TJHSST Computer Systems Lab Senior Research Project
System Dynamics Modeling of Community Sustainability in NetLogo
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Abstract

The goal of this project is to apply system dynamics modeling to a basic instance of the contemporary issue of sustainability. System dynamics modeling is especially well-suited to the topic of sustainability; the flows and stocks involved with this sort of modeling are the keys needed to express the relationships between quantities and to observe their interactions. My project would model an arbitrary system, which would be a basic model representative of more realistic systems. The results of the model will be displayed to the user graphically. The goal of this project is to create a system that functions harmoniously over a sustained period of time rather than one that spirals wildly out of control. Sustainability is of course a large, well-researched field and more complex research has certainly been conducted prior to this. However, I think that my project would nonetheless increase student understanding of the issue and system interactions, and that system dynamics provides a particularly insightful prospective for this topic.

Keywords: System Dynamics, NetLogo

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

1.1 Scope of Study

The numbers on which the system is based, instead of being simply arbitrary, are based loosely on data for Kenya from the CIA World Factbook (https://www.cia.gov/library/publications/the-world-factbook/geos/ke.html). The basis for the system is the relationship between food and population. For example, if there is insufficient food, people starve, which means that there are fewer workers to grow the food, etc. System dynamics are essential for predicting the long-term results of these continual interactions. The key facets of the model are regular spoiling, consuming, and growing of food and births and deaths amongst the population. There are various levels of complexity in these facets: the birth rate is constant; the food is only grown by a fraction of the population selected to represent a normal percentage of people able to work; and the death rate is variable, based on food available (i.e. if people cannot eat, they starve). Also, my project will involve regular periodic perturbations in the form of famines, the intensity of which may be defined by the user. As these features are refined and values are chosen to stabilize the relationship between food and population- thus achieving sustainability- additional complexities will be added. For example, a new stock may be added, so that either food, population, or both are now reliable on yet another quantity.

1.2 Expected results

The results of any given run of this model are naturally dependent on the parameters given. Famine magnitude and famine frequency, for example, are currently determined by sliders operated by the user, whereas to change other parameters one must use the System Dynamics Modeler feature of NetLogo to edit the model itself. Ultimately, a primary goal is to create an instance of the system that neither increases without bound nor perishes, i.e. one that is sustainable. However, the instances in which the system is not sustainable are perhaps just as important as far as educational value is concerned, the real goal of the model not being to conduct applicable research on this particular system but rather on the applications of system dynamics to sustainability in general.

The intent of this project is to apply system dynamics to sustainabilty in such a way that increases the user's overall understanding of both. By clearly modeling relationships and allowing the user to define parameters, the model is very much open to the user, inviting him or her to think in greater depth about the issues it presents. Though the scientific gaps it will fill will be minimal, the project's true value lies in its ability to draw in the user and alter his or her perspectives on the nature of systems and sustainability.

1.3 Type of research

Use-inspired basic research, to pursue fundamental understanding but motivated by a question of use (Pasteur's work on biologic bases of fermentation and disease)

2 Background and review of current literature and research

In order to prepare myself for the implementation of system dynamics modeling in NetLogo, I read the System Dynamics Guide and other sections from the NetLogo 4.0.3 User Manual, consulted the NetLogo dictionary, and read through a guide to Individual (Agent) ? Based Modeling with NetLogo: A Predator-Prey Example which, though it does not relate to system dynamics per se was still useful in increasing my familiarity with and knowledge of NetLogo. I read "System Dynamics Modelling in Supply Chain Management," "?Evaluating Strategies to Improve Railroad Performance– A System Dynamics Approach,? and "System Dynamics and Agent-Based Simulations for Workforce Climate" from the ACM Digital Library. I have also consulted an article called ?The Tragedy of the Sahel,? which uses system dynamics to show the instability of the Sahel desert system. I used this for a paradigm of a basic ecosystem to model, and it eventually inspired me to choose system sustainability as a topic. For reference and facts, some of which I included in the parameters of my model, I consulted the CIA World Factbook's page on Kenya.

