Exploring Complexity

In Science and Technology

Nov. 1, 2010

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Logistics

- Due this Wed
  - HW5 due at the end of class today
  - Lab4: GA due online on Blackboard on Wed.
- Ideas for final papers
  - Proposals due next Monday
- Questions?
- HW 6 reading questions for Ch. 10-12 handed out next time

Evolution by Natural Selection

- Organisms inherit traits from parents

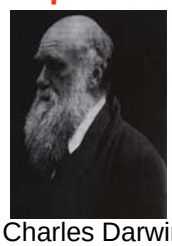
Computer e.g., programs

- Traits are inherited with some variation, via mutation and sexual recombination
- The organisms best adapted to the environment tend to produce the most offspring.

or to satisfying fitness criteria

- This way traits producing adapted individuals spread in the population

in computers

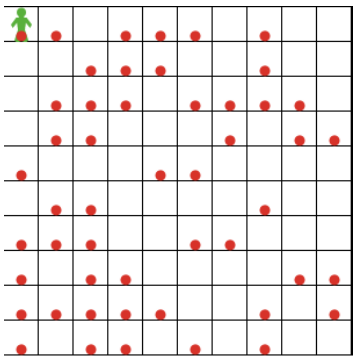


Charles Darwin

John Holland

Example: Evolving Strategies for Robby the Robot

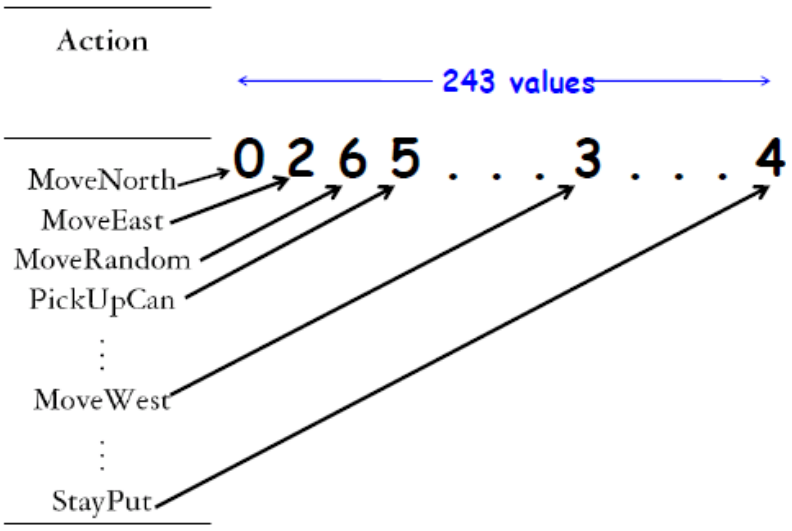
- Lab4 RobbyGraphics.nlogo
- Input: Contents of N, S, E, W, C(urrent)
  - A von Neumann neighborhood
- Possible actions (7 of them): Move N, Move S, Move E, Move W, Move random, Stay put, Try to pick up can
- Reward/Penalties (fitness points):
  Picks up a can: 10
  Tries to pick up a can on empty site: – 1
  Crashes into wall: – 5



Example Strategy

Situation					Action
North	*South*	*East*	*West*	*Current Site*	
Empty	Empty	Empty	Empty	Empty	MoveNorth
Empty	Empty	Empty	Empty	Can	MoveEast
Empty	Empty	Empty	Empty	Wall	MoveRandom
Empty	Empty	Empty	Can	Empty	PickUpCan
⋮	⋮	⋮	⋮	⋮	⋮
Wall	Empty	Can	Wall	Empty	MoveWest
⋮	⋮	⋮	⋮	⋮	⋮
Wall	Wall	Wall	Wall	Wall	StayPut

Encoding a Strategy



Random Initial Popu-lation

Individual 1:
2330032342163034353054600610256251511416226043565433406651151 4
1565022064064205100664321616152165202236443336334601332650300 0
4062205024316500611130514666423240124563334552412614344136102 0
1506306425516540432644631561645105436653463105516460051 64

