TJHSST Computer Systems Lab Senior Research Project 2008-2009 Modeling Virus Transmission on Population Dynamics using Agent Based and Systems Dynamics Modeling

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Abstract

This goal of this project is to model the transmission dynamics of viruses and their affect on populations based on user input. The near complete version of this project will eventually be able to model the effect of virus transmissions on population dynamics of real situations, such as the 1918 Spanish Flu. Since there is ample data about major infections such as the 1918 Spanish Flu, the variables can be modeled using this program [1].

Keywords: modeling, agent based, systems dynamics, netlogo, virus

1 Introduction - Elaboration on the problem statement, purpose, and project scope

1.1 Scope of Study

The approach taken in creating this model is: The more, the better. The model will represent, as close to real life as possible, normal parameters that can significantly affect populations. The end result will likely have different classes of people, different infection rates, and different population densities in addition to random mutations and immunity.

The different types of modeling used in this paper are Systems Dynamics modeling and Agent based Modeling. Systems Dynamics modeling is the general flow of one variable into another variable. Systems Dynamics deals almost exclusively with modeling a general flow, rather than individual agents behaving under a given set of instructions. If the flow from one stock(a mutable variable) to another is given by $f(t)$, then the stock can be represented as

$$\int_0^t f(t)\,dt$$

where t is time. Agent Based modeling on the other hand does have individual agents following a piece of code to perform a certain task.

1.2 Expected results

This model will give the population data for different types of people for a virus in a certain amount of specified time. This data can either be accessed by a plot in the modeling software NetLogo or as a .csv file in Mircosoft Excel.

This project is for both virus transmission modeling and the integration of systems dyanmics and agent based modeling [2]. A research paper written about the integration of these two types of modeling sparked the question of whether they can be effectively combined to create a better model. Thus, the model actually has a dual purpose and the results will help both parts of the research.

1.3 Type of research

My project is a mix of two areas. The use-inspired research and the pure applied research both apply, as the goal of the project is to create a usuable model, applied research, and try to integrate systems dynamics with agent based modeling, use-inspired research. The use-inspired aspect is the creation of a model to better help combat global outbreaks of major diseases, such as the Bird Flu(H5N1) virus. The pure applied research aspect is the use of two very different types of modeling to try to optimize the model from different points of view.

2 Background and review of current literature and research

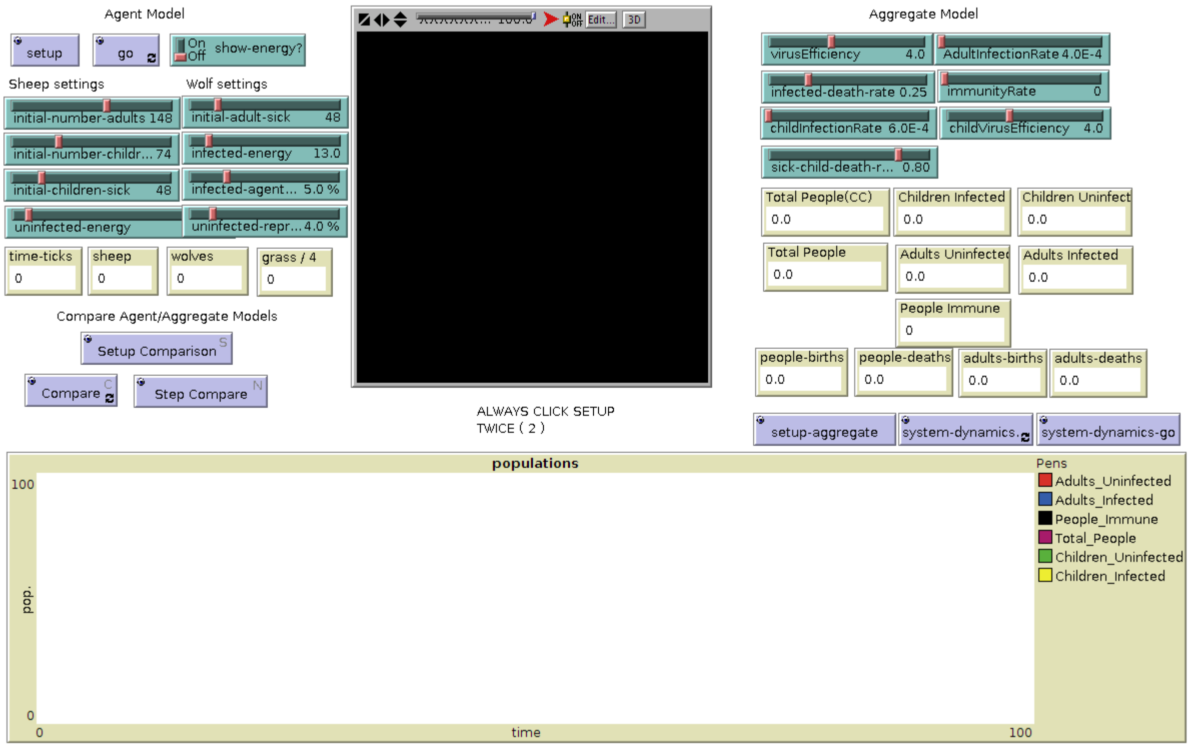
Researchers are currently doing research in this area, trying to create a model to represent a historical virus outbreak, so future outbreaks can be avoided. One such research paper involves creating a model with detailed parameters for infection, susceptibility and transmission in different people in different age categories [1]. This paper just modeled one specific outbreak, but my model will be able to model a general outbreak.

Another paper discusses the pros and cons of the two types of modeling. The ultimate conclusion was that the integration of the two types of models according to the situation was the best idea[2]. My model also strives to do this.

