Exploring Complexity

In Science and Technology

Oct. 27, 2010

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Logistics

- Due this Wed
  - HW4 due in class
  - Lab3 also due in class
- Questions?
- Go over HW3, Lab2

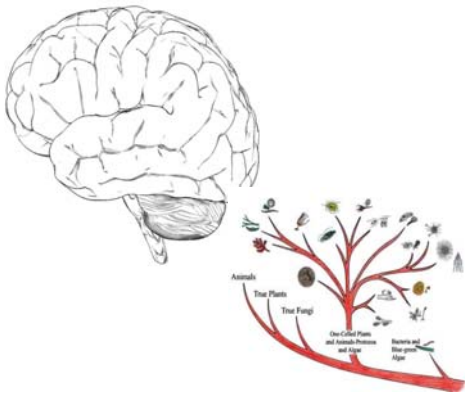
Evolution in Computers

- After answering the question “Can a machine reproduce itself?” in the affirmative, von Neumann wanted to go further, to have machines reproduce themselves with mutation and compete for resources to “survive”.
- This would address the “evolution” and “survival instinct” arguments about artificial life.
- Von Neumann died in 1957 without working on the evolution problem.
- However, by the 1960s, several groups were working on evolution in computers (ALife).

ALife Analogous to AI

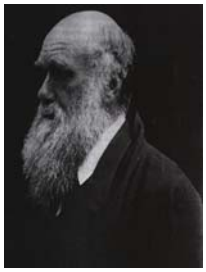
- Two Paths of Artificial Intelligence
- Borrow from logic or Borrow from biology

1.	A v B	
2.	~ A	
3.	B --> D	
4.	D -->~E	
5.	H --> E / ~H	
6.	B	DS 1,2
7.	B --> ~ E	HS 3,4
8.	~E	MP 6,7
9.	~H	MT 6,7



Evolution by Natural Selection

- Organisms inherit traits from parents
- Traits are inherited with some variation, via mutation and sexual recombination
- The organisms best adapted to the environment tend to produce the most offspring.
- This way traits producing adapted individuals spread in the population



Charles Darwin

Evolution by Natural Selection

in computers

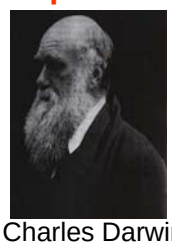
- Organisms inherit traits from parents

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



Charles Darwin

John Holland

Some real-world uses of genetic algorithms

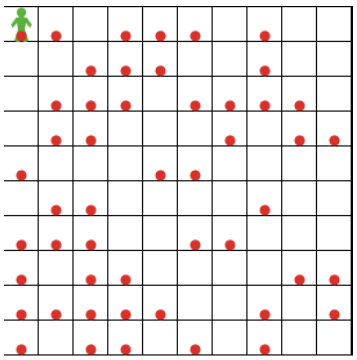
- Used by GE to automate parts of aircraft design
- Used by pharmaceutical companies to discover new drugs
- Used by the London Stock Exchange to automatically detect fraudulent trades
- Used to generate realistic computer animation in the movies *Lord of the Rings: The Return of the King* and *Troy*
- Used to model and understand evolution in nature!

Evolvable Robots

- Roboticist Hod Lipson
  - http://www.ted.com/talks/lang/eng/hod_lipson_builds_self_aware_robots.html

Example: Evolving Strategies for Robby the Robot

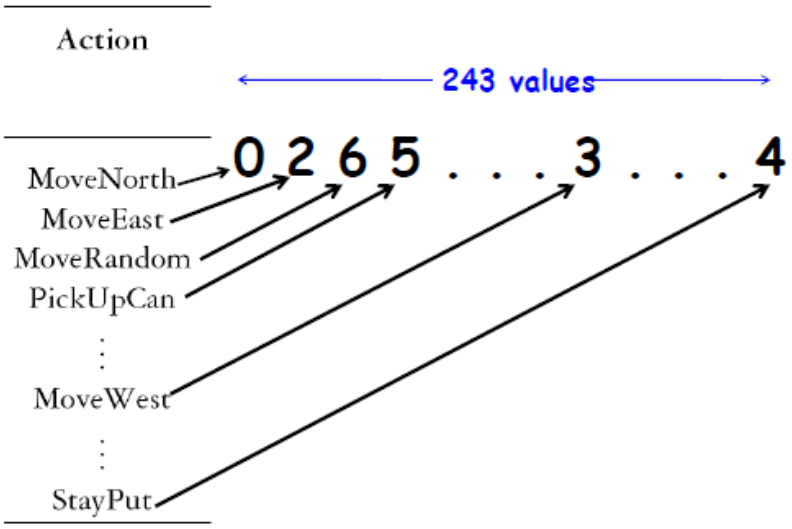
- Lab4 RobbyGraphics.nlogo
- Input: Contents of N, S, E, W, C(urrent)
  - A von Neumann neighborhood
- Possible actions (7 of them): Move N, Move S, Move E, Move W, Move random, Stay put, Try to pick up can
- Reward/Penalties (fitness points):
  Picks up a can: 10
  Tries to pick up a can on empty site: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



