Thinking Too Much: Pathology in Pathfinding

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Introduction
- Real-time pathfinding ⇒ incomplete search methods ⇒ suboptimal actions
- Deeper lookahead believed to produce better actions
- Sometimes the opposite is true: pathology

Setting
- Pathfinding in grid world on maps from computer games
- Algorithm: LRTS [Bulitko & Lee 06]

Pathology Observed

<table>
<thead>
<tr>
<th>Degree of pathology</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>≥ 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pat. problems on-policy (%)</td>
<td>6.3</td>
<td>13.1</td>
<td>24.8</td>
<td>29.0</td>
<td>18.1</td>
<td>8.7</td>
</tr>
<tr>
<td>Pat. problems off-policy (%)</td>
<td>83.1</td>
<td>14.9</td>
<td>2.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

- A lot of pathology on-policy, little off-policy – why?

First Explanation
- LRTS steers the search to pathological areas
- Test: measure off-policy pathology in states visited on-policy ⇒ slightly more pathology than normally off-policy ⇒ explanation correct to a degree

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</tr>
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<tbody>
<tr>
<td>Pathological problems (%)</td>
<td>76.8</td>
<td>13.8</td>
<td>5.7</td>
<td>2.3</td>
<td>1.0</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Second Explanation
- Smaller lookahead depths benefit more from updates to the heuristic ⇒
  ⇒ depths closer to each other ⇒ larger depths more likely worse than smaller
- First test: on-policy experiment, ignore updates when measuring error ⇒
  ⇒ equal updates at all depths ⇒ less pathology than normally on-policy

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<tr>
<td>Pathological problems (%)</td>
<td>29.6</td>
<td>13.8</td>
<td>5.7</td>
<td>2.3</td>
<td>1.0</td>
<td>0.4</td>
</tr>
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- Second test: observe volume of updates to the heuristic ⇒
  ⇒ larger volume at smaller depths

Third Explanation
- Fewer searches at larger lookahead depths ⇒
  ⇒ depths closer to each other ⇒ larger depths more likely worse than smaller
- First test: on-policy experiment, search every move ⇒ less pathology than normally on-policy

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<tbody>
<tr>
<td>Pathological problems (%)</td>
<td>60.2</td>
<td>13.8</td>
<td>5.7</td>
<td>2.3</td>
<td>1.0</td>
<td>0.4</td>
</tr>
</tbody>
</table>

- Second test: observe number of states generated per move when searching every move ⇒ steeper increase than normally ⇒ depths farther from each other

Fourth Explanation
- Optimistic (admissible) heuristic ⇒ lowest values likely have largest error ⇒
  ⇒ state to move to has low value, hence large error; the more states one chooses from, the worse it gets ⇒ larger error at larger lookahead depths (more states to choose from) ⇒ pathology
- Test: use pessimistic heuristic instead
  lowest values likely have smallest error ⇒ state to move to has low value, hence small error; the more states one chooses from, the better it gets ⇒ small error at larger lookahead depths (more states to choose from) ⇒ less pathology

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</tr>
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<tbody>
<tr>
<td>Pathological problems (%)</td>
<td>13.9</td>
<td>4.1</td>
<td>8.3</td>
<td>22.9</td>
<td>27.7</td>
<td>23.1</td>
</tr>
</tbody>
</table>

- Indeed less pathology, but more severe when it appears

Conclusions
- First explanation
  • 23.2 % instead of 16.9 % pathological states among those visited by LRTS
  • Minor factor
- Second explanation
  • 70.4 % instead of 93.7 % pathological states without updates to the heuristic
  (= equal benefit of updates at all lookahead depths)
  • Difficult to get around: increased intrinsic benefit of updates at large depths would reduce the number of revisits, which decreases the benefit of updates
- Third explanation
  • 34.7 % instead of 93.7 % pathological states when searching every move
  • But: d times more states generated per move
  • States generated per problem:
    • 4.5 times more states generated at d = 10 when searching every move
    • Not d times more, though
    • Practical solution: find some middle ground
- Fourth explanation
  • Inconclusive, further investigation needed