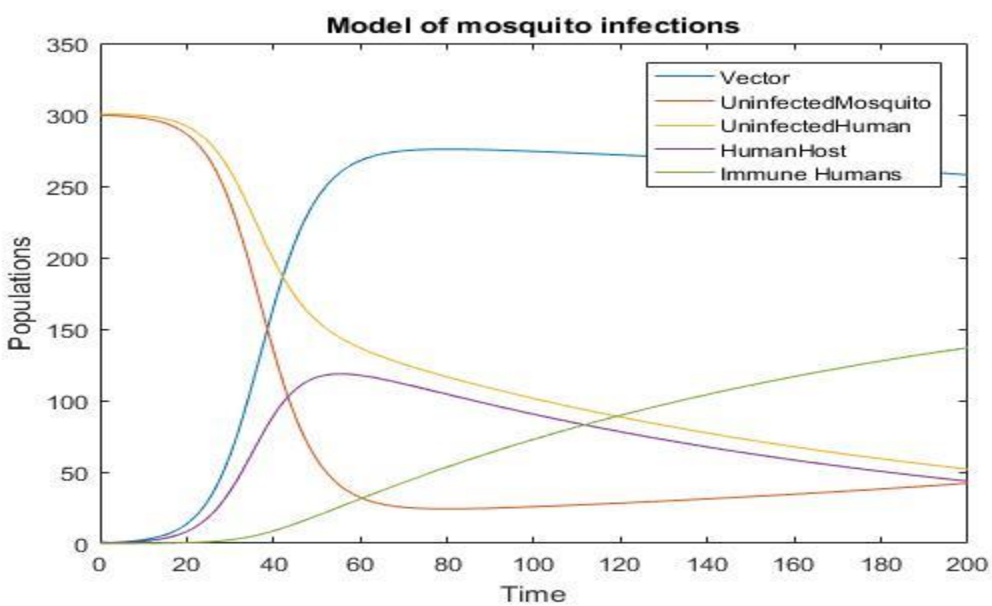


Figure 4. Shows the population of the mosquito and human population when one vector and no human host was incorporated in the code.

Zero death rate for human

When the human death rate is zero, the humans can only recover or become immune after the infection. Removing one of the outflows (death) which causes the number of the infected humans to reduce at a relatively lower rate as compared to the rate at which it reduces if the humans were to die of malaria.

A graph of Population against time.

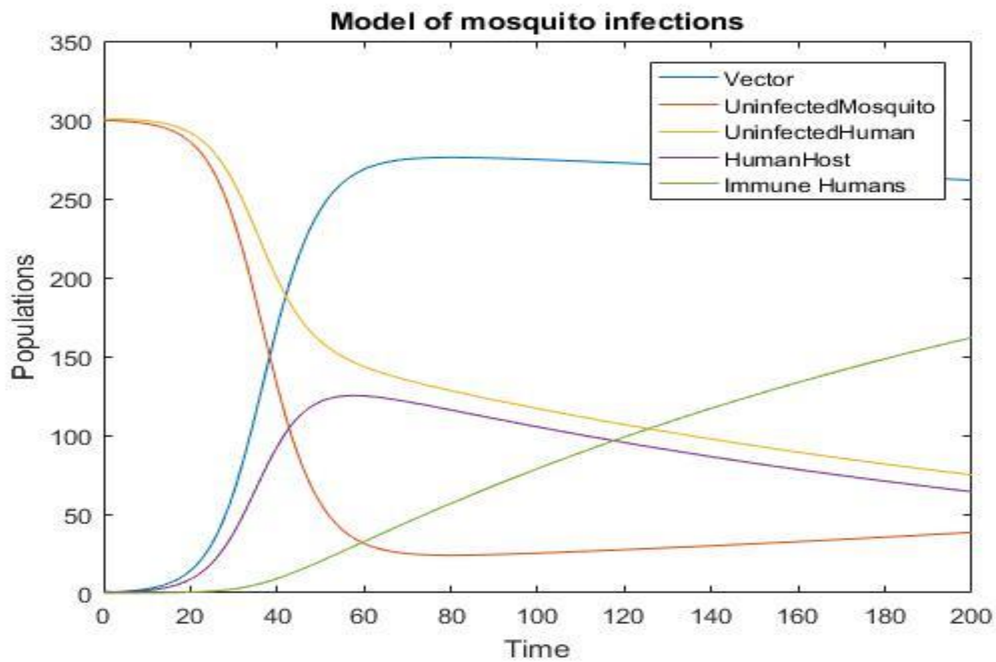


Figure 5. shows the population of mosquitoes and humans with a zero human death rate.

REDUCING PROBABILITY OF HUMAN BITE TO 3%

Uninfected mosquitoes and uninfected human population did not change. The number of immune humans also remained zero. This is because the rate at which mosquitoes bite humans is insignificant as compared to the recovery rate.

