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Introduction

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Our interest in cellular automata started with reading Martin Gardner's Scientific American column about John Horton Conway's "Game of Life" published in the early 1970's. Both the popularity and the lore associated with this game increased rapidly, with the discovery of gliders, blinkers, glider guns, still lifes, oscillators of various periods, and so on. Initially no effort was made to program these artifacts, but characterizing the still lifes seemed like it could be a worthy project in crystallography.

With the advent of microcomputers and Cromemco's graphics board, Life became a favorite display program for video monitors and led to a revival of interest in the game and its evolution which managed to keep the screen in continual motion. Some while later we used it for exercises in a programming course which went by the name of Fortran III, which was devoted to computer graphics. An article in Reviews of Modern Physics described the results of Stephen Wolfram's experiments, wherein he systematically tried out all the possible one dimensional rules of evolution, classifying them into families and speculating as to their presumptive characteristics. It seemed to be an excellent program to incorporate into the computer graphics course.

Naturally all this activity called attention to John von Neumann's work in the late 1940's and early 1950's on cellular automata and his efforts to create a self-reproducing automaton. Although that was somewhat before the elucidation of the structure of DNA, it was definitely a part of the rampant speculation of the era concerning plausible mechanisms for biological reproduction. As constrasted with crystal growth, for example. Before long, his efforts were confronted with Moore's Garden of Eden Theorem, all of which defined the state of cellular automaton theory for a decade or more.

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Prof. Harold V. McIntosh working in the Research Institute for Advanced Studies, Baltimore, Maryland, USA, 1962.

Although a general automata theory continued to advance and might even be traced back to Charles Babbage's Analytic Engine, the growth of cellular automaton theory seems to have experienced three spurts of growth, with approximately fifteen years separating them from one another. The first was von Neumann's, the second Conway's, the third Wolfram's. Perhaps a fourth could be reckoned as containing Matthew Cook's completion of Wolfram's search for universality in the concise one-dimensional Rule 110, depending on the amount of new interest and research which it stimulates.

Against this background, the work on cellular automata at the Universidad Autonoma de Puebla and the Center for Advanced Studies at Mexico's National Polytechnic Institute might best be described chronologically, insofar as it paralleled developments elsewhere. The work was spread across course offerings, research activities, and student theses.

When the use of microcomputers was in its earliest stages and CP/M was the operating system, programs were written to calculate the space-time evolution diagrams, print them, but mostly to display them using the video controllers which were then available. One of the items available was a large Conrac color monitor, which was carried to local expositions for a couple of years. But other properties were also calculated, graphication of statistical data was begun, but especially the construction of graphs in the sense of graph theory with nodes and links connecting them.

Once IBM entered the microcomputer market and MSDOS displaced CP/M as the preferred operating system, all the LCA programs were renamed LCAU and revised to work in the new environment.

Amongst the artifacts discovered in Life were ripples, configurations in which all the cells in a row (or alternatively, a column or even a diagonal) were in the same state. In effect, one had a one dimensional automaton, which turned out to follow Wolfram's Rule 22. Working out cycle diagrams, which are the graphs of the evolution of strings of cells with cyclic boundary conditions, with the objective of encountering the possible classes of cyclic evolution, exhibited some regularities of composition which were noticed by Robert Wainwright. Noting similarities to shift register theory, whose cycles were described by diagrams invented by N. G. de Bruijn or I. J. Good, led to the discovery that one could compute the cycles having a given period, in contrast to getting those of a given length. Since then, the computation of both kinds of cycles has been a standard feature of the cellular automaton programs.

Since much of the analysis of cellular automata can be reduced to constructing and interpreting graphs, considerable effort was devoted to preparing an interactive program which could generate the necessary variety of graphs, and allow their editing either from the keyboard or by use of a mouse, once the latter became available.

The first applications of G'PH were to illustrate the results of such de Bruijn calculations as were feasible, namely still lifes, single generation shifts, two generation phoenix, and the half light speed gliders discovered by Dean Hickerson. The resultant diagrams matched his grammer rules. Unfortunately three generation artifacts require very much more computer power, so entities such as David Bell's one-third light speed gliders have not yet been reproduced. Considering that the three-generation Life rule has 49 cells in contrast to the two-generation rule's 25, giving de Bruijn diagrams with correspondingly more states, continuation seems unlikely.

In 1990 the NeXT computer became available, we managed to acquire one, and the next stage of program revision was undertaken – rewriting the LCAU programs in Objective C to run under the NeXTSTEP operating system, which was truly versatile and advanced. We are extremely reluctant to give it up, even though the company has gone out of business and still more recent operating systems are dominating the market.

Given the integrated circuit hardware available at the time, Tomaso Toffoli and Norman Margolis designed a video controller whose shift registers could be programmed to execute two-dimensional cellular automaton evolution. In those days the speed advantage with respect to CPU computation was great enough to exhibit cellular automaton evolution at the television refresh speed. One of their boards, whose software was written in FORTH, was marketed as CAM/PC. Preferring to have programs written in C, we wrote CAMEX (CAM/PC Exerciser) for the board we meanwhile had bought.

