Proposal to Search for Robustness in Conway's Game of Life

David Larson

December 11, 2001

1 Conway's Game of Life

1.1 Rules of the Game

The game of "life" was invented by John Conway in the 1960's [1] and publicized by Martin Gardner in Scientific American in 1970.[2] The rules of the game are simple. It is played on an infinite planar grid of squares. Each square is called a cell, and at every discrete time step it is either alive or dead. Given some initial configuration, the cells live or die in the next iteration according to how many of their eight closest neighbors are also alive:

1. "A dead cell with exactly three live neighbors becomes a live cell (birth)."[3]
2. "A live cell with two or three live neighbors stays alive (survival)."[3]
3. "In all other cases, a cell dies or remains dead (overcrowding or loneliness)."[3]

1.2 How Life Behaves

A great deal of work has been done to study the patterns that life creates. In fact, there is a surprisingly large amount of material on the web. See [3] for a good introduction and [4] for a list of web pages with cell patterns. Several of the patterns which have been investigated most closely are: patterns that don't change in a given time step, patterns with period two, gliders of live cells that move as a group across regions of all dead cells, oscillators that return to their original configuration after n time steps, and oscillators that produce a stream of gliders–glider guns.

One can look a random initial configuration with live cell densities of roughly 30% in a rectangle (and dead cells everywhere else) easily with the program Life32.[5] See figure 1. On the order of 1000 iterations later, the cells settle down into groups of gliders leaving the rectangle, and static patterns, and period 2 patterns. This debris left over from the random configuration is shown in figure 2. This state (now only 3% or 4% live cells) is *much* more common than a state with a more intricate glider gun.

When viewing the rapid passing of time in a life animation, one can clearly distinguish the chaotically changing regions from the static or simply oscillating ones. Even a computer can find the cells which have not been static or oscillating with period 2. If one is to find artificial life in a life simulation[6], it must be in these active regions, and not in the more static ones.

2 Proposal

2.1 Search for Robustness

Two types of errors could come into a life simulation: the rules of life could sometimes be executed improperly, or gliders could randomly come from a distance to interact with the simulation. One screen saver[7] simulates the first type of error. The second type of error could be easier to overcome, since artificial life could guard against gliders with a barricade of a pattern of glider-stopping cells (if such a pattern could be found).

While much work has gone into finding detailed patterns in life systems, much less work has gone into finding robust patterns. That could be because no one thought of it, or because it is very hard to find robust patterns. Even in the cell patterns left behind after time has removed all but period-2 and static patterns, a single intelligently placed living cell can start a chaotic growth that takes on the order of 100 iterations to die out.

The only cell pattern that approaches robustness (in my limited searching) is the "eater."[6] It has the property of being able to kill a simple glider that approaches it and remain unchanged. See figure 3. Unfortunately, the glider must approach it from a certain direction and at a certain angle, or the eater will not function properly.

Two general cell patterns would be very interesting to find. The first is the previously mentioned wall which would guard against various gliders. A second pattern would behave like an icebreaker. It would be able to move through regions with random static patterns and remain relatively unaffected. In all probability, any pattern that behaves in this second manner would be quite difficult to find.

2.2 A Note on the Software

The obvious method of writing code to simulate the game of life is to write two loops that iterate over the entire 2-D space of cells that the program will use. The neighbors of each cell are counted, and the future of the cell determined. This method works, of course, and it also gives the programmer a good understanding of the simulation.

However, software is available on the web that is orders of magnitude more efficient. [5, 4] The details are somewhat esoteric, but by a combination of only looking at regions of space with live cells, and thoroughly understanding graphical windows programming, several programmers have written life simulations that run quite rapidly.

The user interface to Life32[5], one of several life programs, seems reasonably good. It would be useful for investigating some questions of robustness raised in this paper.

3 Conclusion

The search for robust patterns in the game of life seems like the next step in the search for artificial life. Berlekamp et. al. have already presented the idea of artificial life in Conway's game.[6]

Biology is all about understanding complex systems. Conway's game provides a very simple set of rules that can create complex patterns at much larger scales. Because of this, the game provides an excellent springboard for understanding our universe. Understanding how Conway's rules form complex patterns may be a first step to understanding how simple rules–like the laws of fluid flow–form complex structures in our universe.[3]

References

[1] Gary William Flake. *The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation.* MIT Press, Cambridge, Massachusetts, 1998.

[2] Martin Gardner. Mathematical games: The fantastic combinations of john conway's new solitaire game "life". http://hensel.lifepatterns.net/october1970.html, 1970. First published in Scientific American, 223 (October 1970): 120-123.

