Modeling the Effects of Disasters on Human Population and Resources

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Abstract

Recently over the past decades, numerous disasters such as earthquakes and tsunamis have unleashed chaos on human populations all over the world, and this project is an attempt to not only model the catastrophic effects of these disasters, but also to extrapolate the effects of future disasters on human populations of varying sizes using the System Dynamics approach.

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

1 Introduction

The purpose of this project is to model the effects of a disaster on human populations of varying sizes using system dynamics. The main goals of the project are to accurately model the logistcal behaviors of a human population, create a dynamic relationship between the resources present in an environment and the humans, and to make the effects of the disasters accurate in the sense that the data created during simulations are similar to data collected from real disasters.

Figure 1: Logistic Equation

Before any real testing can begin, an artificial and dynamic human population must be created. To create such a population, differential logistical functions and different aspects of exponential growth and chaos must be implemented, and in System Dynamics, implementation comes through the creation of relationships between the variables present in a system. Logistical functions are expressed mathematically as a differential equation (figure 1) and this equation can then be translated into a logistical curve (figure 2)

Figure 1 is a general differential equation for all logsitcal growth, which will create a graph that looks more or less like figure 2. The main components to note are the birth rate, the death rate, resource growth, carrying capacity and time. All of these variables work interdependently to create a logistical function as seen previously. After creating
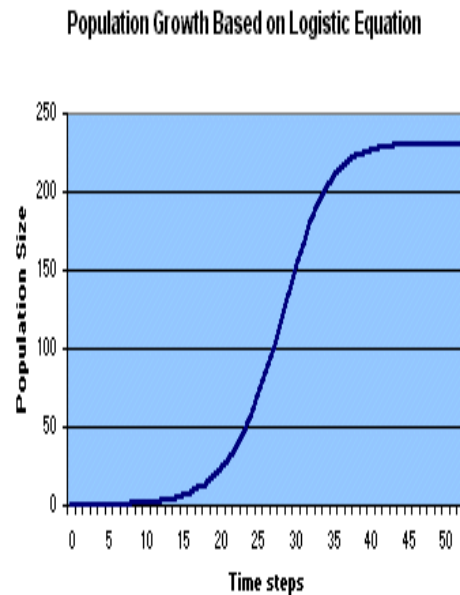

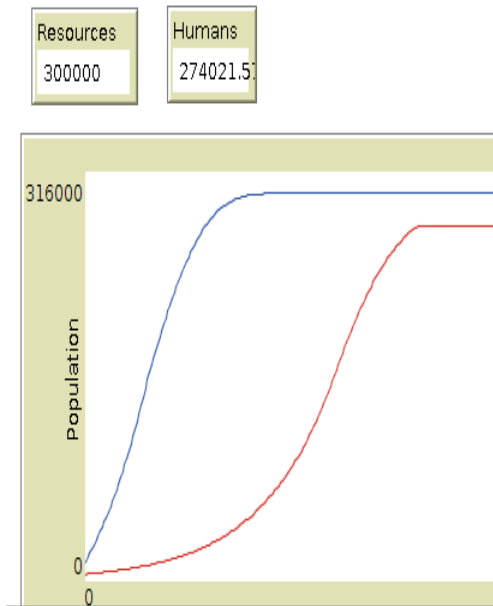
Figure 2: The Typical Logistic Curve
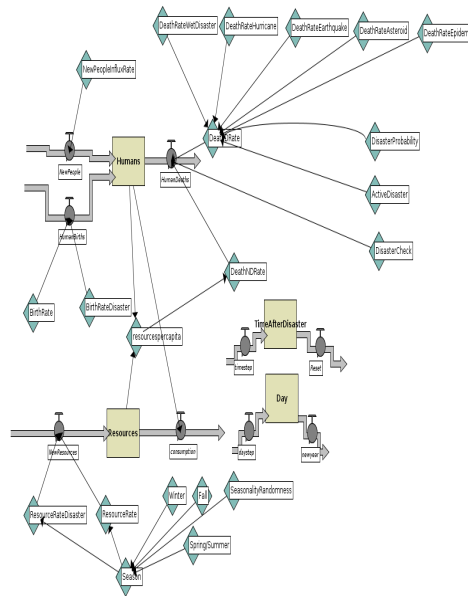
Figure 3: Created Logisitcal Curve

