A Cellular Automata Approach to Population Modeling

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Abstract

This project provides an agent-based model of population growth and change using a 2D cellular automata algorithm to predict behavior. The purpose of this project is to demonstrate how the behavior of a group is dependent on the interactions between individual group members, and to show that a cellular automata approach is valid in modling ecosystem behavior. It will model the effect of various influential factors on populations in an ecosystem and use graphs to show the results of changes in these factors.

Keywords: cellular automata, population modeling, 2D Life, agent-based modeling

1 Introduction

1.1 Cellular automata

Cellular automata (CA) exist as "cells" on a grid, wherein the behavior of each cell is determined by the states of its neighboring cells. In a 2D setup, a cell's behavior is dependent on the states of its eight neighboring cells.

1.2 Life

The "Life" collection of automata rules is based on the idea that survival of individuals in a population requires an adequate number of neighbors; that an individual can die due either to loneliness or overcrowding, and that an individual is only born when a "family" of individuals is already present. In Life models, the appearance of the grid changes at the end of each turn. The best Life models use rules which create lifelike behavior.

1.3 Purpose

The purpose of this project is to model the behavior of a population using a cellular automata approach as well as to demonstrate that cellular automata can be used in population modeling. The model will observe the affects of various influential factors on populations, such as initial population density, food and water availability, climate conditions, and predation.

For this model, the rule 14/3 was chosen because it causes cells to grow and move in a pattern resembling the spread of a species; cells begin localized and become more widespread. The use of the 14/3 rule suggests two types of individuals: "antisocial" (survives with 1 neighbor) and "social" (survives with 4 neighbors). This adds a degree of complexity to the model.

2 Background

2.1 CA Modeling

The field of cellular automata modeling is relatively new to computer science. Some work is being done to determine the usefulness of cellular automata in modeling the growth of cities, the spread of a rumor, the spread of an invasive species[1], and the spread and suppression of forest fires[2]. Cellular automata are useful in modeling because they describe the behavior of groups based on the interactions of individuals, which can produce surprising, realistic, and unique results.

2.2 NetLogo

The language used in this project is NetLogo, an extension of the Java language, created by Uri Wilensky. Specifically, this project is written in NetLogo 4.0.3. In addition to the ability to view the interactions of cells in "real time" in NetLogo's graphics window, NetLogo also provides charts and graphs. By observing both the behavior of individual cells in the graphics window and the changes in population and population density as shown by graphs and charts, the project's performance can be verified and results can be observed.

3 Development

3.1 First Quarter

Currently, the program correctly runs the cellular automata rule 14/3 (live cells with 1 or 4 neighbors survive the turn, dead cells with exactly 3 neighbors are born in the next turn) and allows the user to select the initial population density. It also graphs the percentage of live versus dead cells and provides population counts.

In test runs, the percentage and population of live cells are monitored. Variations occur due to the introduced variable of initial population density and the individual behavior of cells, which changes based on the random placement of cells on the grid. The nature of cellular modeling produces slightly different results with each run.

3.2 Further Development

Other factors to population growth, such as food/water availability, climate, and potential other populations which interact with the current populations will be added. NetLogo's agent-based modeling could be useful in terms of creating a predator/prey situation. Graphs will be used to represent output. Success or failure may be validated using other NetLogo population models or comparison to real life data.

Ideally, this project would expand to provide a model for an ecosystem with environmental factors and predation. The overall goals of this project would be to predict behavior of populations in an ecosystem, and to show that cellular automata models are applicable to such a situation.

4 Results and Discussion

4.1 Results

The program correctly runs the cellular automata rule 14/3 (live cells with 1 or 4 neighbors survive the turn, dead cells with exactly 3 neighbors are born in the next turn) and allows the user to select the initial population density. It also graphs the percentage of live versus dead cells and provides population counts. Initial densities which are too low or too high result in small, isolated groups of individuals; the ideal initial density (shown above), in which the population grows more or less steadily outward, is about 44.5 percent.

4.2 Discussion and Conclusion

This project aims to model the behavior of a population based on the interactions between individuals using a cellular automata approach, in which the state of each individual at the end of a turn or generation depends on the states of its neighbors. By using the 14/3 rule, it creates a population which, under ideal conditions, grows and expands outward. This behavior realistically imitates the growth of a population of organisms. When additional factors are added, this project should demonstrate that cellular automata are valid for use in modeling the behavior of populations.

References

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