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Peer Review

Review of: "Modeling and Simulating Agent-Based City Migration Using Conway's Game of Life"

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Modeling and Simulating Agent-Based City Migration Using Conway's Game of Life

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Overview of the Review by J. Hank Rainwater (ORCID)

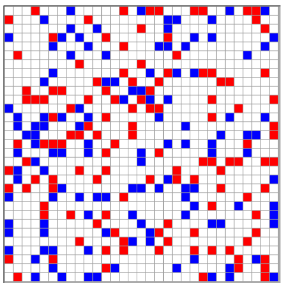
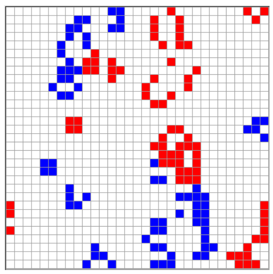
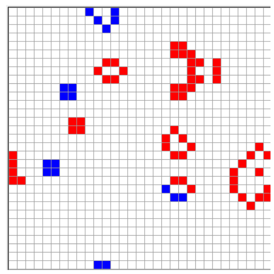
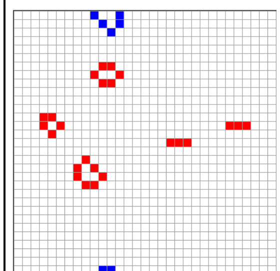
This manuscript is a novel usage of cellular automata (CA) applied to urban environments and shows the extent to which computational modeling can be applied to diverse knowledge domains. The model of adjacent population centers with varying densities is appropriate for the GoL as it emphasizes local areas of change that lead to large-scale results.

The manuscript is not yet ready for publication, as seen by my comments and suggestions identified by the headings in the manuscript.

Introduction

You refer to your model as an agent-based model (ABM), but CA, like Conway's Game of Life (GoL), is technically not agent-based since the state (alive or dead) of a cell on the grid is governed by the state transition algorithm (STA) you describe later in your paper. Therefore, a cell has no agency in the technical sense. See this helpful article about both CA and ABM for complexity research in urban systems: Urban Planning.

I believe a reader would benefit from a reference to Schelling's work on segregation that can be simulated in the GoL; see Using Gamified Experiments to Tame Complexity: the case of the Schelling Model of Segregation as an example of this approach. By using active cells that are either red or blue, the GoL rules lead to segregation over time, as shown below, where the color of a newly born cell is determined by the majority color of its 3 neighbors.

Initial random configuration (equal number of red and blue cells)	25 Generations	50 Generations	Static End State – 332 Generations
			

An appropriate place for this reference might be on page 2, where you cite the work by Del Faro-Odi. While segregation isn't identical to the migration you are modeling, there are some strong similarities between the two methods.

Experimental Setup

Conway's Game of Life (GoL)

In your narrative, you sometimes switch from 'grid' to 'board', and I would stick with 'grid' since this is a common city-like term. You need to mention that each 'timestep' (better named as a 'generation', in my opinion) uses the STA synchronously during evolution.

Pilot Experiment for Validating GoL Implementation

You use the term 'convergence of the simulation', by which I assume you mean that the density of the initial configuration of cells has reached an asymptotic end state. The term 'convergence' is somewhat unusual in describing a GoL end state since the state can be empty, periodic, static, or still

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dynamic if you restrict the number of generations to a specific value such as 1,000 in your 10X10 trials. Don't you want each evolution to be completed even if the number of generations exceeds 1,000? If not, you need to explain why you choose this limit.

I don't understand the sentence 'To determine whether a cell in the grid starts off as alive or dead, we took as user-input a probability, which was used to randomly determine the initial status of the cell'. Do you mean that cells are randomly set to alive or dead by a human action or a random number generator from code that sets the cell values? Also, an initial cell state is either 1 or 0 from a probability value perspective, while the entire grid can be identified as having a density percentage corresponding to the number of cells in state '1', e.g., 50% would mean half the cells are in an alive state. I am being a bit picky here with terminology, so you should go with what you feel is most accurate.

The 15 trials described on page 4 will be viewed as inadequate to draw any meaningful statistical conclusions regarding convergence since the number of generations for random soups of the same density and grid size can vary widely, i.e., the standard deviation of the trials will be quite large. In addition, you've not stated if the grid is a torus or a bound configuration: this makes a difference in how an initial configuration will evolve. For example, a 10X10 random configuration of 50% density (live cells) like this ...

