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Modeling the Human Diaspora out of Africa with Cellular Automata

Abstract

Cellular automata can be used model complex interactions between agents and their environments using relatively simple rules. The *recent single-origin hypothesis*, or the "out-of-Africa" theory, is the predominately accepted model for describing how early proto-humans initially migrated throughout the world. In this paper, I summarize my simulation of how early human beings migrated out of modern day Ethiopia and inhabited the rest of the world.

Methods

In the simulation, human beings are assigned to populations. A population can exist on any *habitable* 16x16 px tile on the world map. Populations grow according to a function dependent on the hospitality of the tile that the population resides on. For instance, tiles on the coast are very hospitable while tiles in the Sahara desert are essentially inhospitable. Tiles which contain more than 50% water are not habitable and have a hospitality score of zero.

A number of factors are used to determine the hospitality of a given tile. These factors (eg. availability of water, temperature, fertile land) are discerned by mapping the pixel colors in a tile to the known colors of different features (eg. water, desert, forest). Moreover, the quantity of factors are multiplied by constants and summed together to determine a tile's hospitality score.

	Water	Desert	Forest	Cold
Multiplier	+30	+0.03	+10	variable, distance from equator
Approximate Color				N/A

Once a population become mature (after 50 ticks in the same place), it will send out explorers. These explorers go to a random cell in the vicinity of their population and note the tile with the highest hospitality score. If the hospitality score of the newly found tile is higher than that of the population (plus or minus some random number, to account for unknown environmental factors), some proportion of the population will relocate to the new square. During the relocation, some proportion of the travelers will die according to the hospitality of the tiles that are traversed. Once the travelers have settled, the cycle continues after 50 more ticks.

Experiment

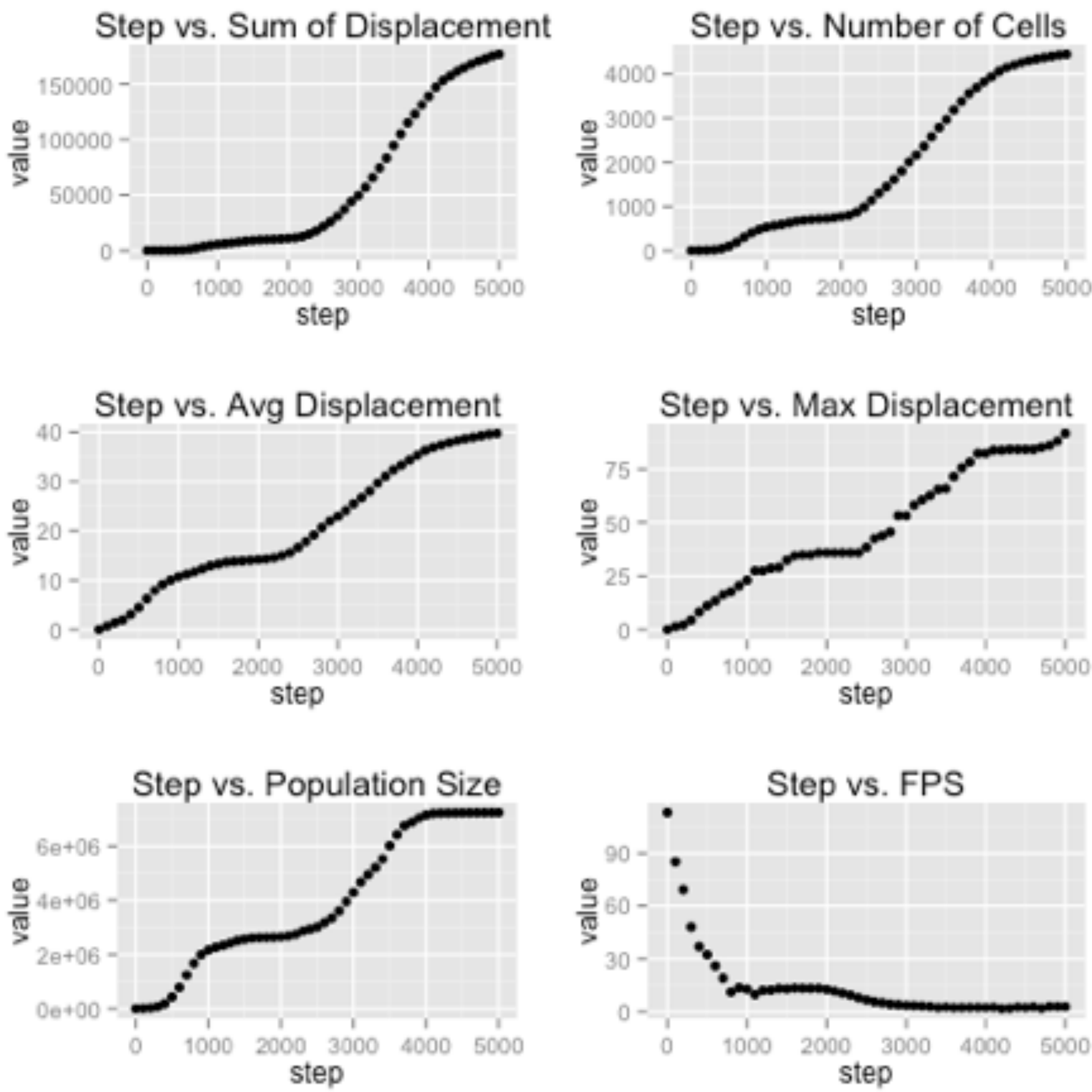
A population of one hundred humans is placed in modern day Ethiopia. Over time, we can observe quantitatively and qualitatively how the population spreads and grows. Quantitative measurements include average distance from the origin, max distance from the origin, etc. Qualitative measurements include observations about where the population migrates to.

