Robot Walking with Genetic Algorithms

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Outline

- Introduction
- Genetic algorithms
- Quadruped Robot
- Hexapod Robot
- Biped Robot
- Evaluation

Why walking?

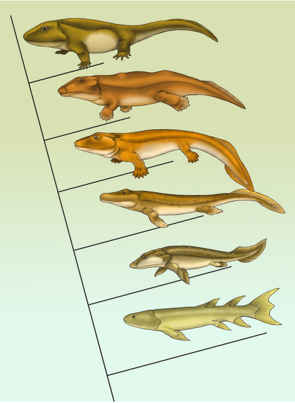
- Mobile robots
- Similar to humans and animals
- Can move forward on different surfaces
- Can climb

Why walking?

- Mobile robots
- Similar to humans and animals
- Can move forward on different surfaces
- Can climb

Problem: Walking is complex

Evolutionary Algorithms


http://www.deviantart.com/art/Fish-Fishapod-Tetrapod-Tree-186821546

- Biological inspired
- Survival of the fittest
- Reproduction and Mutation

Genetic Algorithm

- Population based

Genetic Algorithm

- Population based
- Solution as chromosomes

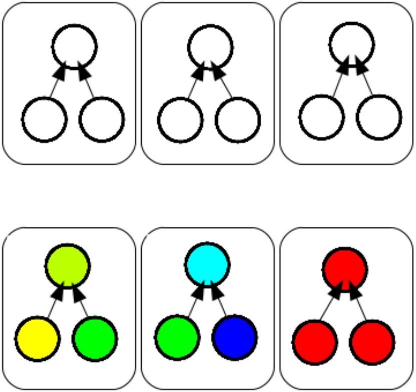
Genetic Algorithm

- Population based
- Solution as chromosomes
- Fitness function

Genetic Algorithm

- Population based
- Solution as chromosomes
- Fitness function
- Generating a new generation

Example: Finding Orange



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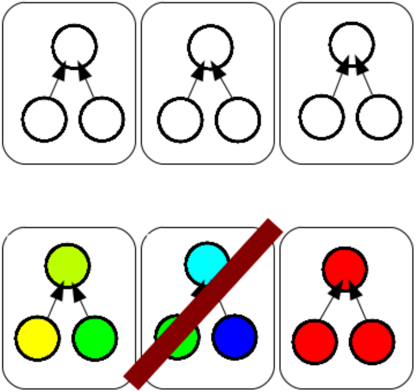

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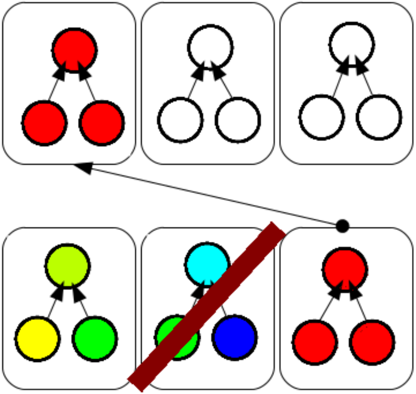

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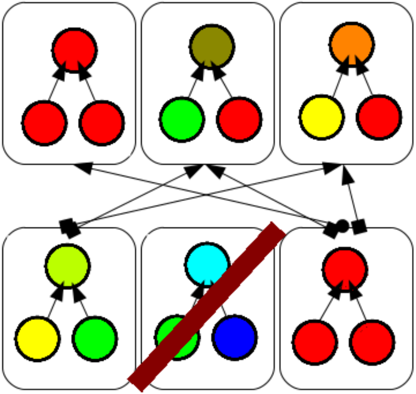

Quadruped Robot

http://www.roboticstoday.com/robots/aibo-ers-7

- 4 legs
- 2 DOF per leg

Setup

- Code for the walking exists

Setup

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- 235 mm/s with human testing

Setup

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- 4 Robots to test parallel and autonomous

Setup

- Code for the walking exists
- 235 mm/s with human testing
- 4 Robots to test parallel and autonomous
- Some hours to learn

Genetic Algorithm

- Population: 30
- Chromosomes: Parameters of the walking algorithm
- Fitness function: Distance moved forward

Result

- Distance measurement sometimes failed

Result

- Distance measurement sometimes failed
- Time was enough

Result

- Distance measurement sometimes failed
- Time was enough
- 290 mm/s with GA optimization

Result

- Distance measurement sometimes failed
- Time was enough
- 290 mm/s with GA optimization
- The robot got faster