Figure 4: System Dynamics Web

various relationships using the NetLogo interface, a logistical function for population has been made (figure 3). The web (figure 4) is a relationship web created in the NetLogo interface. By creating different stocks, which are the actual objects (as represented by the tan boxes) and behavioral controls such as inflows, outflows, variables, and links (as represented by the gray arrows and blue diamonds), a logistical function has been created. This in essence is System Dynamics; which formally is defined as 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 a community, because as opposed to other modeling techniques such as agent-based modeling, system dynamics accounts for all the variables as a holistic entity, instead of individual units. And when working with disasters, which are large relativley instantaneous events that affects whole 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 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 and simulations, Ive discovered all of the projects had one thing in common. The relationships and the interconnection of all the different factors and variables are intricate and numerous, 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 multiple relationships. Thus, large amounts of time have been used for the sole purpose of planning. After I had finished planning, I made the actual web (figure 4). The different growths also needed to be accounted for (ie the growth rate of humans and resources before a disaster is not the same after a disaster has happened). 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 pre-existing System Dynamics program called Stella. My simulation will be similar to every other System Dynamics simulation, in the sense 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. I am also using NetLogo, and the difference between NetLogo and Stella are the pre-existing arguments. Stella comes with the code built in, but NetLogo does not.

3 Development Sections

3.1 The Fabulous Four

The accuracy of a simulation rises as the number of factors implemented rises, and I have implemented four factors, which are human population, resources, time keepers, and disasters. The goal of this project is to have a human population, which behaves as a normal human population as a moderately wealthy country would, when there are no disasters. Then after I finish the main project, I want to add another factor, which is the disaster preventative measures that a society 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 5 controls the human population. The tan box represents the humans and the gray arrows represent an inflow of humans (birth) or an outflow of humans(death). The inflows and outflows are controlled by the teal diamonds, which are variable modifiers that are referenced by the inflows and outflows. If this mechanism is left by itself, the population would increase infinitely and exponentially. So this is just one of four major components needed to make a working system.

Figure 6 controls the resources and resource production. The tan box represents the resources and the gray arrows represent an inflow (resource production) or an outflow (resource consumption) of resources. The resources are also controlled by the teal diamonds, which are variable modifiers that are
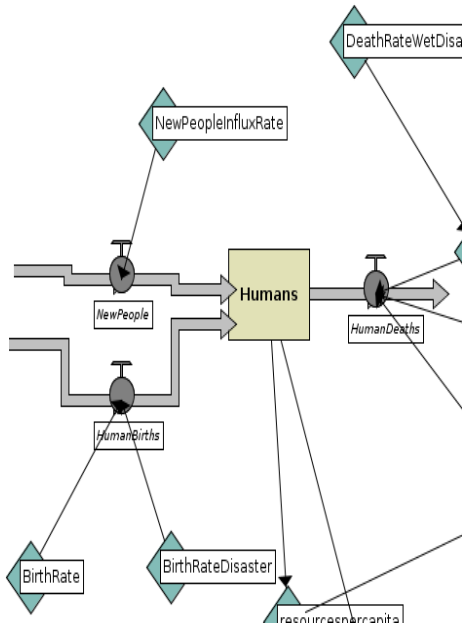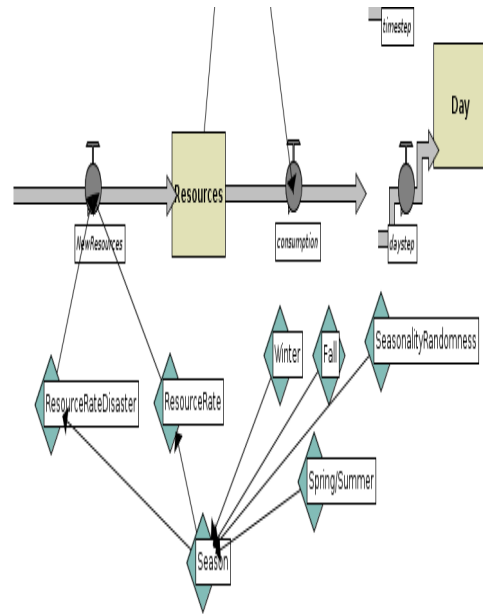
Figure 5: Human Variable

Figure 6: Resource Variable

referenced by the inflows and outflows. This component is extremely important, because this serves as a carrying capacity. A human population can not exceed the limitations of the environment and that is why the resource class was implemented.

There are no actual "real" units present in this component (figure 7). Instead, this component deals with the initiation of the disasters. The different variables generate random numbers and when the right condition (the right set of numbers is created) a disaster is turned on. This component also holds the death rate values of all the disasters and is a large component of the system.

The Figure 8 component may seem extraneous, but this component not only makes things easier, but it is also important to post-disaster recovery. Time must be kept, because a population at some point must recover from a disaster, and the program does not know, when that point is. The point must be made separately and the time keepers creates these time frames in which the population is to recover.

