

“Precursor-Rule”: Otro Autómata Celular binario en dos dimensiones candidato a ser Universal.

Encuentro Internacional de Matemáticas.
Barranquilla Colombia, Octubre 2016.

José Manuel Gómez Soto

Andrew Wuensche

October 25, 2016

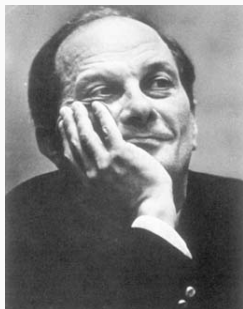
Unidad Académica de Matemáticas
Universidad Autónoma de Zacatecas
Zacatecas, Zac. México.

1. Máquinas que se autoreproducen.
2. El Juego de la Vida
3. Autómatas Celulares con el esquema Nacimiento-Sobrevivencia del Juego de la Vida
4. R-Rule
5. Búsqueda de AC con Computación Universal
6. Precursor-Rule
7. X-Rule

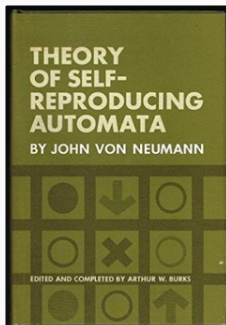
**Máquinas que se
autoreproducen.**

John von Neumann





Theory of self-reproducing automata



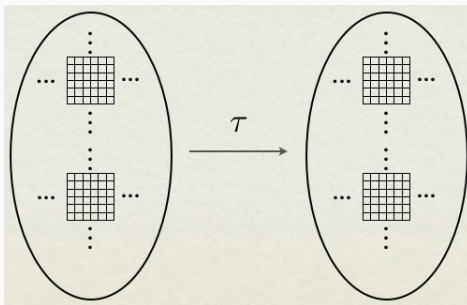
- 29 estados, Vecindad de Moore (John von Neumann 1966)
- 8 estados, Vecindad Von Neumann (Edgar Cood 1968)
- 4 estados, Vecindad Von Neumann (Edwin Roger Banks 1970)
- 2 estados, Vecindad Moore (John Horton Conway 1970)

Video

Autómata Celular

$$G = \mathbb{Z}^2, A = \{0, 1\}$$

$$\tau = A^{\mathbb{Z}^2} \rightarrow A^{\mathbb{Z}^2}$$



$$S = \{x_{i-1,j+1}, x_{i,j+1}, x_{i+1,j+1}, x_{i-1,j}, x_{i,j}, x_{i+1,j}, x_{i-1,j-1}, x_{i,j-1}, x_{i+1,j-1}\}$$

$x_{i-1,j+1}$	$x_{i,j+1}$	$x_{i+1,j+1}$
$x_{i-1,j}$	$x_{i,j}$	$x_{i+1,j}$
$x_{i-1,j-1}$	$x_{i,j-1}$	$x_{i+1,j-1}$

S: Vecindad de von Neumann

$$S = \{x_{i,j+1}, x_{i-1,j}, x_{i,j}, x_{i+1,j}, x_{i,j-1}\}$$

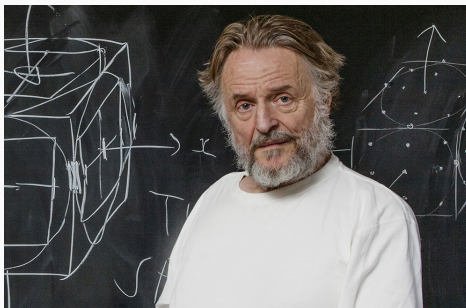
	$x_{i,j+1}$	
$x_{i-1,j}$	$x_{i,j}$	$x_{i+1,j}$
	$x_{i,j-1}$	

$$\mu = A^S \rightarrow A$$

$$x_{i,j}^t t + 1 = \mu(x_{i-1,j+1}^t, x_{i,j+1}^t, x_{i+1,j+1}^t, x_{i-1,j}^t, x_{i,j}^t, x_{i+1,j}^t, x_{i-1,j-1}^t, x_{i,j-1}^t, x_{i+1,j-1}^t)$$