Hexapod Robot

http://robot-kingdom.com/hexapod-robot-tutorials-where-everything-begins/

- 6 legs
- 2 DOF per leg

Setup

- Evolution of a neural network for walking control

Setup

- Evolution of a neural network for walking control
- Separated in two steps

Setup

- Evolution of a neural network for walking control
- Separated in two steps
- Step one: move a leg

Setup

- Evolution of a neural network for walking control
- Separated in two steps
- Step one: move a leg
- Step two: walking with 6 legs

Genetic Algorithm 1

- Chromosomes: Neural Network for one leg

Genetic Algorithm 1

- Chromosomes: Neural Network for one leg
- Fitness function: Range of the oscillation

Genetic Algorithm 1

- Chromosomes: Neural Network for one leg
- Fitness function: Range of the oscillation
- Stops when oscillation reaches the full length

Genetic Algorithm 2

- Population: 10; 2 stay

Genetic Algorithm 2

- Population: 10; 2 stay
- Chromosomes: Neural network for all legs

Genetic Algorithm 2

- Population: 10; 2 stay
- Chromosomes: Neural network for all legs
- Fitness function: distance from starting point in the body axis

Genetic Algorithm 2

- Population: 10; 2 stay
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- Crossover rate 0.1

Genetic Algorithm 2

- Population: 10; 2 stay
- Chromosomes: Neural network for all legs
- Fitness function: distance from starting point in the body axis
- Crossover rate 0.1
- Mutation rate: 0.04

Result

- Learned to move their legs

Result

- Learned to move their legs
- Robots walked backwards

Result

- Learned to move their legs
- Robots walked backwards
- Similar to living insects

Result

- Learned to move their legs
- Robots walked backwards
- Similar to living insects
- Wave-gait vs tripod gait

Biped Robot

http://www.engadget.com/2006/11/28/kondo-adds-pivot-to-khr-1hv-biped-robot-kit/

- 2 legs
- 6 DOF per leg

Experiment

- Truncated Fourier Series and polynomial equations used for motor control

Joint name	Support Leg (Left Leg)	Swing leg (Right leg)
Left Hip Yaw	Sinusoid	Sinusoid
Left Hip Roll	Sinusoid	Sinusoid
Left Hip Pitch	Polynomial	Sinusoid
Left Knee Pitch	Polynomial	Sinusoid
Left Ankle Pitch	Polynomial	Sinusoid
Left Ankle Roll	Sinusoid	Sinusoid

Evaluating GA and PSO Evolutionary Algorithms for Humanoid Walk Pattern Planning

Experiment

- Truncated Fourier Series and polynomial equations used for motor control
- Sinusoid equation the swing leg

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Evaluating GA and PSO Evolutionary Algorithms for Humanoid Walk Pattern Planning

Experiment

- Truncated Fourier Series and polynomial equations used for motor control
- Sinusoid equation the swing leg
- partly polynomial equations for the support leg

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Evaluating GA and PSO Evolutionary Algorithms for Humanoid Walk Pattern Planning

Experiment

- Truncated Fourier Series and polynomial equations used for motor control
- Sinusoid equation the swing leg
- partly polynomial equations for the support leg
- Learning of the equations for every motor

Joint name	Support Leg (Left Leg)	Swing leg (Right leg)
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Left Ankle Pitch	Polynomial	Sinusoid
Left Ankle Roll	Sinusoid	Sinusoid

Evaluating GA and PSO Evolutionary Algorithms for Humanoid Walk Pattern Planning

Genetic Algorithm

- Population: 20
- Chromosomes: Coefficients of the equations
- Fitness function: Walking without falling

Model of implementation	Selection	Crossover	Mutation
GA-1	Random	Random	10%
GA-2	Roulette wheel	Random	10%
GA-3	Roulette wheel	All pitches and all rolls	10%

Evaluating GA and PSO Evolutionary Algorithms for Humanoid Walk Pattern Planning

Result

- Coefficients are learned
- Each motor has specific equation
- robots learned to walk

Algorithm	#chromosome	#Generation	Best Fitness (average 5 iteration)	Iterations to Converge
GA-1	20	20	0.51376	-
GA-2	**20**	**20**	**0.58862**	**20**
GA-3	20	20	0.50434	-

Evaluating GA and PSO Evolutionary Algorithms for Humanoid Walk Pattern Planning

Evaluation

- Optimization algorithm

Evaluation

- Optimization algorithm
- Finds a good solution

Evaluation

- Optimization algorithm
- Finds a good solution
- PSO (particle swarm optimization) usually faster

Thank you for your attention!

References

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