Individual 2:
1641134312102536034036124143120110423546252530420204451643366 5
6103532215310513144062212061463143215461025652364442202534034 5
3050200562063402633100245341643015163121001221440066401266524 6
3516501541231131324533044332126345550053142130644233110 00

Individual 3:
2042334440241122613213645263246421220612212225266062614443612 5
3251266406133534015341111020616422665314552254023405115503130 2
2202006544512506220663142613553201000040003164013015416016200 6
1344406261605056414215531332360215033551312536326426305 51

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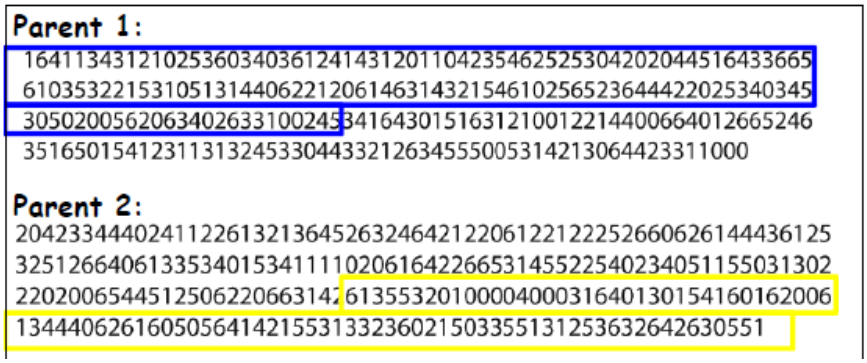
Individual 200:
3463252513600101222561210604330113520515532013065600532223504 3
3242506412425526553463534552305332661201063212455442344061365 4
3024624016066301646464110302654000633412615035226210606362426 0
5506166163442551243544641100234633304401025332121424022 51

Select Breeders Based on Fitness Scores

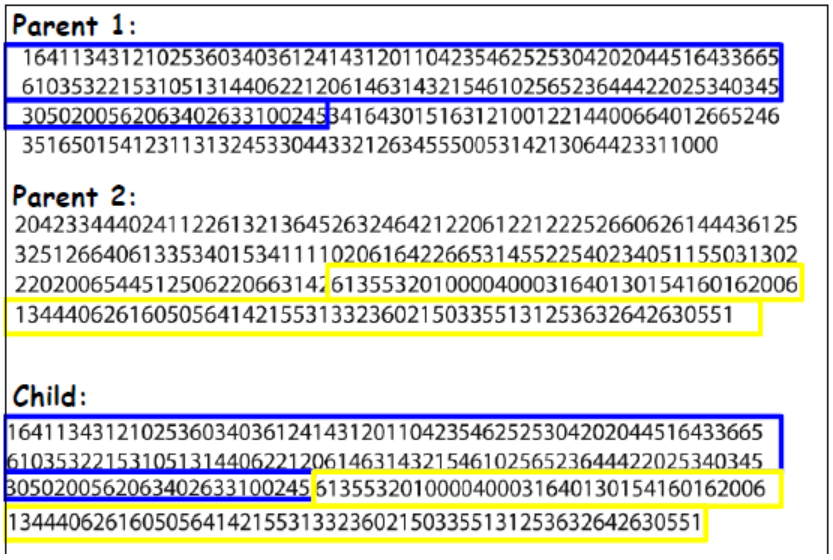
Parent 1:
1641134312102536034036124143120110423546252530420204451643366 5
6103532215310513144062212061463143215461025652364442202534034 5
3050200562063402633100245341643015163121001221440066401266524 6
3516501541231131324533044332126345550053142130644233110 00

Parent 2:
2042334440241122613213645263246421220612212225266062614443612 5
3251266406133534015341111020616422665314552254023405115503130 2
2202006544512506220663142613553201000040003164013015416016200 6
1344406261605056414215531332360215033551312536326426305 51