It is interesting to note that in most simulations, the populations travel through the Cairo river valley into modern-day Saudi Arabia. Further, they go on to inhabit most of India, Eastern China, and Western Europe. Due to the mechanics of the map, it is impossible for the populations to cross the English channel.

Finally, it is possible for the populations to traverse the Bering Strait into North America. This has been confirmed through other experiments, but remains to be seen when testing the “out-of-Africa” hypothesis. This is due to the frame rate of the simulation approaching 0 FPS after most of Africa, Europe, and Asia are inhabited.

Analysis

A number of metrics were recorded to quantitatively evaluate the efficacy of this experiment.



We can see that population size and displacement increases with time! The “Step vs. Sum of Displacement” graph is interesting — the inflection point is due to human beings crossing through Egypt and into Southeast Asia around 2,500 steps into the simulation. Prior to this, they were confined to Africa and did not have much room to spread out.

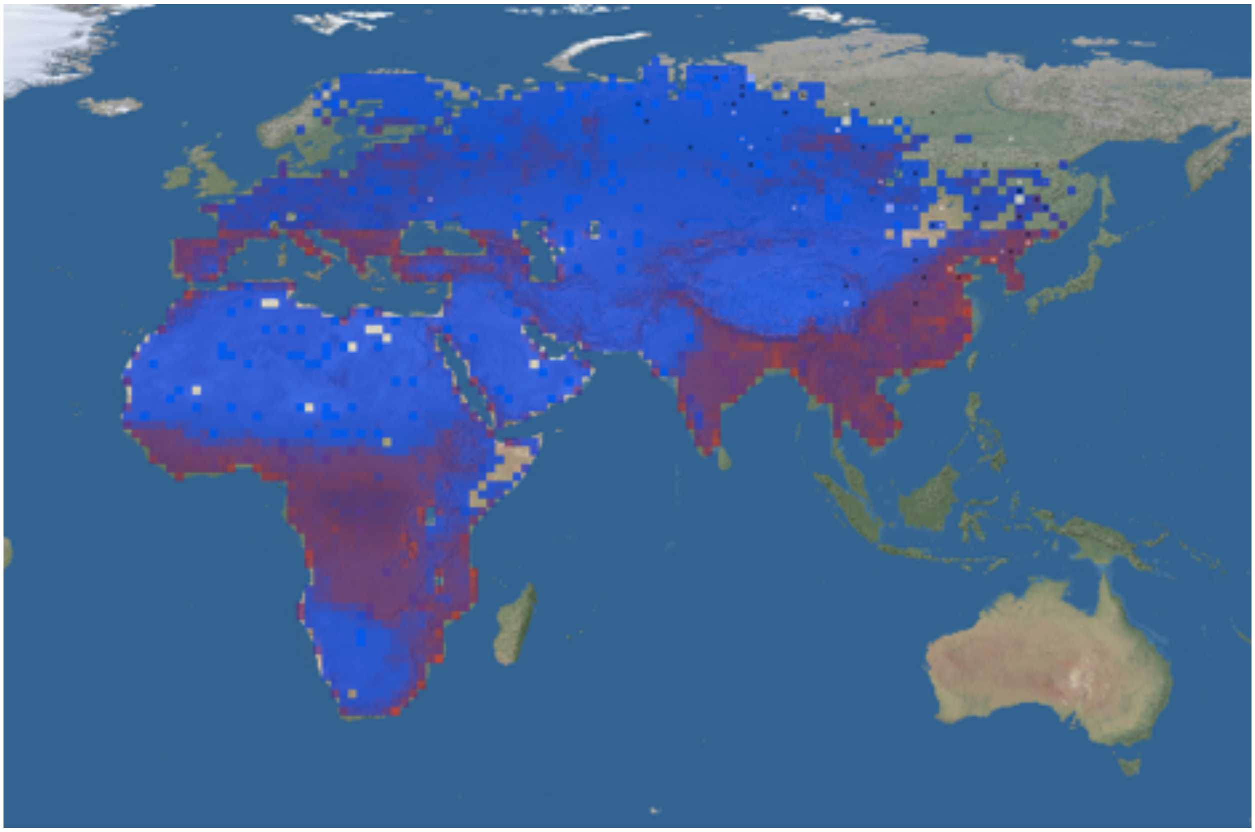
This notion is corroborated by the “Step vs. Population Size” graph. The population grows exponentially from its initial population in Ethiopia until about 1,000 steps into the simulation. At this point, the fertile areas of Africa have been inhabited. Population growth now slows until human beings cross into Southeast Asia at around the 2,500 step mark.

Discussion

In my proposal, I intended to measure population displacement, population size, time to run the simulation, and memory consumed. Further, I intended to measure these variables as a function of different environmental factors in the simulation. Due to time and sanity constraints, I only collected data for one experiment up to 5,000 steps. It would be incredibly interesting to see how something like an ice age would affect the population growth and migration. This is considered a source of future work.

This simulation indicates that simple rational agents acting to maximize their expected values can indeed spread out across the world! By far, the most interesting outcome of this experiment is the observation that some populations crossed the Red Sea into Saudi Arabia, despite my thinking that such a traversal would be impossible. Apparently, the Red Sea had a much lower sea level roughly 125,000 years ago, and this likely actually occurred! Too cool, man.

Appendix



Population distribution after 5,000 steps of the experiment. Red areas are densely populated, blue areas are sparsely populated. Note the especially high densities around the Mediterranean Sea, India, Eastern China, and South Africa. North America is not shown because human beings failed to cross the Bering Strait in this simulation.