Project 3: Modelling

CS 423/523: Complex Adaptive Systems
Assigned March. 21th
Due: April 14th, 6:00pm Mountain Time
Version: 1.4 updated on April 4, 2017

1 Change Log

Version 1.1 (3-22-17):

- Clarified that model details not specified in this document are to be decided upon by the teams.
- Specified the initial state of the model (all cells are empty).
- Specified that for the two species model each species should evolve separate values for p.

Version 1.2 (3-24-17):

- Clarified the longevity measure.
- Specified the initial state of the model (all cells are empty).
- Specified that for the two species model each species should evolve separate values for p.

Version 1.3 (3-27-17):

- Biomass means the average biomass over the CA lifetime.
- Finding the value p_m that maximises the biomass and longevity means finding the values (potentially 2 values) of p_m that maximise each.
- The GA for this project does not need to use cross-over, islands, or any of the other techniques from the previous project. The 1D landscape may not require any of these to solve.

Version 1.4 (4-4-17):

- Changed the due date.
- Plotting the relationship between longevity and biomass with the corresponding growth rate, p, makes plotting the fitness landscape redundant. You do not need to do both.
- Depending on when you check for the forest being empty in the update cycle, it may be impossible for the forest to ever be empty is there is at least one firefighter. You may count trees that are on fire, even when extinguished as empty for that time step if it makes your model more interesting.

- I have removed the restriction that you use p_m for the firefighter analysis. You may use any value of p, but support your choice in the paper. For example, you may choose to use a value of p that is actually a local maxima in the landscape rather than the global maxima because the behaviour is more interesting.

2 Introduction

Create an agent-based, 2D cellular-automata model of forest growth in the presence of lightning. Investigate the effect of multiple tree species and fire-fighters on the dynamics of forest growth. Produce plots showing the relationships between forest biomass, forest longevity, the evolved growth rate, and the amount of fire-suppression. Discuss your results in terms of phase transitions and critical values (if there are any, if there are no critical points that is OK).

2.1 The Model

The model consists of a 2D lattice of cells. Each cell can be in one of three states: fire, tree, empty. During each time period barren cells grow a tree with probability p. Cells that already contain a tree are unchanged. For each cell there is a independent probability, f, that a lightning strike will hit the cell. If there is a tree in the cell and lightning strikes, the cell changes to the "fire" state. Cells adjacent (using a Moore neighbourhood) to a cell that is in the fire state also enter the fire state. Any cells in the fire state transition to the barren state. In the presence of n fire-fighters, n randomly chosen cells in the fire state, transition to the tree state. After you have evolved your forest fire model examine the effect of fire-fighters. Do not include fire-fighters in your GA.

For the two species model each species will be evolved by separate genetic algorithms (GAs). Each species will have its own separately evolving p_m. For the multiple species version the possible cell states are: empty, fire, tree species 1, tree species 2.

The initial state of the model is for all cells to be empty.

Be able to visualise your model as a 2D grid. Use greens for the species of tree, orange for cells that are on fire, and black or white for the background. Show cells that were just extinguished by fire fighters in blue.

Longevity is defined to be the time till all cells are empty. Note that the forest will repopulate but that you should stop your longevity analysis when the forest is completely depleted.

In summary:

- A burning cell turns into an empty cell
- A burning cell causes all adjacent cells containing a tree to ignite.
- Due to lightning, trees ignites with probability f even if no neighbour is burning

- An empty space fills with a tree with probability p
- Given k fire-fighters they extinguish k randomly chosen burning trees per time step. Extinguished trees are not replaced by empty space as other burned trees are.

Lightning strikes should be random and uniformly distributed across the set of trees. Cap your longevity and biomass fitness evaluations at 5,000 time-steps The 2D grid is 250 by 250. Increment your fire-fighter count from 0 to 1000 in increments of 50. Use a Moore neighbourhood for your adjacency calculations.

Fix your lightning strike probability at 1/1000 per cell per time step.

You can find numerous examples of the forest fire model written in different languages here: http://rosettacode.org/wiki/Forest_fire

Any details of the model that have not been specified here can be filled in by your team. For example, the border conditions of the 2D arena are unspecified. You might have the borders wrap around like the 1D CAs we have looked at, or your team might choose to have a hard border. The cell update scheme is unspecified, there are a variety of approaches but the simplest is to iterate through all the cells in order updating as you go. Alternatively you could update all the cells in random order each time step.

3 The Paper

Organise your paper using the same format as with the previous projects.

Examine the following questions in the absence of fire-fighters using a GA to evolve p_m.

- Create plots that show the relationship between tree biomass and longevity.
- Using a GA, identify the growth rate, p_m, that maximises biomass and longevity.
- Plot the fitness landscape of growth-rate vs longevity and growth-rate vs biomass (unless already shows in the biomass vs longevity plot above).
- Plot the effect of introducing another tree species on the evolved growth rates, do the tree species evolve the same growth rate as the single-tree model and as each the other tree species? Do the growth-rates for the two species influence each other?

Use a p value of your choosing for your analysis. Add fire-fighters to your model and address the following:

- Create plots that show the relationship between the number of fire-fighters, tree biomass and longevity.
- Are there any phase transitions caused by the number of fire-fighters in the biomass and longevity of the forest - or is the relationship smooth?

Discuss the relationship between the microstates and macrostates of the model.

4 Author Contributions

Include a contributions statement before the introduction section. The contributions may fall into three categories: analysis, code, and writing. For example your author contribution statement might look like this:

\section*{Author contributions}
J. C. wrote the code that generated Figs. 1, 3, and 5. V. W. wrote the code that generated Fig. 4. Both authors wrote the code that generated Figs. 6 and 7. J.C. wrote sections 1 though subsection 2.3, and section 3.6 of the paper. V. W. wrote subsection 2.4 through 3.5. The authors wrote sections 4 and 5 together. J. C. performed stability analysis for the map and V.W. identified the fixed points for the flow.

5 Notes

Format your paper as described in the project section of the web syllabus. Use the ACM paper template provided. Organise the paper into the following sections:

1. Abstract
2. Introduction
3. Related Work
4. Methods
5. Results
6. Conclusions
7. References

The paper may not exceed 5 single spaced pages including references.