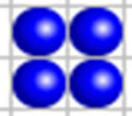
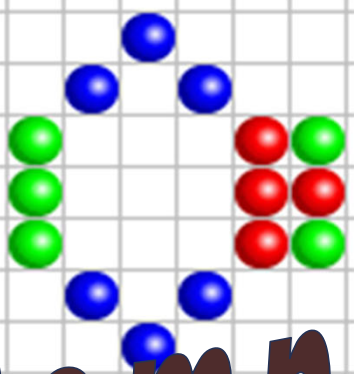
lecture 9





Computation in Cellular Automata

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key events coming up

- Labs: 35% (ISE-483)
  - Complete 5 (best 4 graded) assignments based on algorithms presented in
    - Lab 3: **March 31st**
      - Cellular Automata and Boolean Networks (Assignment 3)
        - Delivered by Kaeli Ahn and Erik Fiolkoski
        - Due: **April 7th**
    - Lab 4 : April 22nd (Tuesday after Easter break)????
      - Evolutionary Algorithms, (Assignment 4)
        - Delivered by Kristen Beideman
        - Due April 29th
- SSIE – 583 -Presentation and Discussion: 25%
  - Present and lead the discussion of an article related to the class materials
    - Enginet students post/send video or join by Zoom
  - April 22, 2025
    - Rik Pardun
      - Conrad, M. [1990]. "The geometry of evolution." *Biosystems* 24: 61-81.
    - Kiet Ngo Tuan
      - Garg, Shivam, Kirankumar Shiragur, Deborah M. Gordon, and Moses Charikar. "Distributed Algorithms from Arboreal Ants for the Shortest Path Problem."*PNAS* **120**, no. 6 (February 7, 2023): e2207959120.
    - Eric Fiolkoski
      - Schmidt, M. and H. Lipson [2009]. "Distilling Free-Form Natural Laws from Experimental Data". *Science*, **324**: 81-85.

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- Projects
  - **Due by May 7th** in Brightspace, "Final Project 483/583" assignment
    - ALIFE 2025
      - Not necessarily to submit to actual conference due date
        - May 4 full paper, July 4, abstract
      - https://2025.alife.org/
      - Max 8 pages, author guidelines:
      - https://2025.alife.org/calls#paper-call
      - MS Word and Latex/Overleaf templates
    - Preliminary ideas **by March 7**
      - Submit to "Project Idea" assignment in Brightspace.
  - Individual or group
    - With very definite tasks assigned per member of group

ALIFE 2025

Tackle a real problem using bio-inspired algorithms, such as those used in the labs.

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Reusing and expanding labs is highly encouraged.

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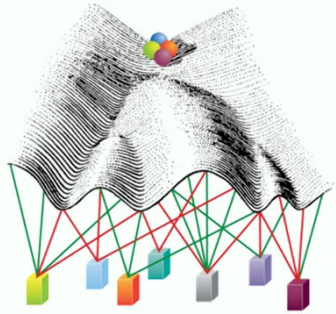
Additional information

- Class Book
  - Floreano, D. and C. Mattiussi [2008]. *Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies*. MIT Press. Preface**, Chapters 1 and 4.**
- Lecture notes
  - Chapter 1: What is Life?
  - Chapter 2: The logical Mechanisms of Life
  - Chapter 3: Formalizing and Modeling the World
  - Chapter 4: Self-Organization and Emergent Complex Behavior
  - Chapter 5: Reality is Stranger than Fiction
    - posted online @ http://informatics.indiana.edu/rocha/i-bic
- Papers and other materials
  - Optional
    - Nunes de Castro, Leandro [2006]. *Fundamentals of Natural Computing: Basic Concepts, Algorithms, and Applications*. Chapman & Hall.
      - Chapter 2, 7, 8
      - **Chapter 3, sections 3.1 to 3.5**
    - Flake's [1998], *The Computational Beauty of Life*. MIT Press.
      - Chapters 10, 11, 14 – Dynamics, Attractors and chaos



John Horton Conway

$$x_{i,j} = \{0,1\}$$

2-D

Sum N^8	0	1	2	3	4	5	6	7	8
$x_{i,i}= 0$	0	0	0	1	0	0	0	0	0
$x_{i,i}= 1$	0	0	1	1	0	0	0	0	0

1) Any living cell with fewer than two neighbors dies of loneliness.
2) Any living cell with more than three neighbors dies of crowding.
3) Any dead cell with exactly three neighbors comes to life.
4) Any living cell with two or three neighbors lives, unchanged, to the next generation

Introduced in Martin Gardner's *Scientific American* "Mathematical Games" Column in 1970.

