6.034
Search
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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 \textit{abstract} plans (= sequences of actions)
Map Search: Cambridge

Basic search

Enqueueings: 0
Extensions: 0
Queue size: 0
Path elements: 0
Path length: 0.0 k
Cambridge, Simplified

Diagram with nodes labeled A, B, C, D, E, and S, interconnected with arrows.
British Museum Algorithm

"placing monkeys in front of typewriters" in order to reproduce all the books in the British Museum"
BM (Random Search)

[ 'SASADASBSBCBCBCECECECECECECCBCEC...', 'SBADG', 'ASBSBABSBSBSBCECECECECBADG', 'SABCECECBSADG', 'SBADASADG', 'SADASBADG', 'SASADADG', 'SASBSASBSBCECBCECBCECBABABA...', 'SADG', 'SASBASBSASBCECECBECECBECCBADASAS...', 'SABSBCBADADASASADG', 'SASBADG', 'SADG', 'SADG', 'SADADADASBABSABABASBSADG', 'SABSABCBCECBCECBASBCBADG', 'SABSADAG', 'SBADASBADADG', 'SBCBABCBSBSBABADG', 'SBSADG', 'SASABCECECECECBCECCECECECBCECECBCEC...', 'SADASBSADAG', 'SBSBABSBSASBADASBSBCBCECBSBSBC', ...

'SADADASBSBABCBSADG',
'SADABADG',
'SASBSASBSBSBSBASBSBADG',
'SADABABADG',
'SADG',
'SBSBASBSASBSBCBADG',
'SBCECECECECECECECECBECECBECECECC...',
'SBCBSABCBCBCECBSBSASBSBCSABCBA...',
'SABADADASASBSADG',
'SBSADG',
'SABSBSABSBABCECBABCECBSABCECBSBSA...',
'SBABSBSBSASBSBCBABCBSBSASBSBADG',
'SBADASABCECECBECBASBSADG',
'SBSBSBSBSBSBCBCBADG',
'SADG',
'SBSADADAG',
'SBSADASBSBASBSBCBCECBSBSBSBC...',

...

]
“British Museum” Search

path can’t loop!
Depth First Search
Breadth First Search
Generic Algorithm

**Agenda for depth first search:**

(S)
(S A) (S B)
(S A B) (S A D) (S B)
(S A B C) (S A D) (S B)
(S A B C E) (S A D) (S B)
(S A D) (S B)
(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>

**H* is estimate of distance to goal**
## 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>“British Museum”</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)

This is a contour plot
Plateau
Ridge
# How Much Work?

<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></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>
<tr>
<td></td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*italic* results use extended list as optimization, no difference if not listed in table

Why? Artifact of demo implementation
Different Results from Different Notions of Distance
What Problems Can You Formulate as Search?

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