

Modeling the Effects of Disasters on Human Population and Resources 2008-2009

Joshua Yoon

Thomas Jefferson High School for Science and Technology
Alexandria, Virginia

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Abstract

Recently over the past decades, numerous disasters such as the earthquakes and tsunamis have struck all over the world, and this project is an attempt to not only model the effects of these disasters on a human population accurately, but also to extrapolate the effects of future disasters on a nearby human population using a System Dynamics approach.

Keywords: disaster, system dynamic based modeling, computer simulation, extrapolation, population

1 Introduction

The subject of the project is to model the effects of a disaster on a human population using system dynamics. The main goals of the project is to accurately model the behaviors of a human population and to make the effects of the disasters accurate in the sense that the data created during the simulation is similar to data collected from real disasters.

Before any real testing can begin, an artificial and dynamic human population must be created. To create such a population, logistical functions and exponential growth must be implemented, and in the System Dynamics, implementation comes through the creation of relationships between variables. Logistical functions are expressed mathematically as a differential equation



Population Growth Based on Logistic Equation

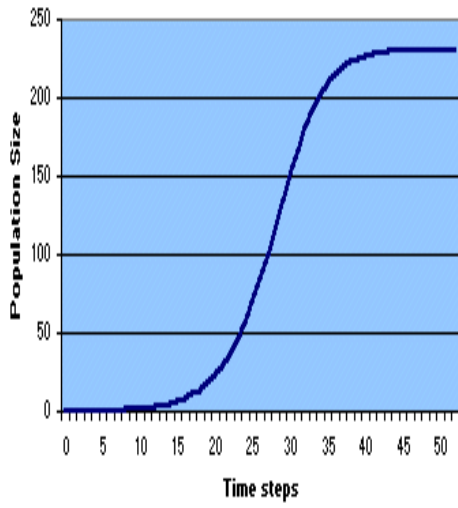


Figure 1: Logistic Curve

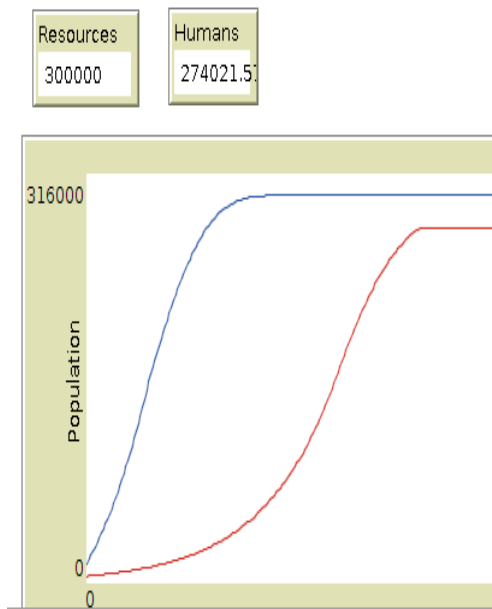


Figure 2: Logistic Curve

$$\text{Growth Rate} = \frac{\text{Growth in Population}}{\text{Population Size}}$$

$$= \frac{dP/dt}{P} = \beta - \delta \cdot P$$

$$\therefore dP/dt = P(\beta - \delta \cdot P)$$

The solution for this is:

$$P(t) = \frac{\beta}{\delta + \left[\left(\frac{\beta}{P_0} \right) - \delta \right] e^{-\beta t}}$$

where

- β = avg. birth rate
- $\delta \cdot P$ = avg. death rate
- δ = proportionality constant for death rate
- $\frac{\beta}{\delta}$ = asymptote at $t \rightarrow \infty$

Figure 3: Logistical Equation

The equation shown, is a general differential equation for logistical population growth. The main component to note are the birth rate, the death rate, and time. All of these variables work interdependently to create a logistical function as seen previously. After creating various relationships using the NetLogo interface, a logistical function for population has been made (red line signifies the human population). The web below is a relationship web created in the NetLogo interface. By creating different variables (as represented by the tan boxes) and behavioral controls (as represented by the gray arrows and blue diamonds), a logistical function has been created. This in essence is System Dynamics; which formally is the approach to understanding the behavior of complex systems over time. It deals with internal feedback loops and time. (Google) System dynamics is also the ideal choice when working with disasters and humans, because as opposed to other modeling techniques such as agent-based modeling, system dynamics takes certain variables as a whole, instead of individual units. And when working with disasters, which are large events that affects groups as opposed to individuals, system dynamics is the most efficient and appropriate way to model such a scenario. As mentioned before, the language that is being used is the NetLogo language

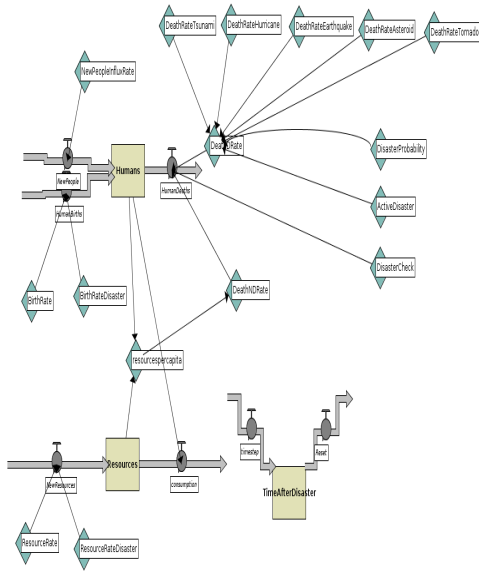


Figure 4: System Dynamics Web

and NetLogo offers two options: agent-based modeling and system dynamics, I am using the System Dynamics portion of the NetLogo language.