Conway was interested in a rule that for certain initial conditions would produce patterns that grow without limit, and some others that fade or get stable.

Popularized CAs.

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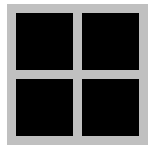
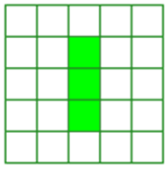
wide dynamic range

Simple Attractors



block



Blinkers

More complicated attractors

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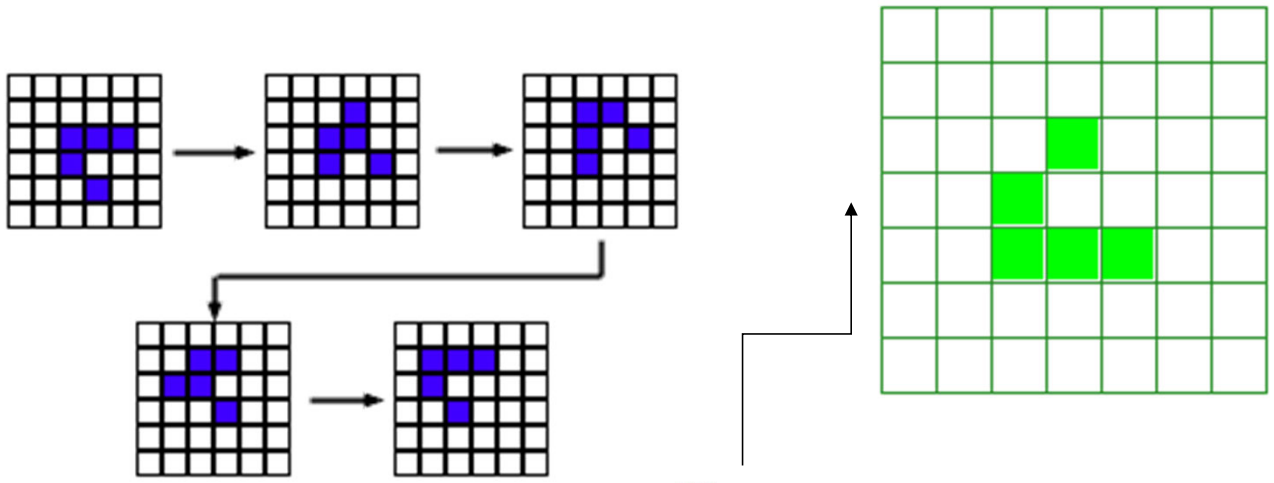
moving patterns



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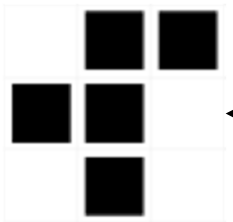
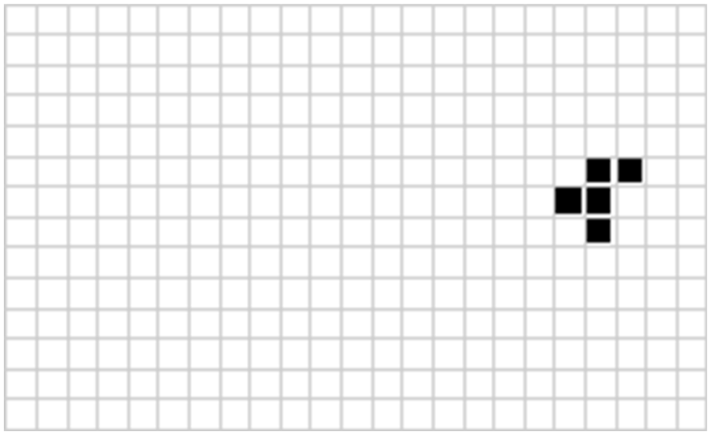
a threshold of complexity?



R-pentomino



runs 1103 steps before settling down into 6 gliders, 8 blocks, 4 blinkers, 4 beehives, 1 boat, 1 ship, and 1 loaf.

something that lasts forever?

