Improved Heuristics for Multi-Agent Path Finding with Conflict-Based Search

Jiaoyang Li, Eli Boyarski, Ariel Felner, Hang Ma and Sven Koenig
jiaoyanl@usc.edu, eli.boyarski@gmail.com, felner@bgu.ac.il, {hangma,skoenig}@usc.edu

Abstract

Conflict-Based Search (CBS) and its enhancements are among the strongest algorithms for Multi-Agent Path Finding. Recent work introduced an admissible heuristic (called here CG) to guide the high-level search of CBS. In this work, we introduce two new admissible heuristics, DG and WDG, by reasoning about the pairwise dependency between agents. Empirically, CBS with both new heuristics significantly improves the success rate over CBS with the recent heuristic and reduces the number of expanded nodes and runtime by up to a factor of 50.

Heuristics for Conflict-Based Search

I. CG Heuristics [1]
1. Cardinal Conflicts
Two agents have a cardinal conflict iff all their shortest paths use the same vertex/edge at the same timestep.
2. Conflict Graph
Edges represent cardinal conflicts.
3. Minimum Vertex Cover (MVC)

II. DG Heuristics
1. Pairwise Dependency
Two agents are dependent iff every pair of their shortest paths has at least one conflict.
2. Dependency Graph

III. WDG Heuristics
1. Dependency Weight
The weight for a pair of agents is the difference between the minimum sum of the costs of their conflict-free paths and the sum of the costs of their shortest paths.
2. Weighted Dependency Graph

Experimental Results

Build Cardinal/Dependency/Weighted Dependency Graph

Identify Cardinal Conflicts for CG
Find the same singleton in both MDDs.

Identify Pairs of Dependent Agents for DG
Merge the two MDDs into a joint MDD.

Calculate Dependency Weights for WDG
Solve a 2-agent pathfinding problem (ignoring all other agents).

Table 1: h-values at the root node. k represents the number of agents.

<table>
<thead>
<tr>
<th>Empty map</th>
<th>Dense map</th>
<th>Large map</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>CG</td>
<td>DG</td>
</tr>
<tr>
<td>0 30</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>0.5</td>
<td>1.6</td>
</tr>
<tr>
<td>50</td>
<td>0.5</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Figure 1: Success rates (=% solved instances) within 1 min. ICBS always uses zero as h-values.

Notes: