6.034
Search
Prof. Peter Szolovits
(friend of Dr. Kimberle Koile and Prof. Randall Davis)
ai6034.mit.edu
September 11, 2019

Remember
• AI is …
• Algorithms/methods enabled by
  • Constraints exposed by
    • Representations that support
      • Models of
        • Thinking, perception and action

Search
• A class of algorithms that allow exploration of abstract plans (= sequences of actions)

Map Search: Cambridge
Cambridge, Simplified

British Museum Algorithm

BM (Random Search)

“British Museum” Search

“placing monkeys in front of typewriters in order to reproduce all the books in the British Museum”

path can’t loop!
**Depth First Search**

- Agenda for depth first search:
  1. (S)
  2. (S A) (S B)
  3. (S A B) (S A D) (S B)
  4. (S A B C) (S A D) (S B)
  5. (S A B C E) (S A D) (S B)
  6. (S A D) (S B)
  7. (S A D G) (S B)

**Breadth First Search**

**Generic Algorithm**

- Agenda for depth first search:
  1. (S)
  2. (S A) (S B)
  3. (S A B) (S A D) (S B)
  4. (S A B C) (S A D) (S B)
  5. (S A B C E) (S A D) (S B)
  6. (S A D) (S B)
  7. (S A D G) (S B)

**Avoid Duplication**

- Don’t expand paths from the same node again: keep “extended” list
Hill Climbing

- Prefer paths that lead *toward* the goal!
- Need an estimate of distance to goal: “as the bird flies”

Beam Search

Beam width = 2

Variations in the Generic Method

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Extend which Q entry?</th>
<th>Add extensions to Q</th>
<th>Possible path guaranteed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth First</td>
<td>first</td>
<td>front</td>
<td>yes</td>
</tr>
<tr>
<td>Breadth First</td>
<td>first</td>
<td>back</td>
<td>yes</td>
</tr>
<tr>
<td>Hill Climbing w/ backtrack</td>
<td>first</td>
<td>front, sorted by H*</td>
<td>yes</td>
</tr>
<tr>
<td>Beam</td>
<td>best by H*</td>
<td>anywhere</td>
<td>no</td>
</tr>
<tr>
<td>Best First</td>
<td>best by H*</td>
<td>anywhere</td>
<td>yes</td>
</tr>
</tbody>
</table>
Search of Maps

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Backtracking</th>
<th>Extended list</th>
<th>Informed (heuristic info)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;British Museum&quot;</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Depth First</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Breadth First</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Hill Climbing</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Beam</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Hill Climbing in *Continuous Spaces* e.g., walk to top of mountain

- Infinite number of possible extension
- Often have only *local* estimate of best direction rather than distance to goal

Potential problems:
- Local maxima
- Plateau
- Ridge

Foothills (Local Maxima)

Plateau

This is a contour plot
Different Results from Different Notions of Distance

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Enqueuings</th>
<th>Extensions</th>
<th>Max queue size</th>
<th># nodes in path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth First</td>
<td>48</td>
<td>32</td>
<td>18</td>
<td>29</td>
</tr>
<tr>
<td>Breadth First</td>
<td>414</td>
<td>239</td>
<td>177</td>
<td>9</td>
</tr>
<tr>
<td>Breadth First</td>
<td>90</td>
<td>49</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Hill Climbing</td>
<td>27</td>
<td>14</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Beam</td>
<td>46</td>
<td>24</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>

Italic results use extended list as optimization. No difference if not listed in table.

Why? Artifact of demo implementation?

Ridge

How Much Work?
What Problems Can You Formulate as Search?

- Integration
- Class schedules
- Traveling Salesman
- VLSI layout
- Drug synthesis
- Sequencing manufacturing steps
- Diagnosis of co-occurring diseases
- ...