The CAM/PC was designed for two-dimensional cellular automata, but could be readily programmed to display the space-time evolution of one dimensional cellular automata. By using additional CPU memory, sections of the evolution of three-dimensional automata could also be displayed. Had we paid more attention to Wolfram's Rule 110 at that time, the existence of solitons would have been apparent, but we missed the opportuinty. On the other hand, the board was of great assistence in visualizing the operation of Jan Hemmingson's three-dimensional version of the Chaté-Manneville Rules

The Law of Large Numbers suggests that a large data set should have an average with a Gaussian distribution about that average with a certain variance. That would seem to imply that if a cellular automaton had a preferred density of states it could be found, Monte Carlo style, by averaging the results of evolution starting from a wide selection of initial configurations. By looking for fixed points an invariant density should appear. This expected convergence failed for some higher dimensional rules examined by Hugues Chaté and Paul Manneville; rather it converged to distinct values taken on cyclically in successive generations, or even drifted through separated values in a nearly cyclical manner. A first reaction was that one was seeing a mean field theory return map with an unstable fixed point but a stable cycle, but as an explanation it turned out to be not entirely adequate.

The discussion of universality in Rule 110 and the visual appearance of its graphical evolution as a lattice of triangles was reminiscent of Hao Wang's tiling problem. The logical question of the decidibility of AEA proposition in symbolic logic was converted into a tiling problem whose successful resolution resulted in tiling the plane with an assortment of mosaics. By laying down tiles whose matching rules followed the evolution of a Turing machine caught up in the halting problem, the futility of completing the mosaic could be foreseen, thereby resolving the underlying AEA construction. Actually, although the scheme was proposed by Hao Wang, there were some subtleties related to the existence of aperiodic tilings which were eventually resolved by Robert Berger in 1966.

Some modest reasoning confirmed the fact that Rule 110 evolution constituted a tiling for the lower semiplane, so it was reasonable to investigate the tiling as a dynamical system and see if it conformed to the Wang-Burger construction. At the very least, it was possible to reproduce some of Cook's results, such as limiting velocities for gliders and obligatory gaps between velocities.

The question of whether an automaton is reversible is a longstanding one which naturally carries over to cellular automata. Even earlier than that, reversibility was a concern in Hedlund's analysis of dynamical systems, but S. Amoroso and Y. N. Patt published the first explicit application to a cellular automaton in 1972. Their two results, the nonexistence of a path from the full set to the empty set in the subset diagram as a condition for surjectivity and the absence of cycles outside the diagonal of the pair diagram as a criterion for injectivity neatly capture Hedlund's much more abstract characterization.

With greater available computer power, it was possible to examine the lower order evolution rules looking for reversible rules. Due to equivalences, it is only necessary to check two-neighbor rules, which we have done up to 8h or so. At the same time another challange arose, to secure an accurate limit on the size of the neighborhood of the reversing rule. A good solution was obtained by Eugen Czeizler and Jarkko Kari, nicely interpretable by Lind and Marcus's process of state splitting and state amalgamation.

DISSERTATIONS SUPERVISED BY PROF. H. V. McINTOSH

PhD thesis

Title: Comportamiento colectivo no trivial en autómatas celulares
Date: March, 2007
Institute: CINVESTAV
Author: José Manuel Gómez Soto

Title: Procedimiento para producir comportamientos complejos en Regla 110
Date: October, 2006
Institute: CINVESTAV
Author: Genaro Juárez Martínez

Title: Máquina celular de computación basada en mosaicos regla 110
Date: February, 2005
Institute: CINVESTAV
Author: Abdiel Emilio Cáceres González

Title: Análisis Dinámico Topológico de los Autómatas Celulares Unidimensionales Reversibles
Date: March, 2002
Institute: CINVESTAV
Author: Juan Carlos Seck Tuoh Mora

MSc thesis

Title: Modelación de tránsito de autos utilizando autómatas celulares
Date: October, 2002
Institute: CINVESTAV
Author: René Rodríguez Zamora

Title: Teoría del Campo Promedio en Autómatas Celulares Similares a "The Game of Life"
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Author: Genaro Juárez Martínez

Title: Comportamiento Colectivo no-Trivial en Autómatas Celulares
Date: August, 2000
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Author: José Manuel Gómez Soto

Title: Caracterización del Comportamiento de los Autómatas Celulares Lineales Reversibles
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Institute: CINVESTAV
Author: Juan Carlos Seck Tuoh Mora

BSc thesis

Title: CAMEX, Un sistema para el manejo de la CAM-PC
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Institute: UNAM, FES Acatlán
Author: Victor Jiménez Arellano and Luciano de la Rosa Aguilar

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Date: March, 1998
Institute: UNAM, ENEP Acatlán
Author: Genaro Juárez Martínez

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Date: August, 1997
Institute: UNAM, ENEP Acatlán
Author: Juan Carlos Seck Tuoh Mora