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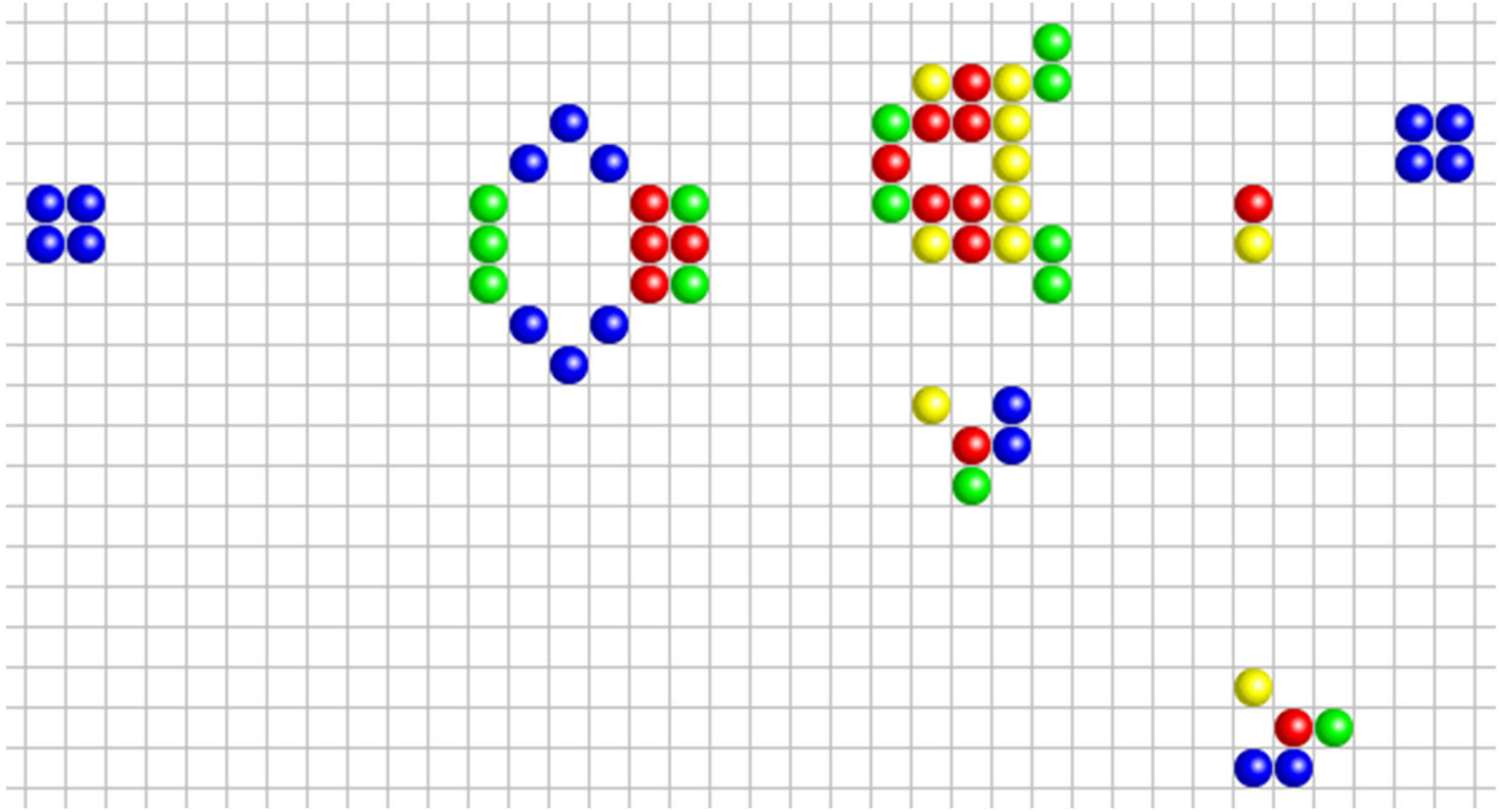
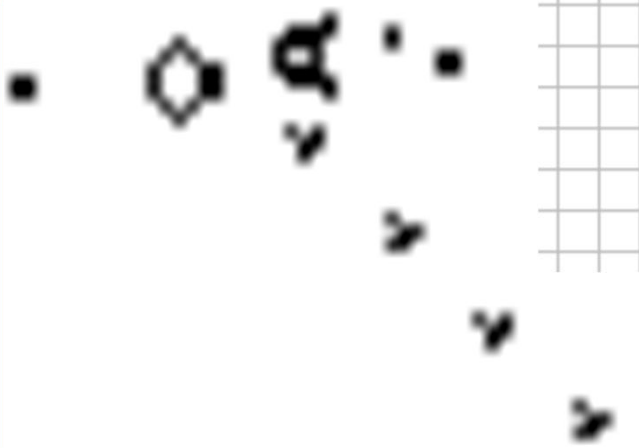
the glider gun

Unbounded growth but not complexity





Fires a glider every 30 iterations.