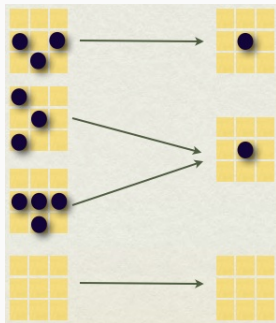
El Juego de la Vida

$$G = \mathbb{Z}^2, A = \{0, 1\}$$



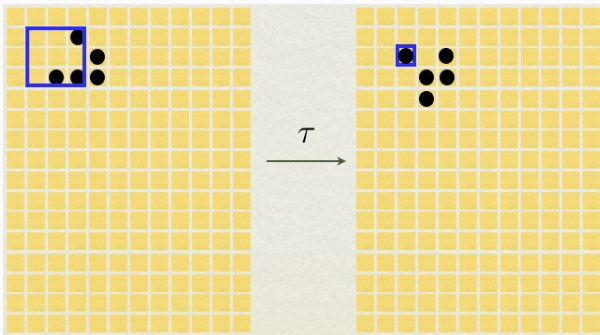
Juego de la Vida

$$G = \mathbb{Z}^2, A = \{0, 1\}$$



Esquema nacimiento-sobrevivencia: $B3/S23$

$$G = \mathbb{Z}^2, A = \{0, 1\}$$



Glider

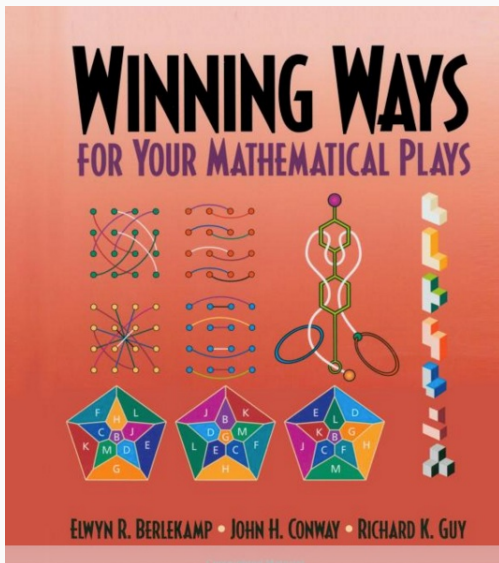


Definición Autómata Celular

Sea G un grupo y A un conjunto. *Un autómata celular sobre el grupo G y un alfabeto A es un mapeo $\tau: A^G \rightarrow A^G$ que satisface la siguiente propiedad: existe un subconjunto finito $S \subset G$ y un mapeo $\mu: A^S \rightarrow A$ tal que*

$$\tau(x)(g) = \mu((g^{-1}x)|_S)$$

para toda $x \in A^G$ y $g \in G$, donde $(g^{-1}x)|_S$ denota la restricción de la configuración $g^{-1}x$ a S .



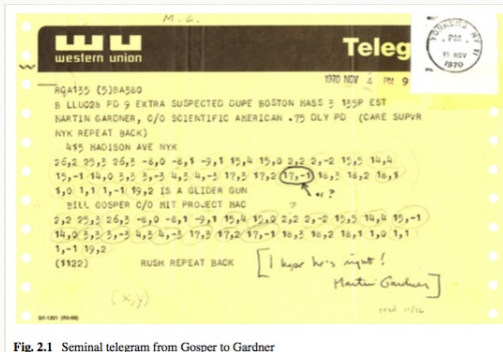
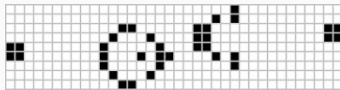


Fig. 2.1 Seminal telegram from Gosper to Gardner

Glider Gun





**Autómatas Celulares con el
esquema
Nacimiento-Sobrevivencia del
Juego de la Vida**

- B35678/S5678
- B35/S236
- B27/S0
- B2/S7
- ...