3 Procedures and Methodology

The basis of the project is to establish a relationship between food and population dependent on several factors, e.g. food spoiling and available workforce. As the project progresses, complexity will increase. For example, a disease like AIDS might become a factor, or a bad crop might poison a portion of the population. My current plan calls for the addition of a third primary factor- weather. Natural disasters would occur semi-randomly; seasonal patterns might or might not be included. Although they would be certainly increase model complexity, their usefulness is dubious- since dt currently represents 1 year, the weather patterns within that year, insofar as they occur with dependable regularity, are essentially averaged into the year as a whole. Testing and research must be conducted as progress occurs. It would be useless to research something now, only to realize that it cannot yet be implemented. It is extremely important to test the model thoroughly after each addition to make sure that it functions as expected; testing the final project would essentially be useless, since the degree of complexity prohibits the understanding of its components unless they are thoroughly tested when they are first added. Resources that may provide useful include the NetLogo dictionary, the Global Change Labs (http://www.globalchange.umich.edu/globalchange1/current/labs/), and the Tabonuco Yagrumo model in the NetLogo Models Library, as well as other resources yet unforeseen. NetLogo is the only necessary programming software.

Visuals will be provided by the display functions in my NetLogo interface, which I have set to display a graph of population and food over time, as well as monitors reporting the values of population, food, and food per capita. The model itself serves as a visual aid as well; instead of having to pore over code, one must in must cases simply look at the model diagram to determine relationships. The input for the visual displays comes from within NetLogo; I have set the graph to take the stock values and display them.

The program performance must be tested after each new major addition to ensure that the system continues to function in a reasonable manner, as described above. Methods of testing include checking program data against real data from the CIA World Factbook, examining data for unanticipated aberrations, and checking the data trend against trends from similar models. For example, upon adding the famine functionality, I checked the trend against data from generic models with periodic perturbations and found that these generic trends supported the famine trend; therefore it was reasonable. As previously stated, I can perform specific structural and functional testing to examine the effects of new additions; sometimes, this may require other components to be disabled for simplification's sake. A large part of this functional testing would be dynamic testing, in which many different combinations of widely varying values for different parameters would be used to test functionality. Process modeling would be useless for trend comparison, but the use of mathematical relationships would probably not extend beyond graph comparisons.

This model must operate within the range of system dynamics insofar as is possible, and any non-system dynamics code segments must serve the purpose of the model without corrupting its nature. For example, the famine code is a p0ermissible exception because it is a key portion of the program, is not codeable within the NetLogo system dynamics interface, and does not corrupt the system dynamics template. However, the relationships between components may not be defined outside of the system dynamics portion of the model, i.e. all interaction must be accomplished with system dynamics tools. The main specification is that as little code as possible is situated in the Procedures tab of the main NetLogo interface and as much as possible in the system dynamics interface, which compiles code directly from the model diagram. To use outside code segments instead of stocks and flows would effectively negate the use of system dynamics in the first place. As for the program itself, it must run in a reasonable manner, as explained above. You could describe particular algorithms you'll be using and learning about.

4 Expected Results

I expect a reasonably sustainable simulation of the system over a considerable length of time; it may prove impossible to create infinite sustainability in NetLogo, given various mathematical inaccuracies. The sustainabilty would be dependent on the parameters, some of which are user defined; thus there are a wide variety of outcomes available, but it is the ability of the program to simulate a reasonable degree of sustainability which will be regarded as a success. The user defined aspects allow for some interaction; the user will have the power to experiment with sliders in the NetLogo interface, which will display a graph and monitors for food and population, giving the user the results of the model under the parameters he or she has just defined.

This model will hopefully provide an understandable, interactive example for next year's seniors and anyone else interested in system dynamics. As the awareness of the need for sustainability grows, interest in the results of the model will hopefully grow as well, and possibly influence next year's seniors to do other projects in the field.