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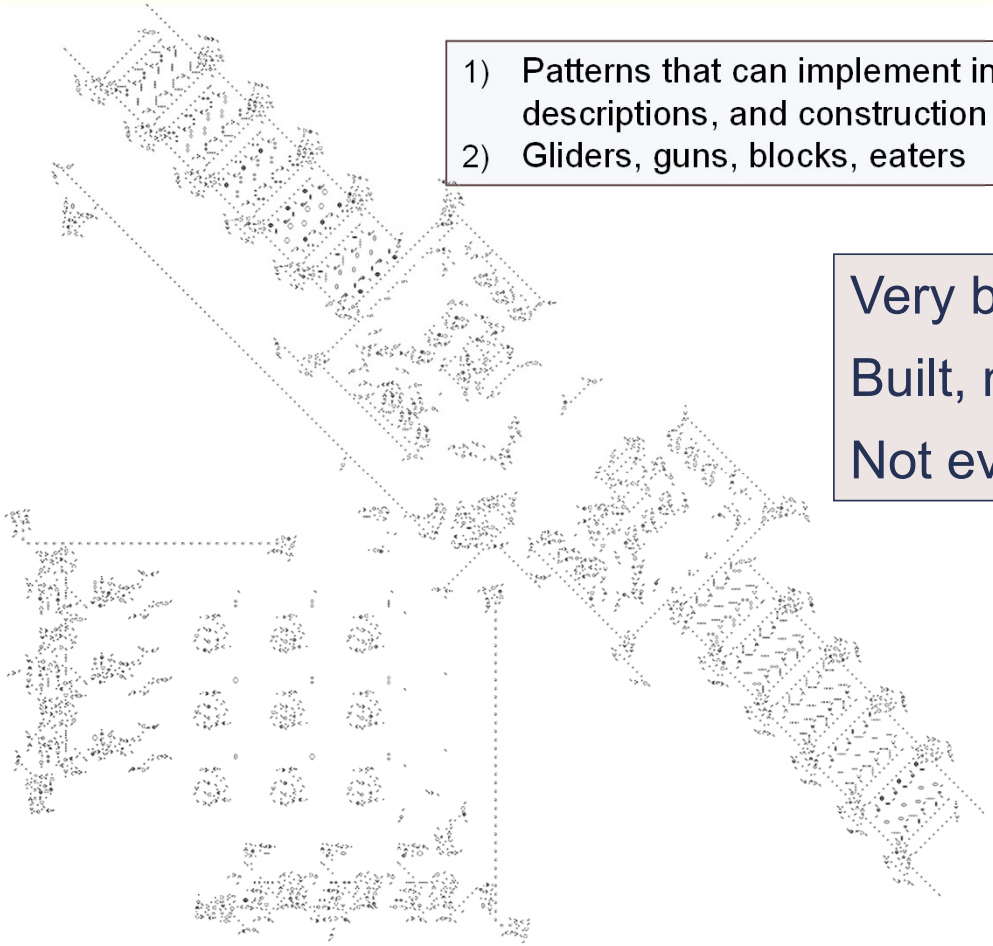
unbounded complexity requires information

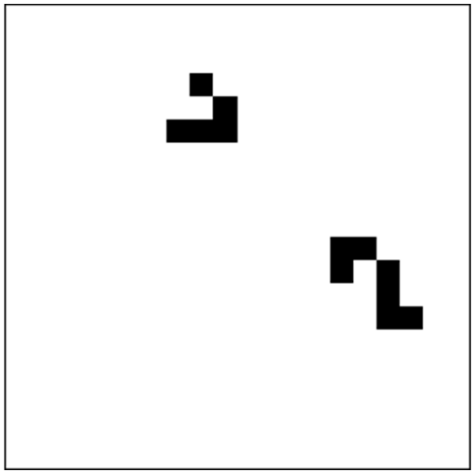


1) Patterns that can implement information, descriptions, and construction
2) Gliders, guns, blocks, eaters

Very brittle

Built, not evolved

Not evolving



Universal Turing Machine on game of life!!!