3 Procedures and Methodology

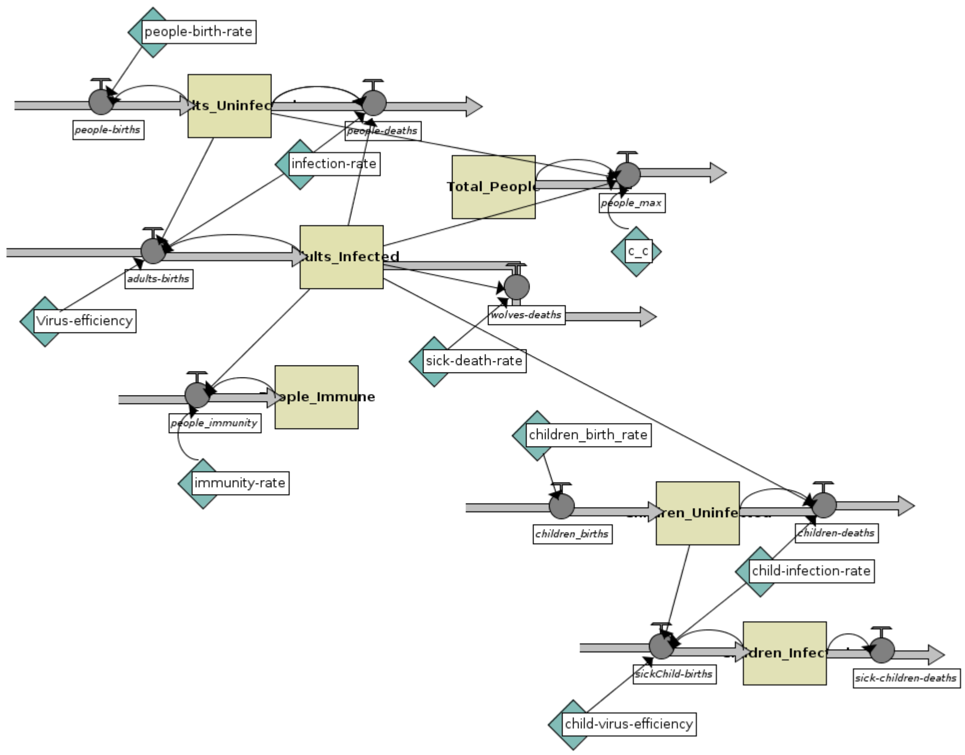
My breakdown of the project is as such. In the 1st Quarter, create the basic framework for the program including people who are infected, uninfected and the transmission probabilities, birth rates, and death rates(See Fig-1). In the 2nd Quarter, add age factors and create different classes of people so children and seniors are more susceptible to catching the infections. Model the birth and death rates of the different age classes, so people can age. Create the carrying capacity to model the limitations of infrastructure. In the 3rd Quarter, modify the general infection rate to specific susceptibility rates so each individual has a different chance of getting the virus depending on immunization, immunity rate and age. Create a population density stock to make people who are in higher density more susceptible. Finally, in the 4th Quarter, troubleshoot and test the final model.

The program is created using NetLogo, which has a GUI interface(See Fig-2). It displays the graphs the user defines and can show visually the patterns in the data.



$Fig - 2$

Testing of the program is done as soon as a new part is completed. Since the model is dynamically affected by every new parameter, the testing is an ongoing phase. The final test of the model will include actually modeling a real situation, so the results of the model will be compared against the real situation and see how close the model actually was to predicting a real outbreak. NetLogo includes a built in method called BehaviorSpace, which tracks the values of every variable and outputs it into a csv file in excel. That can be used to plot and test whether the model works.



$Fig - 1$

The Systems Dynamics flowchart above represents the flow of the model. The methods that have been implemented in the model are: birth rate for adults and children, death rate for adults and children, immunity rate for adults, and carrying capacity for the total population. The next methods to be implemented are the methods stated above for seniors, the susceptibility rate, population density, and aging of the population to adults and seniors, and virus spread timing.

The Maryland Virtual High School for Science and Math has a model on their website dealing with epidemics. The model creates a basic starting point for an epidemic study [4]. I am looking to integrate some of the functions used in the model with my study.

4 Expected Results

Models are used frequently to predict various situations in life and are used by individuals, companies, organizations and the government. Even though agent based and system dynamics models are used, they are not used often together, so integrating them will offer a different outlook to the model. My primary purpose is to model a realistic situation, so this model will not be specific to any situation, but rather just have the basic necessities for the virus transmission model and the user will choose the others values.

This project is a good fundamental starting point for a virus model and for a modeling project. The students next year might be able to add additional features, which I might not be able to add this year. Any number of odd factors could affect virus transmission, so there will be no shortage of features to add.

The results of the population graph should be in a form of harmonic motion. Oscillations are expected and are part of the normal patterns and results[5].

References

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[2] Nadine Schieritz and Andreas Grler. Emergent Structures in Supply Chains A Study Integrating Agent-Based and System Dynamics Modeling

[3] Uri Wilensky. BehaviorSpace Guide NetLogo 4.0.3 User Manual. Northwestern University http://ccl.northwestern.edu/netlogo/docs/behaviorspace.html

[4] MVHS Modeling the Spread of an epidemic http://mvhs1.mbhs.edu/mvhsproj/epidemic/epidemic.html

[5] Leon Kaganovskiy Predator-Prey Models-Generalization of Lotka-Volterra Model University of Michigan-Ann Arbor http://faculty.ncf.edu/lkaganovskiy/LaTeX/talkmylotkaextend.pdf