Reading Critique

Cellular Automata and Lattice Gases

This paper presents the subject of lattice gases, or more generally, cellular automata to reduce both microscopic and macroscopic descriptions. The challenge of gas is that on the macroscopic level, it can be described by the continuous distribution of pressure, temperature and velocity. However, the model breaks down for short length scales and individual molecules need also to be tracked on a microscopic level. The question is if it’s possible to reconcile the microscopic and macroscopic levels without having to pass through a continuum description.

And the answer is a resounding yes due to the cellular automata. The most important elements of the automaton are the set of connected sites, states allowed on the sites, and rule for update. The connection of the sites through links enables modeling of continuous events, allowing the macroscopic level analysis. Meanwhile, the state (direction) of individual site saves behavior of specific particles, enabling modeling of the microscopic level. This idea by Ulam and von Neumann proves that two very different aspects of interaction can be captured on one model.

For lattice gases, there are two examples that were given in the paper. One was the FHP rule which had for every site, there were 6 links equally spaced around the site. The update rule follows 2 simple procedures. First, collisions of particles are handled with conservation of momentum considered. Secondly, particles that pass/transport through are moved one unit in the direction that it was pointing. The neat part was that there are only a finite amount of possibilities for updates, so that essentially the update is simply finding the states in a lookup table. The other example given was the HPP which is basically the same as the FHP except it uses 4 links on each site instead of 6. This however changes the possibilities significantly as there is one possible direction after scattering. And, even after that simplification, it still models the lattice structure accurately.

As an automaton, it is universal. Meaning, the cellular automata can compute anything. This was surprisingly, considering it essentially has only one instruction. However, it makes sense. The paper provides evidence of this by describing how the states can represent an AND or NOT operation. Colliding generates the AND while transporting generates the NOT. That is sufficient to build up all other logic. Also, after seeing the differential equation calculated out, I realized that the automata actually simplify the mathematical models by creating relationship through the links. Although there are some criticisms, it’s a definite start to solve the initial problem of reconciling the microscopic and macroscopic levels.