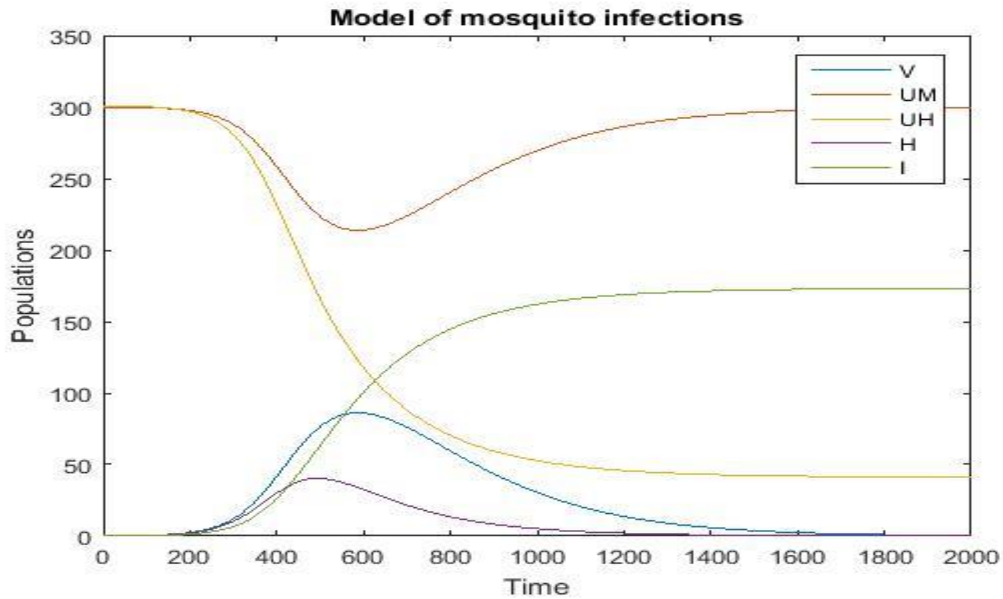


Figure 6. Shows the population of humans versus mosquitoes when probability of human bites is reduced to 3%

<u>REDUCING PROBABILITY THAT HUMAN IS BITTEN BY MOSQUITO TO 3%</u>

Reducing this probability reduces the chance that a human being is bitten by a mosquito. This also causes a drastic drop in the number of human hosts because less humans are bitten.

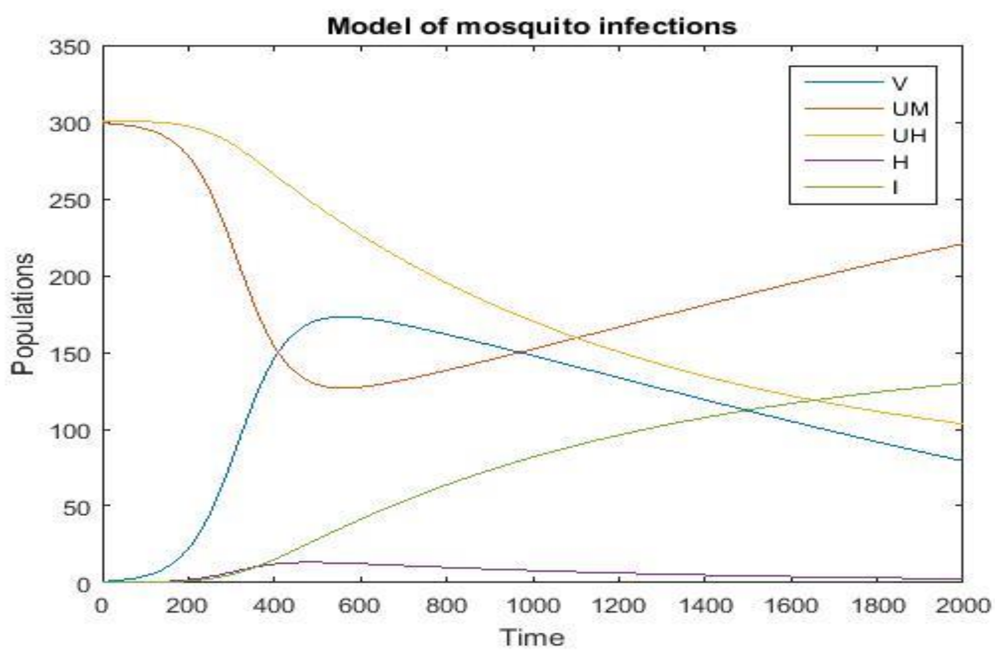


Figure 7. Shows the population of humans against mosquitoes when probability of human of getting bitten is reduced to 3%.

CHANGES TO BE INCORPORATED IN THE MODEL

In order to make the model true to life, the humans can be considered to have a birth rate and a death rate other than deaths caused by malaria. The incubation period of malaria in humans and mosquitoes will also be included in the model.

LIMITATION

The following are the limiting factors that were recorded in the course of making this project, and they are as follows;

- There was a closed domain for the population of humans
- The rate at which the mosquitoes were reproducing was constant
- Both infected and uninfected mosquitoes were assumed to die at a constant rate
- It was considered that the individual who is bitten by mosquito immediately becomes a host
- It was also assumed that a mosquito that bites a host immediately becomes a vector

Conclusion

Malaria has been a serious factor in almost every health campaign done in the world. each year billions of dollars are spent on malaria control with over hundred million dollars spent on Africa alone. The high rate of human death caused by malaria can be drastically reduced if lots of research go into modelling the key factors illustrated in this insightful project such as infected and uninfected mosquitoes, human host etc. that enable the mosquito parasites increasing the population of mosquitoes affect the lives of humans.

Reference

Centers for Disease Control and Prevention - USA (2016, March 11). Retrieved from http://www.cdc.gov/malaria/about/history/

Sullivan, D & Johns Hopkins Bloomberg School of Health. (2006) Malariology Overview. Retrieved from http://*ocw.jhsph.edu/courses/malariology/PDFs/lecture1.pdf*