R-Rule

A New Universal Cellular Automaton Discovered by Evolutionary Algorithms

Emmanuel Sapin¹, Olivier Bailleux¹, Jean-Jacques Chabrier¹, and
Pierre Collet²

¹ Université de Bourgogne, 9 av. A. Savary, B.P. 47870, 21078 Dijon Cedex, France
`emmanuel.sapin@hotmail.com` {`olivier.bailleux`, `jjchab`}@u-bourgogne.fr

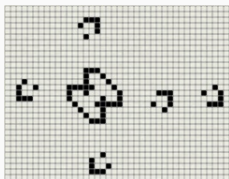
² Laboratoire d'Informatique du Littoral, ULCO, Calais, France
`Pierre.Collet@Univ-Littoral.Fr`

Abstract. In *Twenty Problems in the Theory of Cellular Automata*, Stephen Wolfram asks “how common computational universality and undecidability [are] in cellular automata.” This paper provides elements of answer, as it describes how another universal cellular automaton than the Game of Life (*Life*) was sought *and found* using evolutionary algorithms. This paper includes a demonstration that consists in showing that the presented *R* automaton can both implement any logic circuit (logic universality) and a simulation of *Life* (universality in the Turing sense). All the elements of the evolutionary algorithms that were used to find *R* are provided for replicability, as well as the analytical description in *R* of a cell of *Life*.

Glider Sapin



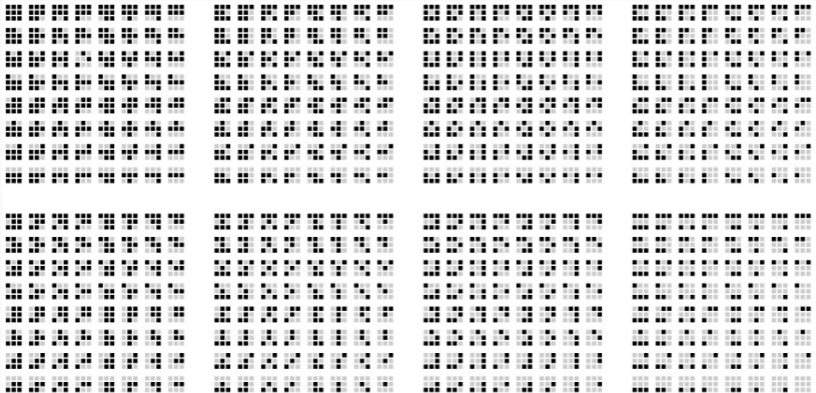
Glider Gun Sapin



Búsqueda de AC con Computación Universal

Problema Combinatorio

μ



μ

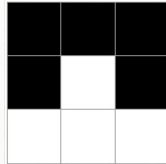
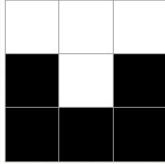
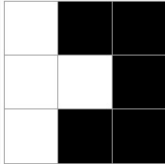
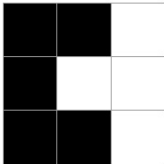
2^{512}

1340780792994259709957402499820584612
7479365820592393377723561443721764030
0735469768018742981669034276900318581
8581864860508537538828119465699464336
49006084096

μ

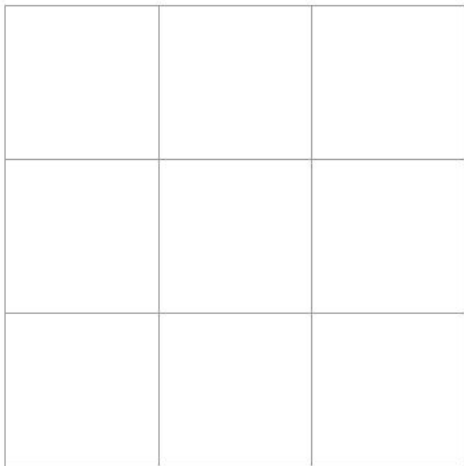


Equivalencias por Simetría



- 8 grupos con 1 elemento
- 8 grupos con 2 elementos
- 50 grupos con 4 elementos
- 36 grupos con 8 elementos
- 102 en total