4   Conclusion

The simulation is a success, because it models the behavior of a human population with respects to the resources that are available for population growth accurately, the disasters kill off a portion of the population with respects to the general proporionality trends found on EMDAT and REDAT, which are
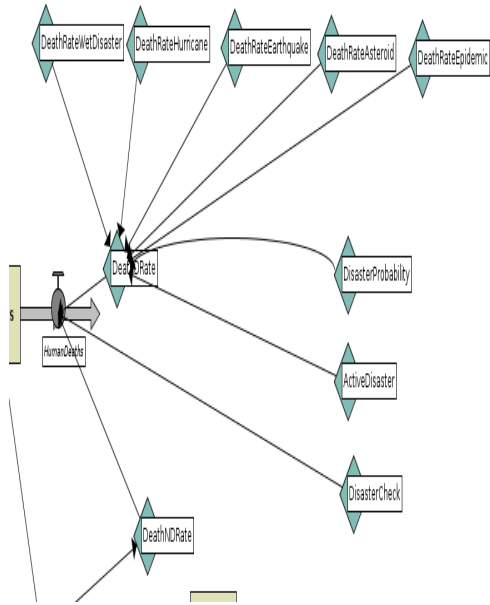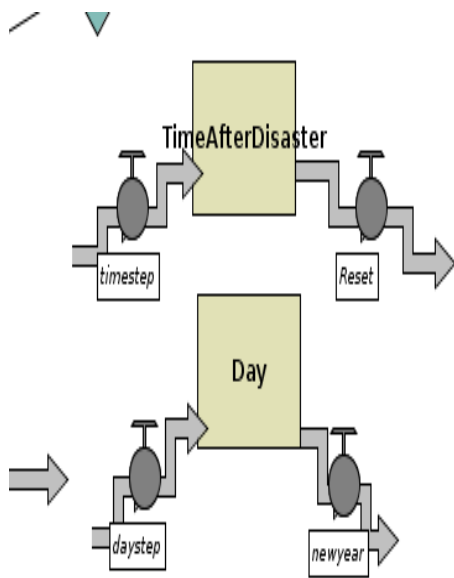
Figure 7: Disaster Variables

Figure 8: Time Keeper Variables

database websites for disasters. Within these sites, are general trends and statistical data, which I used to find fatality rates and general trends. To test if I have created an accurate model, I looked at other human population models and compared my test runs, which are made by running and plotting the program on a graph inside of NetLogo, to the models and the curves were similar. After I created an accurate behavior, I started implementing different types of disasters that not only affect the population, but also the resources and the recovery rates of both items. Once I had created the necessary variables and relationships, I tested the effects of the disaster on a human population and the fatality rates were found as general trends from a website. The results of the test runs were similar to that of real data, and then small minute changes were made to best fit the data from the test runs to the data found from real situations. Recovery rates after a disaster is not a popular thing to take data of and realistically, it would be difficult to, so no data was actually found on the post-disaster recovery rates, but I hypothesize that an actual recovery rate would look similar to that within my simulation.

The program correctly models a human population and the population and resources exhibit a recovery-curve, after the population is struck by a disaster. The results are shown by Figures 9 and 10, which were made inside of the NetLogo program. Figure 9 shows population growth unhindered by disasters and one thing to note is the random osciallations once the carrying capacity has been reached. This can be considered the perks of life be-
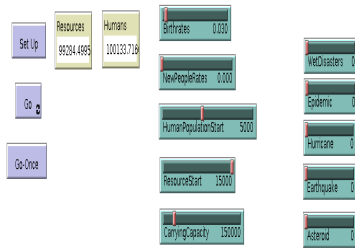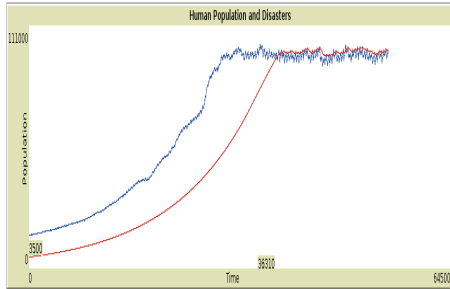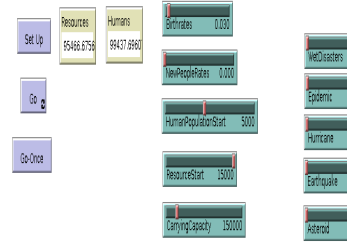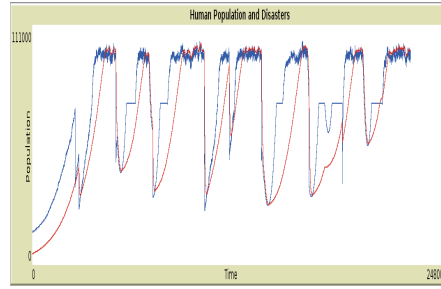
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Figure 9: Logisitical Curve No Disasters

Figure 10: Trial Test Run

ing represented in the system on the microscopic level. Figure 10 shows a trial test run with dramatic drops in population and this represents disaster striking a community and shows population dynamics on a macroscopic level.

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