Modeling and Simulation, CS302

Lab-4

Due Date: Feb. 22, 2017

1. **(Modeling of Malaria) Module 4.4**: The aim of this lab is to model the progress of malaria using the methods developed in the lectures. Malaria involves relationship between humans and mosquitoes. Not all mosquitoes spread malaria. We do not go into the details of this part. The part that is important from a modeling perspective is that out of the total mosquito population only a fraction have the potential to spread malaria. Amongst these we can think of ones which are already infected and the ones which are not infected (susceptible). Amongst humans all have equal chance of being infected with malaria (all are susceptible). A bite from an infected mosquito can lead to malaria in humans. Alternatively, if a susceptible mosquito bites an infected human they can become infected.

   We work under the following assumptions

   - Since life expectancy of humans is much larger than that of mosquito we assume that the human population is closed with no births, immigration and deaths except from malaria.
   - As soon as an infected mosquito bites a susceptible human, it becomes infected.
   - As soon as a susceptible mosquito bites an infected human it becomes infected.
   - Because of their relatively short life expectancy mosquito's births and deaths are considered.

   We therefore consider the following processes in malaria spread:

   Humans:

   - susceptible humans get infected due to mosquito bite from an infected mosquito.
   - Infected humans can recover and become susceptible again.
   - Infected humans can die due to malaria.
   - Infected humans can become immune.

   Mosquitoes:

- Susceptible mosquitoes can become infected when they bite an infected human.
- Mosquitoes can be born. All mosquitoes are born susceptible.
- All mosquitoes can die natural deaths.

Based on these observations

(a) Draw the compartment model for malaria spread.

(b) Identify all the variables and write differential equations for malaria spread assuming that except were interactions takes place all other changes are unconstrained growth and decay.

(c) Using the following information in your model implement on the computer and comment on the observations (Make a single figure with all the susceptibles and infected):

i. **(Initial values (t=0)):** Susceptible humans = 300, Infected human = 1, immune humans = 0, susceptible mosquitoes = 300, infected mosquito= 0.

ii. **Constants:** recovery rate of humans = 0.3, immunity rate = 0.01, malaria induced death rate = 0.005, mosquito birth rate = 0.01, probability of mosquito biting a susceptible human = probability of mosquito biting an infected human = 0.3.

(d) If you we take into account spraying or fumigation which quantity changes in your equations. How does this change reflect in the figure that you made in part (c).

(e) If instead of spraying we went for vaccination what would you change and again how does it impact malaria spread.

(f) **Exploratory:** If you are interested in exploring more search for more realistic models of malaria (and similar vector models), and look at the modifications that are done to make it more realistic. These include, exposed state for mosquito, age-based analysis on humans etc. (The original malaria model was by Ross and further refined by Macdonald. If interested, you could also take a look at them)