$$2^{102} = 5070602400912917605986812821504$$



$$2^{101} = 2535301200456458802993406410752$$

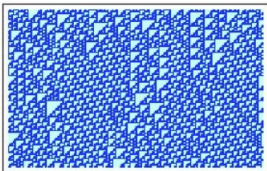
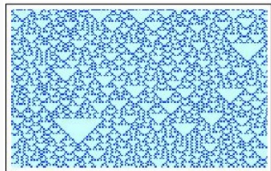
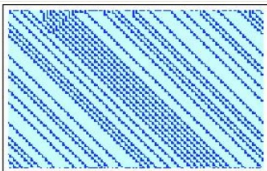
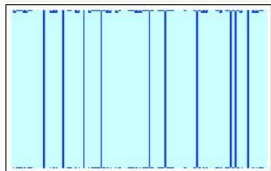
Physica 10D (1984) 1–35
North-Holland, Amsterdam

UNIVERSALITY AND COMPLEXITY IN CELLULAR AUTOMATA

Stephen WOLFRAM*

The Institute for Advanced Study, Princeton NJ 08540, USA

Cellular automata are discrete dynamical systems with simple construction but complex self-organizing behaviour. Evidence is presented that all one-dimensional cellular automata fall into four distinct universality classes. Characterizations of the structures generated in these classes are discussed. Three classes exhibit behaviour analogous to limit points, limit cycles and chaotic attractors. The fourth class is probably capable of universal computation, so that properties of its infinite time behaviour are undecidable.



Physica D 42 (1990) 12–37
North-Holland

COMPUTATION AT THE EDGE OF CHAOS: PHASE TRANSITIONS AND EMERGENT COMPUTATION

Chris G. LANGTON

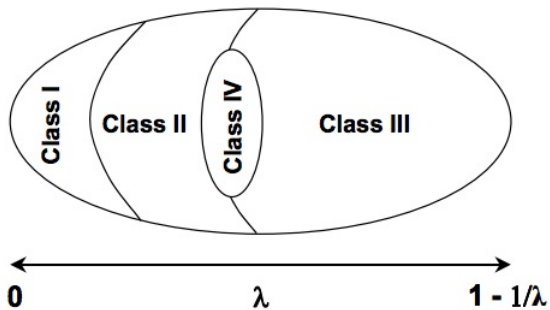
Complex Systems Group, Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87454, USA

In order for computation to emerge spontaneously and become an important factor in the dynamics of a system, the material substrate must support the primitive functions required for computation: the transmission, storage, and modification of information. Under what conditions might we expect physical systems to support such computational primitives?

This paper presents research on cellular automata which suggests that the optimal conditions for the support of information transmission, storage, and modification, are achieved in the vicinity of a phase transition. We observe surprising similarities between the behaviors of computations and systems near phase transitions, finding analogs of computational complexity classes and the halting problem within the phenomenology of phase transitions.

We conclude that there is a fundamental connection between computation and phase transitions, especially second-order or “critical” transitions, and discuss some of the implications for our understanding of nature if such a connection is borne out.

parámetro lambda



Complex Systems 2 (1988) 177–190

Undecidability of CA Classification Schemes*

Karel Culik II

*Department of Computer Science, University of South Carolina,
Columbia, SC 29208, USA*

Sheng Yu

*Department of Mathematical Sciences, Kent State University,
Kent, OH 44242, USA*

Abstract. Stephen Wolfram introduced the use of cellular automata as models of complex systems and proposed a classification of these automata based on their statistically observed behavior. We investigate various properties of these classes; in particular, we ask whether certain properties are effective, and we obtain several somewhat surprising results. For example, we show that it is undecidable whether all the finite configurations of a given cellular automaton eventually become quiescent. Consequently, it is undecidable to which class a given cellular automaton belongs, even when choosing only between the two simplest classes.

Reprinted with corrections from *The Bell System Technical Journal*,
Vol. 27, pp. 379-423, 623-656, July, October, 1948.

