Modern Robots: Evolutionary Robotics

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News

- Undergraduate HyperNEAT paper accepted
  - it can be done!
Seeded-CPPN

Clune, Chen, & Lipson. IEEE CEC. 2013
Seeded-CPPN

Seeded-CPPN

CPPN

dimensions: 1024.0x768.0

Clune, Chen, & Lipson. IEEE CEC. 2013
Projects

• Homestretch!
  • less than a week left till the first presentation

• Your story should be taking shape

• Plan for
  • bugs
  • statistics software not working easily
  • video-editing being hard
Plots, Stats, and Labels

- Median plus 25th/75th quartiles
Natural Selection Fails to Optimize Mutation Rates for Long-Term Adaptation on Rugged Fitness Landscapes

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Conclusions

• natural selection fails to optimize mutation rates for long-term adaptation on rugged fitness landscapes

• evolvability can involve short-term vs. long-term tradeoffs, and natural selection is short-sighted

• bad idea: self-adaptive mutation rates

• medical and practical implications
Background

- **Evolvability**
  - quickly adapting to new environments
  - important biological property

- **Mutation rates**
  - key driver of evolvability
  - ultimate source of genetic variation
  - evolve
  - medically important (e.g. viruses)
Question

- Are evolving mutation rates optimized?

- ...for long-term adaptation
Experimental Design

- Identify the optimum
  - evolve organisms with different, fixed (non-evolving) mutation rates in new environment
- Does evolution produce the optimum?
  - allow mutation rates to evolve
  - start well below and well above the optimum

![Diagram showing mutation rate vs fitness with an optimum point.](image-url)
System

- computational evolution
- Avida
  - well-studied
  - population of self-replicating digital organisms
Avida Organisms

- genome: list of computer instructions
- phenotype: execution of instructions with virtual hardware

Lenski et al. Nature 2003
Avida Organisms

self-replication
Fitness

- limited space (overwrite neighbors)
- faster replication = more offspring
- extra energy = faster replication
  - traditional: 9 logic tasks (Lenski et al. 2003)
Experiments

- sweep range of fixed mutation rates
- allow mutation rates to evolve
Evolved Mutation Rates Less Fit

- natural selection fails to optimize for long-term
- ...in a complex fitness landscape (Avida default)
Short Term vs. Long Term

- Competitions between
  - A = long-term optimum mutation rate
  - B = zero mutation rate
  - 50:50 split to start, 50 runs

- Results
  - B drove A extinct in < 40 generations every time
Hypothesis

Ruggedness of fitness landscape?

X (low mutation rate): higher avg. fitness
Y (high mutation rate): lower avg. fitness
Simplified Avida Environment

Season A

<table>
<thead>
<tr>
<th>fitness</th>
<th>genome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AAAAAAAAAAAAb</td>
</tr>
<tr>
<td>9</td>
<td>bbbbbbbbbbbA</td>
</tr>
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</table>

Season B

<table>
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<tr>
<th>fitness</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
</tr>
<tr>
<td>1</td>
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A = key instruction
Simplified Avida Environment

Season A

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Season B

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</table>
• Optimized on smooth landscapes

• Not optimized when ruggedness above threshold

• Gap grows with valley size
Dynamics

• Lowering is a function of ‘waiting time’

• Optimal vs. Suboptimal for 300 gens
  • all below valley
  • one Optimal across valley

• Result
  • with waiting time: suboptimal fixes ~1%
  • without waiting time: suboptimal fixes 0% \( (p=0.0082) \)

• Note low probability of suboptimal fix
  • Valley crossed many times, but any delay = self-reinforcement