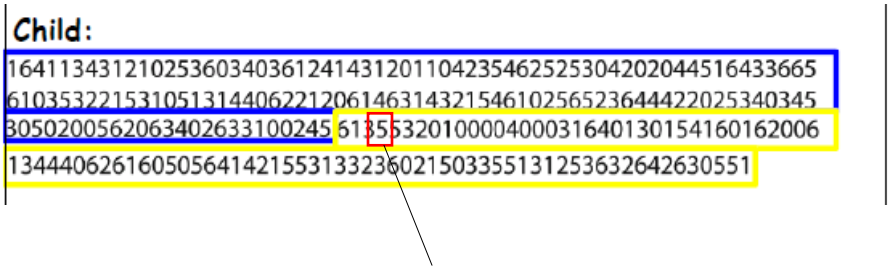
Randomly Chosen Cross-over Point



Recombination



Point Mutation

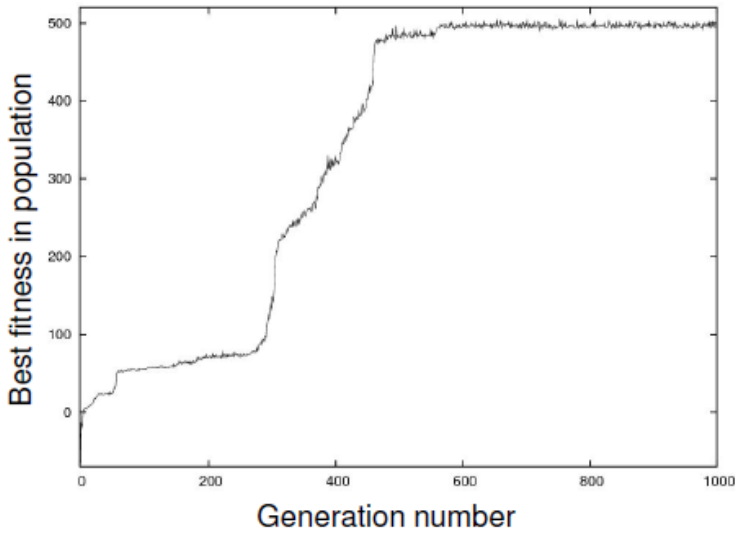


Each number in strategy has a small chance, e.g. 0.005, of being replaced by a randomly chosen action (integer from 0 – 6).

Genetic algorithm for evolving strategies for Robby

1. Generate 200 random strategies (i.e., programs for controlling Robby)
2. For each strategy, calculate fitness (average reward minus penalties earned on random environments)
3. The strategies pair up and create offspring via “sexual recombination” with random mutations the fitter the parents, the more offspring they create.
4. Keep going back to step 2 until a good-enough strategy is found!

One Run of the Genetic Algorithm



Principles of Evolution Seen in Genetic Algorithms

- Natural selection works !
- Evolution proceeds via periods of stasis "punctuated" by periods of rapid innovation
- *Exaptation* is common
- Co-evolution speeds up innovation
- Dynamics and results of evolution are unpredictable and hard to analyze

Evolving Art

- Karl Sims
  - http://www.karlsims.com/genetic-images.html
  - http://www.karlsims.com/papers/siggraph91.html
- Evolving Darwin's Gaze
  - http://www.darwinsgaze.com/evolveit.php
  - http://www.youtube.com/watch?v=8LChmQjR0O0 (5:48)
- Evolving artificial creatures (Nicolas Lassabe)
  - http://www.youtube.com/watch?v=d4BGLp0wcdE (4:43)