A Mathematical Theory of Communication

By C. E. SHANNON

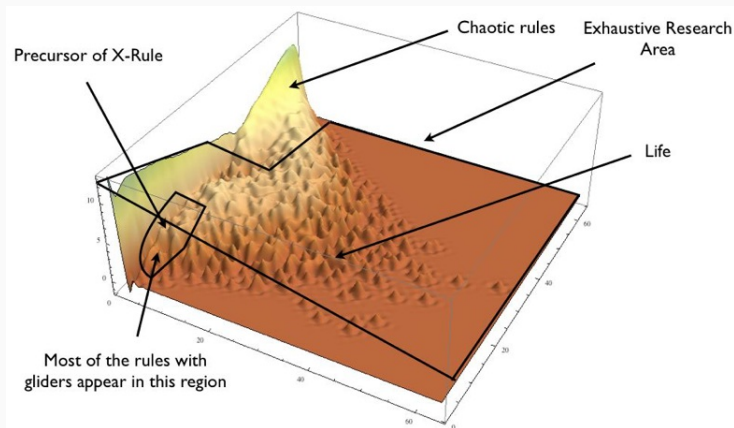
INTRODUCTION

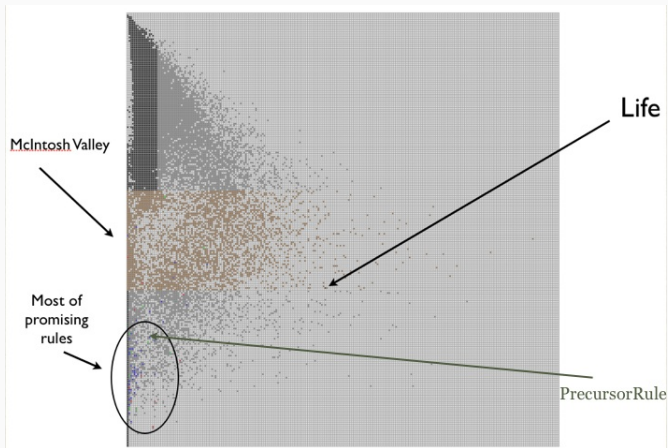
THE recent development of various methods of modulation such as PCM and PPM which exchange bandwidth for signal-to-noise ratio has intensified the interest in a general theory of communication. A basis for such a theory is contained in the important papers of Nyquist¹ and Hartley² on this subject. In the present paper we will extend the theory to include a number of new factors, in particular the effect of noise in the channel, and the savings possible due to the statistical structure of the original message and due to the nature of the final destination of the information.

The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one *selected from a set* of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design.

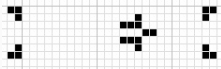
If the number of messages in the set is finite then this number or any monotonic function of this number can be regarded as a measure of the information produced when one message is chosen from the set, all choices being equally likely. As was pointed out by Hartley the most natural choice is the logarithmic function. Although this definition must be generalized considerably when we consider the influence of the statistics of the message and when we have a continuous range of messages, we will in all cases use an essentially logarithmic measure.

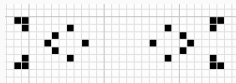
$$E = -\sum_{i=1}^n p \text{Log}(p)$$





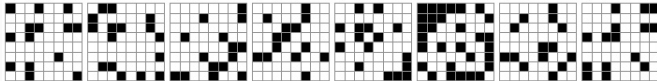
Precursor-Rule



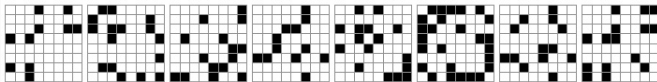


X-Rule

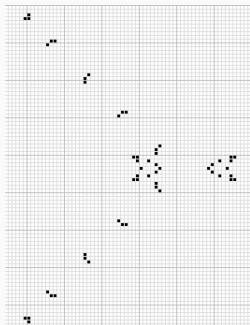
Precursor-Rule



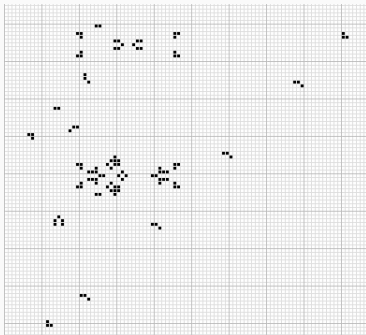
X-Rule



Glider gun “a”



Combined Glider Gun NE



Journal of Cellular Automata, Vol. 0, pp. 1–34
Reprints available directly from the publisher
Photocopying permitted by license only

©2015 Old City Publishing, Inc.
Published by license under the OCP Science imprint,
a member of the Old City Publishing Group.