[3] Paul Callahan. Wonders of math – the game of life. http://www.math.com/students/wonders/life/life.html.

[4] Alan Hensel. Conway's game of life. http://hensel.lifepatterns.net/, 2001.

[5] Johan Bontes. Conway's game of life for microsoft windows. http://psoup.math.wisc.edu/Life32.html, April 1999.

[6] Elwyn R. Berlekamp, John H. Conway, and Richard K. Guy. *Winning Ways for Your Mathematical Plays*, volume 2. Academic Press, New York, first edition, 1982.

[7] Greatis life – conway's life screen saver with delphi sources. http://www.greatis.com/life.htm.

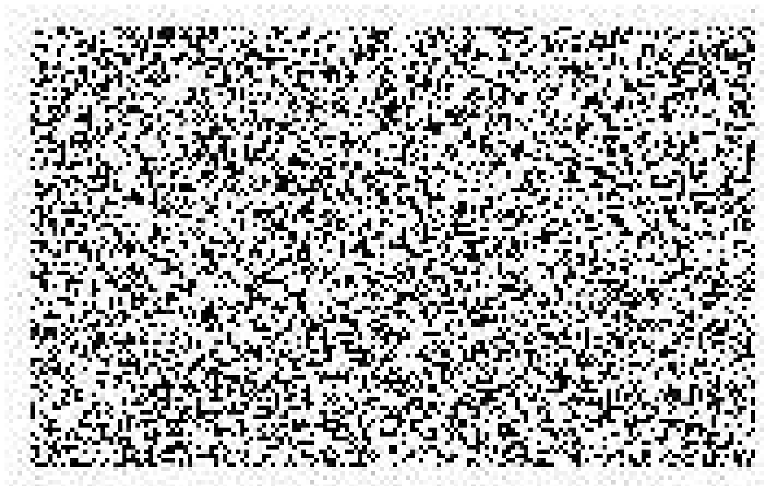

Figure 1: The initial random rectangular configuration of cells (black is alive).

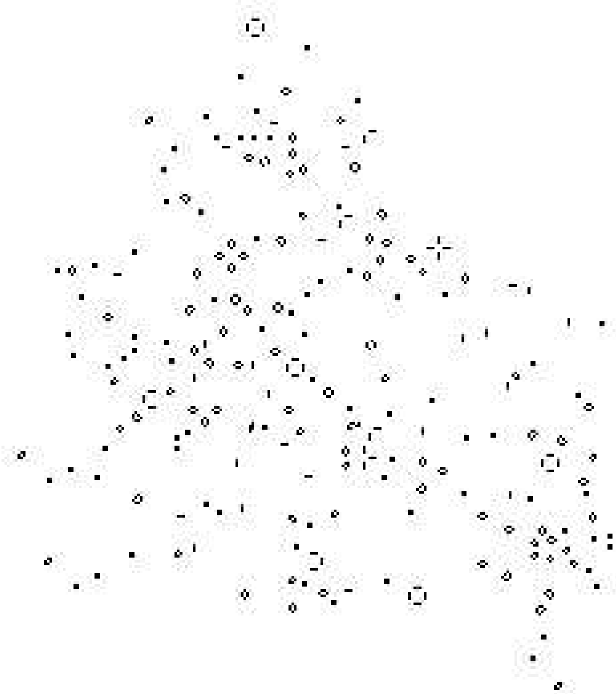

Figure 2: The static and period-2 aftermath of the previous configuration. The gliders are too far away to see.

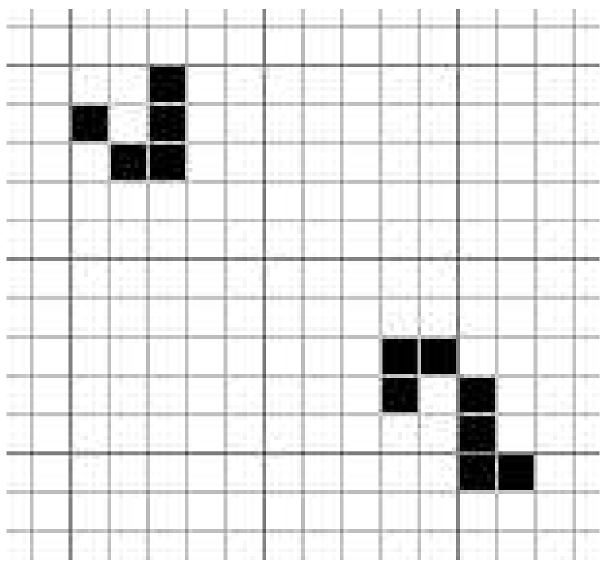

Figure 3: A glider, upper left, approaching an eater, lower right.