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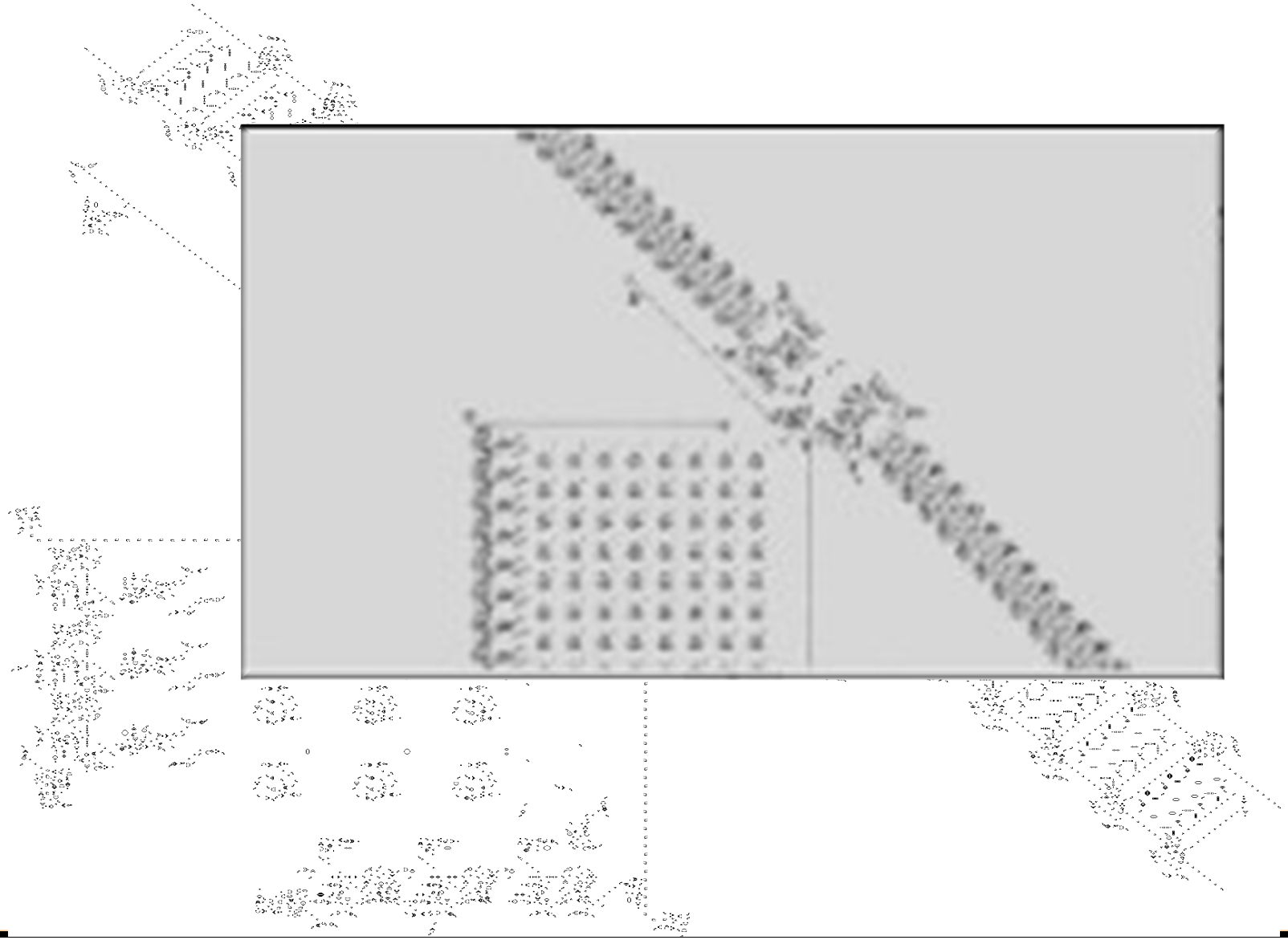