2 Background

After reading many articles on other System Dynamics programs, I've discovered all of the projects had one thing in common. The relationships and the interconnection of all the variables are very complex, and to have an accurate simulation, almost all, if not all, of the factors of a system need to be accounted for and worked into numerous relationships. I also realized that population to recover as a normal population would after a disaster has struck. If I finish my drawing a diagram of all the relationships and factors would help me visualize the problem better, because many of the authors of the article had drawn up their designs on paper first, before actually beginning to model their idea using a computer program. Many of the authors, also used a preexisting System Dynamics program called Stella. My simulation will be like every other System Dynamics simulation, in the sense

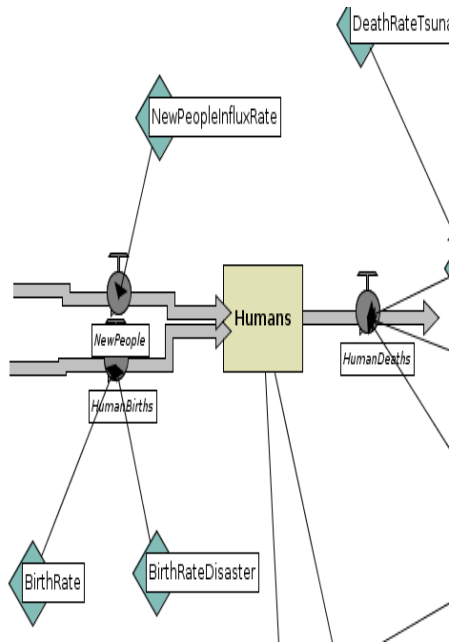


Figure 5: Human Variable

that I'm simulating something based on relationships between the factors in a system, and more specifically in my case, disasters on human population and resources.

3 Development Sections

3.1 The Big Three

At the moment, I only have implemented three factors, which are human population, resources, and disasters. The goal of this project is to have a human population, which behaves as a normal human population in a wealthy country would, when there are no disasters. Then I want the main project early, I want to add another factor, which is the disaster preventative measures that a population would take after a disaster has struck. Adding this factor would make the simulation more realistic and the extrapolated data would account for future disaster preventative measures or expert opinion.

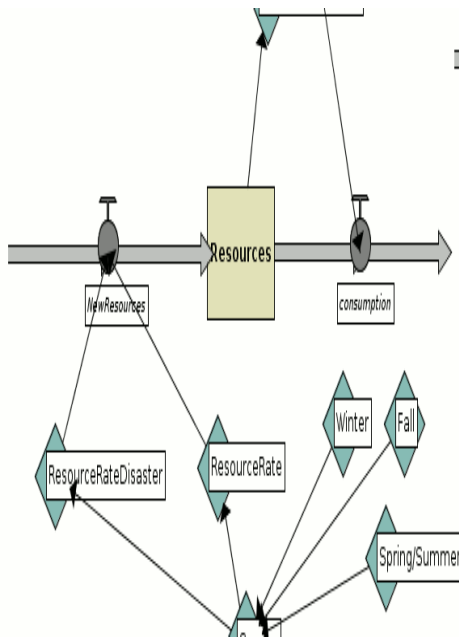


Figure 6: Resource Variable

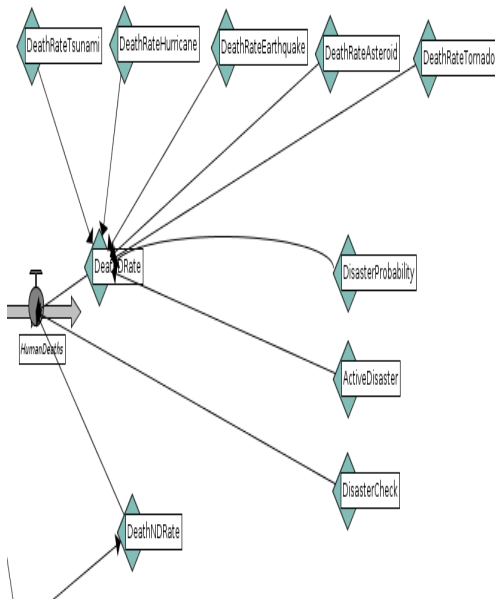


Figure 7: Disaster Variables

4 Final Plans

For this project, I plan to first model the behavior of a human population with respects to the resources that are available for population growth accurately. To test if I have created an accurate model, I will look at other human population models and compare my test runs, which are made by running and plotting the program on a graph inside of NetLogo, to the models and check if the curves are similar. After I create an accurate behavior, I will then start implementing different types of disasters that will not only affect the population, but also the resources in different ways. Once I have created the necessary variables and relationships, I will then test the effects of the disaster on a human population. The results of the test runs will be compared with that of real data, and then changes will be made to best fit the data from the test runs to the data found from real situations. If everything is finished, then a disaster preventative variable will be taken into account and tested in similar ways (ie with data from real situations).

When I am finished with the project, I expect the program to correctly model a human population and the population and resources will exhibit a recovery-curve, after the population is struck by a disaster. In the end, all of the results will be shown by graphs, which are made inside of the NetLogo program. Even though I have created a simple simulation, the simulation is still missing many possible variables and this program may be used as a shell or foundation for future researchers.

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