The X-Rule: Universal Computation in a Non-Isotropic Life-Like Cellular Automaton

JOSÉ MANUEL GÓMEZ SOTO^{1,*} AND ANDREW WUENSCHÉ[†]

¹*Universidad Autónoma de Zacatecas
Unidad Académica de Matemáticas, Zacatecas, Zac. México*

²*Discrete Dynamics Lab, London, UK*

Received: March 15, 2015. Accepted: March 26, 2015.

We present a new Life-like cellular automaton (CA) capable of logic universality – the X-rule. The CA is 2D, binary, with a Moore neighborhood and λ parameter similar to the game-of-Life, but is not based on birth/survival and is non-isotropic. We outline the search method. Several glider types and stable structures emerge spontaneously within X-rule dynamics. We construct glider-guns based on periodic oscillations between stable barriers, and interactions to create logical gates.

Keywords: Universality, cellular automata, glider-gun, logical gates.



ConwayLife.com

A community for Conway's Game of Life and related cellular automata

Sesión de Golly

- Glider c
- Glider a
- GliderGun c
- GliderGun a
- GliderGun a
- Compuerta Lógica Negación (no)
- Compuerta Lógica Conjunción (y)
- Compuerta Lógica Disyuncion (o)
- osciladores
- puffer Trains
- Rake
- Breeder

Gracias

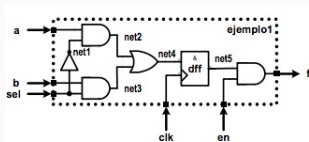
Contacto:

José Manuel Gómez Soto

jmgomezuam@gmail.com

<http://matematicas.reduaz.mx/~jmgomez>





```
module ejemplo1(a,b,sel,clk,en,f);
//Inputs-Outputs
input      a,b,sel,clk,en;
output     f;
wire       f;
//Descripción de los nodos internos
reg        net5;
wire       net1,net2,net3,net4;
// Descripción del diseño

endmodule
```





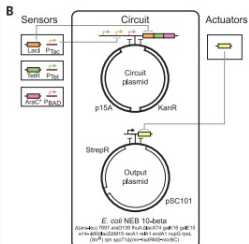
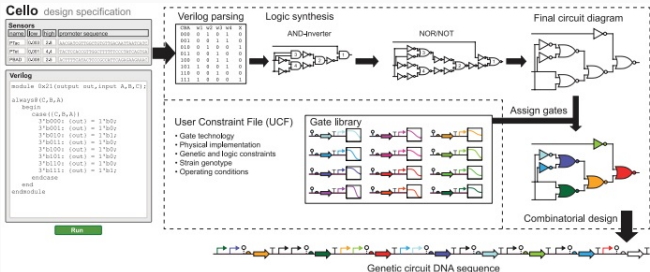


Fig. 1. Overview of Cello (A) Cello users write Verilog code and select or upload sensors and a UCF. On the basis of the Verilog design, a truth table is constructed from which a circuit diagram is synthesized. Regulators are assigned from a library to each gate (each color is a different repressor). Combinatorial design is then used to concatenate parts into a linear DNA sequence. SBOL Visual (101) is used for the part symbols. Raised arrows are promoters, circles on stems are ribzyme insulators, hemispheres are RBSs, large arrows are protein-coding sequences, and "T"s are terminators. Part colors correspond to physical gates. (B) The physical specification for the EcoCIGIT1 UCF. The circuit and sensors are inserted into one plasmid; the other plasmid contains the circuit output promoter, which can be used to drive the expression of a fluorescent protein or other actuator. Both plasmids must be present in the specified strain for the design to be valid.

Gracias

Contacto:

José Manuel Gómez Soto

jmgomezuam@gmail.com

<http://matematicas.reduaz.mx/~jmgomez>