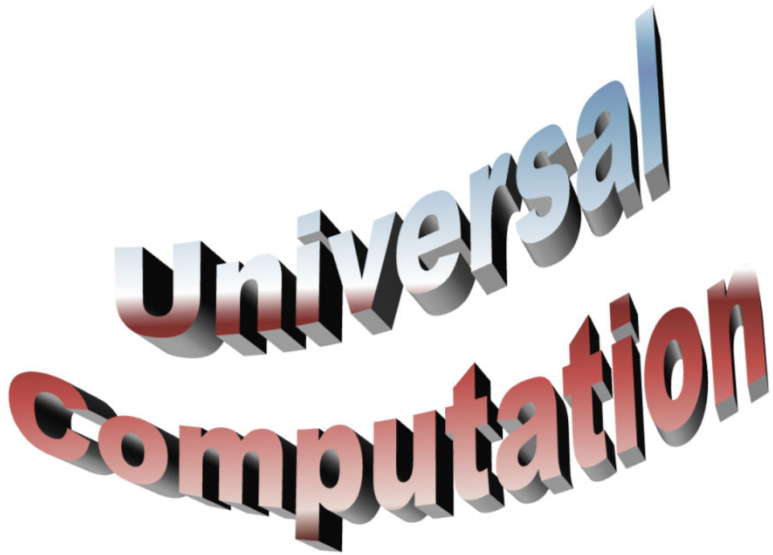
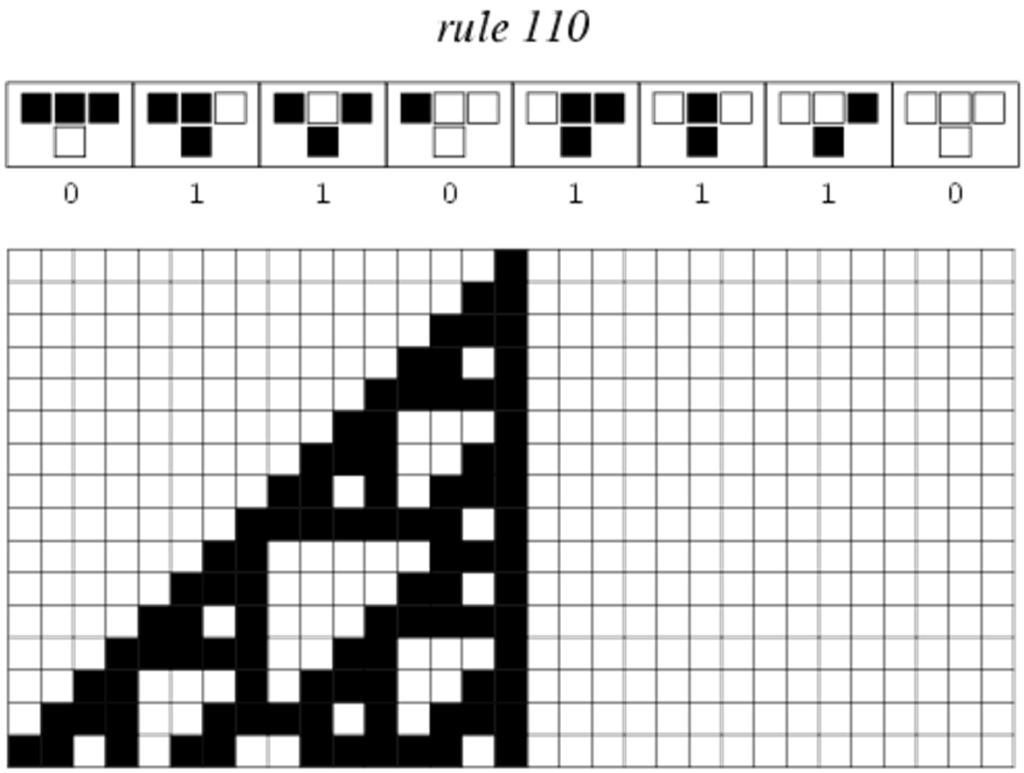