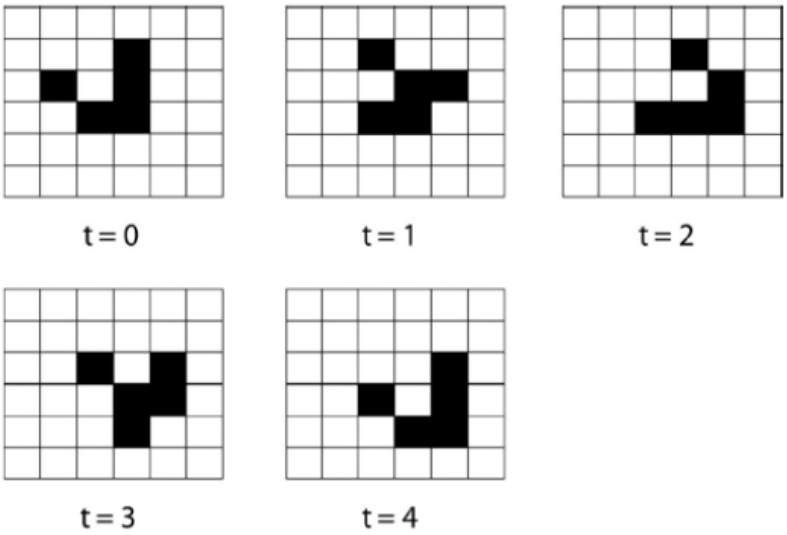
What is a cellular automaton?

- Models of parallel processes with simple rules
  - Emergence
- light bulbs pictures
- relation to Turing machines
  - "non-von-Neumann-style architecture"
- invented by von Neumann
- CAs and universal computation

Example: Game of Life (John Conway, 1970s)

- Neighborhood: 2 dimensional 3x3 neighborhood:
- Rules:
  - A dead cell with exactly three live neighbors becomes a live cell (birth).
  - A live cell with two or three live neighbors stays alive (survival).
  - In all other cases, a cell dies or remains dead (overcrowding or loneliness).
- Demo: http://www.bitstorm.org/gameoflife/

A “glider”



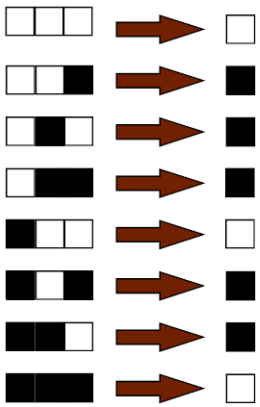
Predictability?

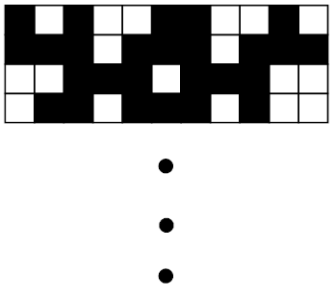
- Is there a general way to predict the behavior of Life from a given initial configuration?
- No. Life is Universal.

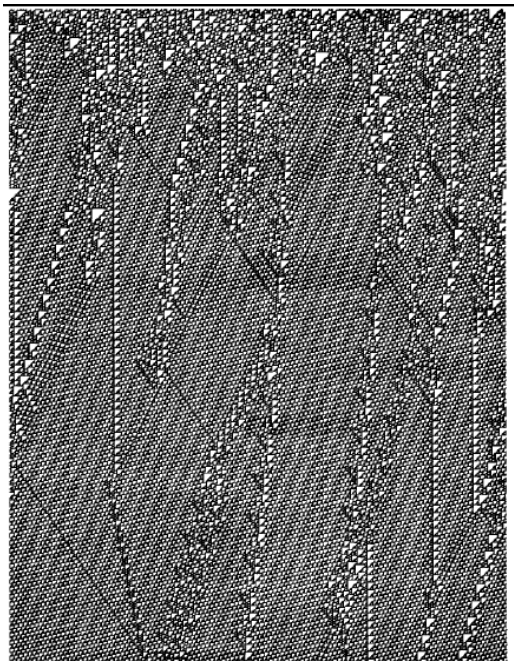
Elementary cellular automata

- one-dimensional, two states (black and white = on and off)

Rule:







Stephen Wolfram

Stephen Wolfram. (Photograph courtesy of Wolfram Research, Inc.)

- http://mathworld.wolfram.com/ElementaryCellularAutomaton.html