Genetic algorithm for evolving strategies for Robby

- Generate 200 random strategies (i.e., programs for controlling Robby)

Random Initial Popu-lation

Individual 1:
233003234216303435305460061025625151141622604356543340665115141565022064064205100664321616152165202236443336334601332650300040622050243165006111305146664232401245633345524126143441361020150630642551654043264463156164510543665346310551646005164

Individual 2:
164113431210253603403612414312011042354625253042020445164336656103532215310513144062212061463143215461025652364442202534034530502005620634026331002453416430151631210012214400664012665246351650154123113132453304433212634555005314213064423311000

Individual 3:
204233444024112261321364526324642122061221222526606261444361253251266406133534015341111020616422665314552254023405115503130222020065445125062206631426135532010000400031640130154160162006134440626160505641421553133236021503355131253632642630551

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Individual 200:
346325251360010122256121060433011352051553201306560053222350433242506412425526553463534552305332661201063212455442344061365430246240160663016464641103026540006334126150352262106063624260550616616344255124354464110023463330440102533212142402251

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.

Select Breeders Based on Fitness Scores

Parent 1:

164113431210253603403612414312011042354625253042020445164336651
610353221531051314406221206146314321546102565236444220253403451
305020056206340263310024534164301516312100122144006640126652461
351650154123113132453304433212634555005314213064423311000

Parent 2:

204233444024112261321364526324642122061221222526606261444361251
325126640613353401534111102061642266531455225402340511550313021
220200654451250622066314261355320100004000316401301541601620061
134440626160505641421553133236021503355131253632642630551

Randomly Chosen Cross-over Point

Parent 1:

164113431210253603403612414312011042354625253042020445164336651
610353221531051314406221206146314321546102565236444220253403451
305020056206340263310024534164301516312100122144006640126652461
351650154123113132453304433212634555005314213064423311000

Parent 2:

204233444024112261321364526324642122061221222526606261444361251
325126640613353401534111102061642266531455225402340511550313021
220200654451250622066314261355320100004000316401301541601620061
134440626160505641421553133236021503355131253632642630551

Recombination

Parent 1:

1641134312102536034036124143120110423546252530420204451643366561035322153105131440622120614631432154610256523644422025340345305020056206340263310024534164301516312100122144006640126652463516501541231131324533044332126345550053142130644233110000

Parent 2:

2042334440241122613213645263246421220612212225266062614443612532512664061335340153411110206164226653145522540234051155031302220200654451250622066314261355320100004000316401301541601620061344406261605056414215531332360215033551312536326426305510

Child:

1641134312102536034036124143120110423546252530420204451643366561035322153105131440622120614631432154610256523644422025340345305020056206340263310024561355320100004000316401301541601620061344406261605056414215531332360215033551312536326426305510

Point Mutation

Child:

1641134312102536034036124143120110423546252530420204451643366561035322153105131440622120614631432154610256523644422025340345305020056206340263310024561355320100004000316401301541601620061344406261605056414215531332360215033551312536326426305510

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

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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!

Dr. Mitchell's Hand-Designed Strategy

- 243 symbol long strategy that immplements
  - "If there is a can in the current site, pick it up."
  - "Otherwise, if there is a can in one of the adjacent sites, move to that site."
  - "Otherwise, choose a random direction to move in."
- Average fitness of this strategy: 346
  - Out of possible ~ 500
- **Average fitness of GA evolved strategy: 486!**

One Run of the Genetic Algorithm