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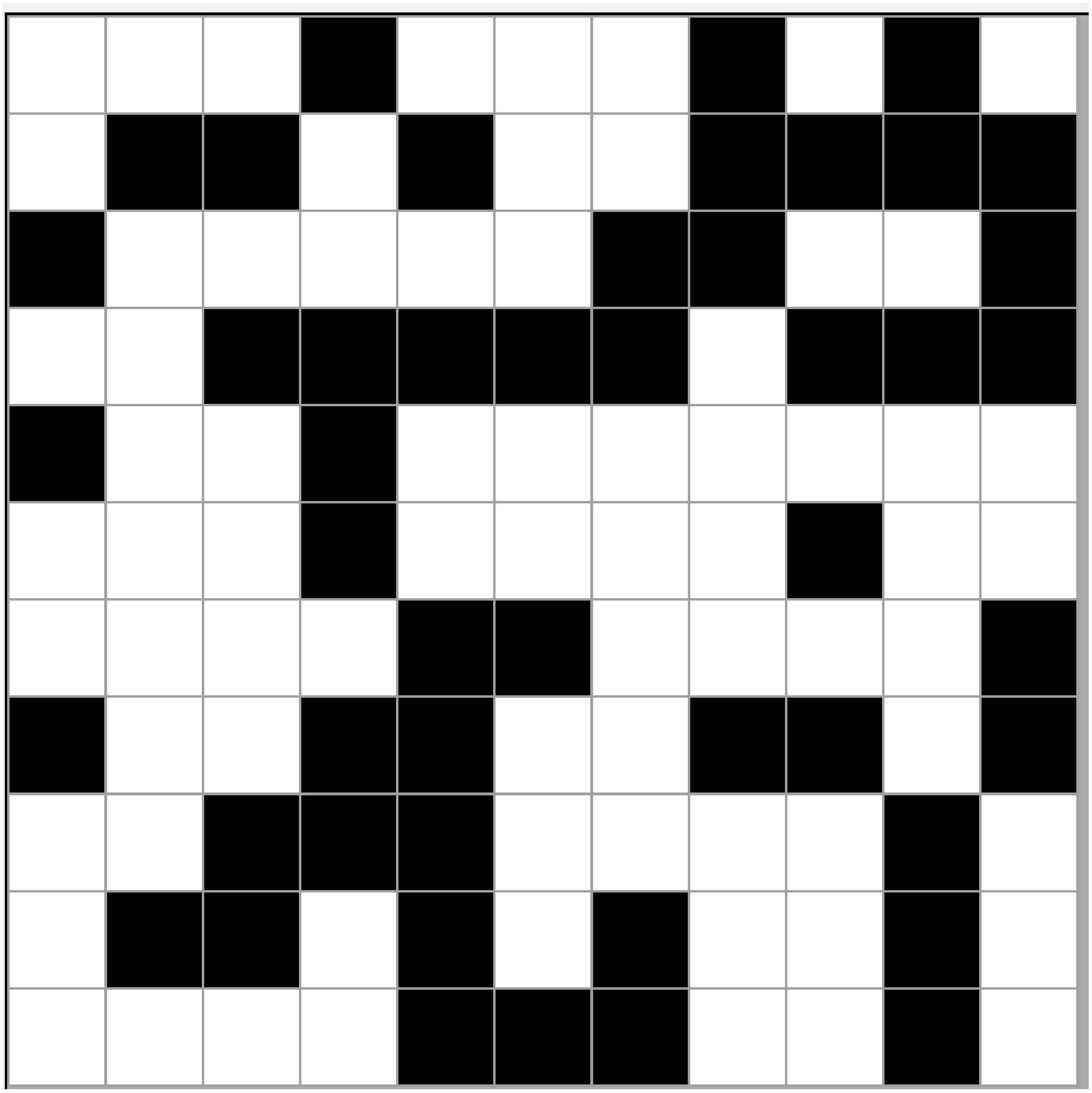

… becomes empty on a bound grid at 32 generations, but on a toroidal grid, it is empty at 171 generations.

In Figure 2 on page 5, where you describe the 100X100 grid with 50% density (0.5 probability), you might describe the effect as the natural power-law behavior of the GoL noted by many researchers that results from the change in rate of birth and death of cells during evolution. For example, Pena & Sayama, 2021 define complexity in terms of conditional entropy for the GoL STA, reporting that the “rule’s inherent complexity is independent of grid size”, and “maintains a level of balance between order and randomness”.

Ring Agent-Based City Migration Model

An example picture of a populated ring-style grid in the initial state prior to evolution would be helpful in this section; it took me a while to imagine what this would look like. Also, showing the migration at various intervals of evolution (like the segregation model I showed above) would be helpful.

It isn't clear from the narrative in the second paragraph of this section that all the concentric rings exist on the same grid and that each ring can create changes that affect the entire grid during evolution. I assume that it is the case when you say 'a grid within a grid' that you do mean a single grid segmented into concentric rings. Again, a figure showing this configuration is needed.

Results and Discussion

Is the term '110 X 110 inner grid model' the same as 'grid within a grid' described in the previous section? I assume it is, and you should stick with the same terminology.

The data presented in this section is based on only running the grid for 1,000 generations according to Figure 3, and you do mention 'outliers' that I assume are configurations that did not fully result in a static end state by 1,000 generations. As mentioned above, you need to justify your limit of 1,000 generations. Also, you don't mention how many times the experiment is run with different random configurations in each ring while keeping the density values for each of the rings the same. The narrative makes me think that only a single experiment was performed: many thousands of experiments should be run and an average taken of how each ring experienced migration as well as the entire grid.

When you say that the 'probability values of 0.4 and 0.2 are the two most frequent in the entire grid', do you mean that there are more rings with these values than the other rings? This isn't clear.

I found Figure 3 to be a valid presentation method but would have liked to see each of the rings as separate graphs alongside the existing charts. Figure 4 again makes it appear that only a single experiment was run. Also, the y-axis of Figure 4 is 'percentage of alives,' but I think you mean probability in this case.

Figure 5 (a) would be enhanced if the initial configuration prior to evolution was shown alongside incremental generations prior to reaching the end state. I would exclude the 10X10 grid from the

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results since a grid this small doesn't display the dynamics of complex interactions as well as the larger grid.

On page 8, the paragraph following Figure 5 proves the hypothesis of the model as stated in the second paragraph of page 2 – this is good; you've started with an idea and shown that it's valid.

Conclusions and Future Work

Here you suggest advancing from a CA model to an ABM where an agent has a defined behavior. I think this future work is worth pursuing and would show the distinction between the two modeling approaches that I mention in the beginning of my comments.

Declarations

Potential competing interests: No potential competing interests to declare.