Rule 110

information in attractor patterns

- Radius 1
  - Neighborhood =3
- Binary
  - 2^3 = 8 input neighborhoods
  - 2^8 = 256 rules





http://mathworld.wolfram.com/Rule110.html

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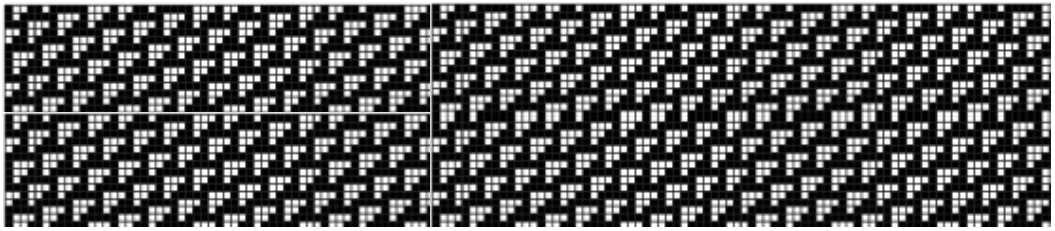
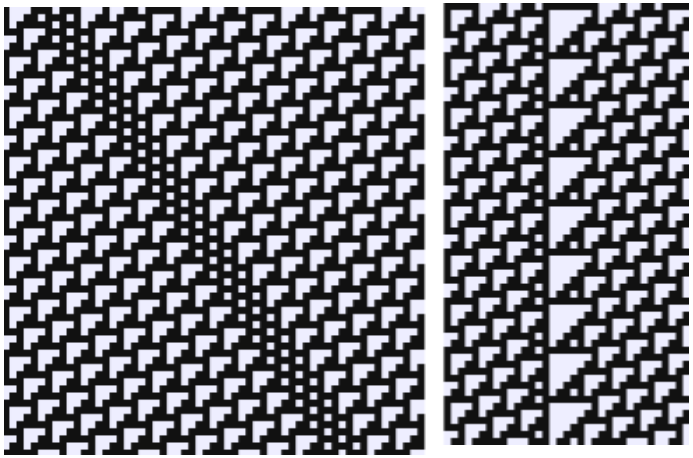
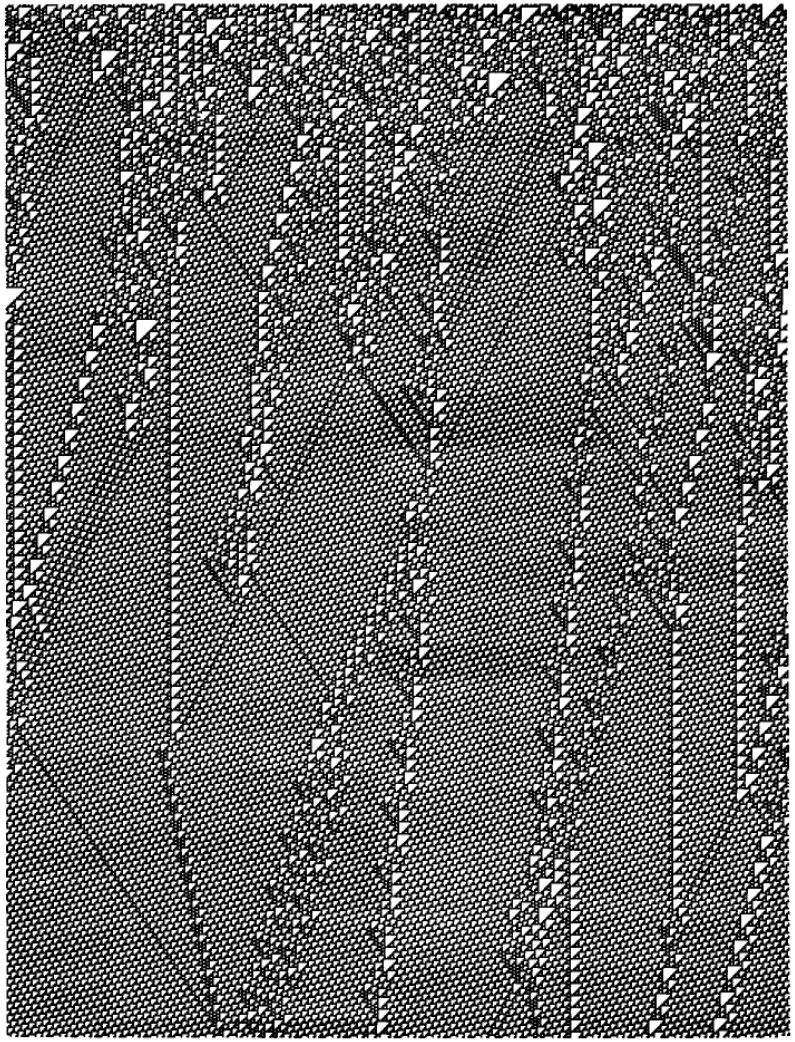
computing structures in rule 110



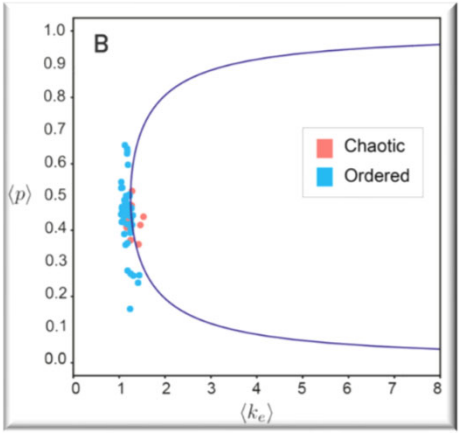
- Universal Computation
  - Identification of gliders, spaceships, and other long-range or self-perpetuating patterns
    - On the background domain produced by rule 110
      - 14 cells repeat every seven iterations: **00010011011111**
  - Collisions and combinations of glider patterns are exploited for computation.

