Applying Evolutionary Computation to Robotics

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Outline

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2. Background
3. Research Cases
4. Simulation
5. EvolutionaryProcess
6. Results
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The big picture

- Robots are faced with difficult problems
- Evolutionary computation is a process which can can solve difficul t problems in programming
- Since a robot interacts with the physical world, EC is slower by s everal magnitudes
- It is possible to use EC to evolve robots

Bluedrakon
`http://tr.im/pWUi`

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- Evolutionary Computation
- Genetic Algorithm
- “One Max” Example
- Artificial Neural Networks

3 Research Cases

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Evolutionary Computation

- Evolutionary Computation (EC) is a problem solving technique which mimics natural selection

Evolutionary Computation: Requirements

- A population of candidates
- A fitness function

Evolutionary Computation: Process

- Candidates are evaluated
- The best performing candidates are selected
    - Two candidates cross-over with one another
    - Some candidates are subject to mutation
- This process repeats until the population is recreated

Genetic Algorithm

- Genetic Algorithms are a type of EC
- Candidates are represented as bit strings

Genetic Algorithm: Cross-over

- A Cross-over point is selected from two candidates. All bits are swapped beyond the point, creating two new candidates.

- Before:

$$C_i = [1, 0, 1, 0, |0, 0, 1, 0, 0, 1]$$

$$C_j = [0, 0, 1, 1, |0, 1, 1, 0, 1, 0]$$

- After:

$$[1, 0, 1, 0, 0, 1, 1, 0, 1, 0]$$

$$[0, 0, 1, 1, 0, 0, 1, 0, 0, 1]$$

Genetic Algorithm: Candidate Manipulation

- Mutation:

$$[1, 0, 1, 0, 0, 0, 1, 0, 1, 1]$$

$$[1, 0, 1, 0, 0, 0, 1, 0, 0, 1]$$

Example: “One Max”

- Goal: Evolve an array consisting of the most ones from 20 candidate arrays with 10 bits

$$20\left\{\begin{array}{c}[1,\ 1,\ 1,\ 0,\ 0,\ 0,\ 1,\ 0,\ 0,\ 1]\\ [0,\ 0,\ 1,\ 1,\ 0,\ 1,\ 1,\ 0,\ 1,\ 0]\\ \ldots\\ [1,\ 0,\ 1,\ 0,\ 1,\ 1,\ 1,\ 0,\ 0,\ 0]\end{array}\right.$$

Example: "One Max"

- The fitness function $F()$ is used to calculate the fitness of each candidate
- In this case, the function counts the number of ones in the array

$$F([1,\ 1,\ 1,\ 0,\ 0,\ 0,\ 1,\ 0,\ 0,\ 1]) = 6$$

$$F([0,\ 0,\ 1,\ 1,\ 0,\ 1,\ 0,\ 0,\ 1,\ 0]) = 4$$

$$\ldots$$

$$F([1,\ 0,\ 1,\ 0,\ 1,\ 1,\ 1,\ 0,\ 0,\ 0]) = 5$$

Example: “One Max”

- The top 10 candidates are selected to create a new population
- Top candidates are randomly selected to cross-over with one another

$$C_1 = [1,1,1,0,|0,0,1,0,0,1] \qquad C_x = [1,1,1,0,0,1,1,0,1,0]$$

$$C_2 = [0,0,1,1,|0,1,1,0,1,0] \qquad C_y = [0,0,1,1,0,0,1,0,0,1]$$

Example: "One Max"

- Some created candidates may undergo mutation:

$$C_x = [1, 1, 1, 0, 0, 1, 1, 0, 1, 0]$$

$$C'_x = [1, 1, 1, 0, 1, 1, 1, 0, 1, 0]$$

Example: "One Max"

- Once the population is recreated, the process repeats until eventually a limit is reached
- In this case, the limit would be time or finding an array of all 1's

$$F([1,1,1,0,1,1,1,0,1,0]) = 7$$

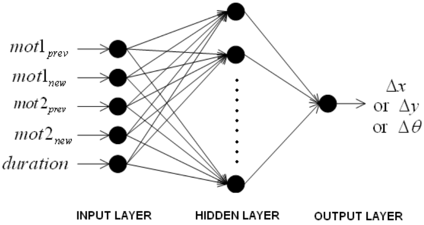
$$F([0,0,1,1,0,0,1,0,0,1]) = 4$$

$$\dots$$

$$F([1,0,1,1,0,1,0,0,1,1]) = 6$$

Artificial Neural Networks

- Artificial neural networks are a collection of nodes with weighted vertices.



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- WalkingRobot
- CoordRobot

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Swimming Robot

Walking Robot

Coordinate Tracking Robot

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   - SimCoordRobot

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Swimming Robot: Simulation

Walking Robot: Simulation

Coordinate Tracking Robot: Simulation

Coordinate Tracking Robot

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- EPSwimmingRobot
- EPWalkingRobot: Evolutionary Process
- EPCoordRobot: Evolutionary Process

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Swimming Robot: Evolutionary Process

Walking Robot: Simulation

Coordinate Tracking Robot: Simulation

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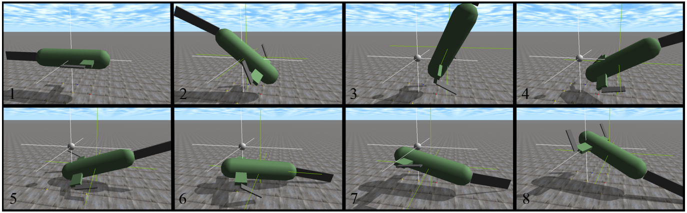
- Station Keeping Robot
- ResultsWalkingRobot
- ResultsCoordRobot

Station Keeping Robot: Results



Moore et al.

- Each trial had a candidate which successfully maintained the position
- When the flow was coming from behind, the evolved candidate would flip end-over-head to orient itself (http://y2u.be/UufbnEGFwV4)

Results Robot: Results

Coordinate Tracking Robot: Results

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Any Questions?
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