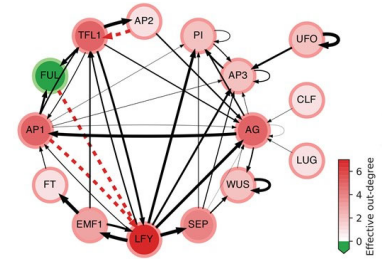


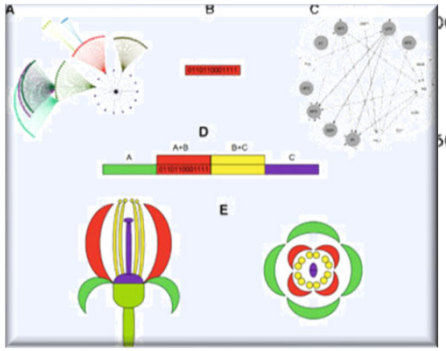


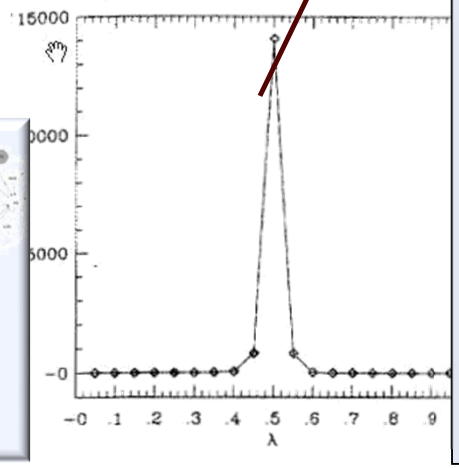
computation and the edge of chaos

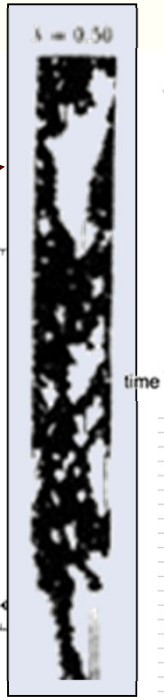
is self-organization enough?

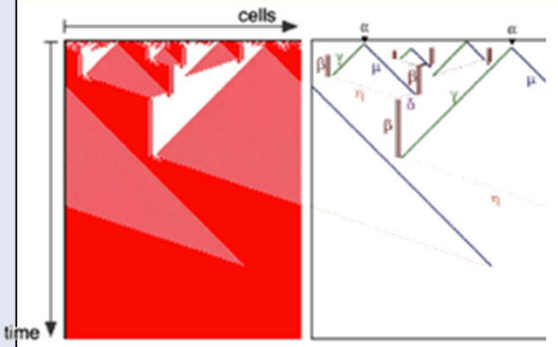


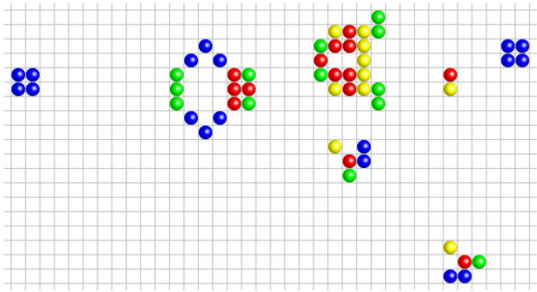












- systems biology models operate in near critical regime, though many are ordered
- Dynamical systems capable of computation exist before the edge of chaos
  - A wider transition due to redundancy?
- Most important information transmission and computation in Biology an altogether different process than self-organization
  - Turing/Von Neumann memory

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readings

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    - **Chapter 2**.
- Lecture notes
  - Chapter 1: What is Life?
  - Chapter 2: The logical Mechanisms of Life
  - Chapter 3: Formalizing and Modeling the World
  - Chapter 4: Self-Organization and Emergent Complex Behavior
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- Papers and other materials
  - Optional
    - Nunes de Castro, Leandro [2006]. *Fundamentals of Natural Computing: Basic Concepts, Algorithms, and Applications*. Chapman & Hall.
      - Chapter 2, all sections
      - Chapter 7, sections 7.3 – Cellular Automata
      - Chapter 8, sections 8.1, 8.2, 8.3.10
    - Flake's [1998], *The Computational Beauty of Life*. MIT Press.
      - Chapters 10, 11, 14 – Dynamics, Attractors and chaos