MoHex: Computer Hex World Champion

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NSERC/iCORE/UofA GAMES/Schaeffer/Müller

4 Aug 2010
Hex

- properties: $n \times n$, no draw, monotonic, 1pw (swap)
- inferior cells
- connections

- books on Hex by Cameron Browne
  - Hex Strategy: Making the Right Connections
  - Connection Games: Variations on a Theme
Hex v Go

- stones on a grid
- connected groups
- subgame decomposition
- wide branching
- connect
- win/loss

territory score

MoHex: Computer Hex World Champion
inferior cells: dead/captured
inferior cells: reversible/dominated
connections: VC/SC
connections: mustplay
### alpha-beta players

<table>
<thead>
<tr>
<th>Year</th>
<th>Player</th>
<th>Game</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>Shannon</td>
<td>(Hex)</td>
<td>circuit saddle point</td>
</tr>
<tr>
<td>1950</td>
<td>Shannon</td>
<td>(Bird Cage)</td>
<td>circuit voltage drop</td>
</tr>
<tr>
<td>2000</td>
<td>Van Rijswijck</td>
<td>Queenbee</td>
<td>2-distance</td>
</tr>
<tr>
<td>2000</td>
<td>Anshelevich</td>
<td>Hexy</td>
<td>circuit + virt’l conn’n</td>
</tr>
<tr>
<td>2003</td>
<td>Melis</td>
<td>Six</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>H . . .</td>
<td>Mongoose</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>AHH</td>
<td>Wolve</td>
<td></td>
</tr>
</tbody>
</table>
MoHex basic framework

- MCTS: tree traversal, game simulation, tree update
- MoHex
  - tree traversal/update: AMAF on, UCT off
  - game simulation: bridge pattern
unused simulation pattern
MoHex enhancements: lock-free

- MCTS: lock-free parallelization
MoHex enhancements: tree knowledge

- MCTS: tree knowledge

1. node hits visit threshold: apply ICE/VCE
MoHex enhancements: tree knowledge

- MCTS: tree knowledge . . .

2. prune inferior/non-mustplay children
MoHex enhancements: tree knowledge

- MCTS: tree knowledge...

3. remove other children’s subtrees
MoHex enhancements: tree knowledge

- tree knowledge: typical position, ICE OFF ...
MoHex enhancements: tree knowledge

- tree knowledge: typical position, ICE ON . . .
Hex
MoHex
experiments

exp’s: scaling

![Graph showing percentage wins vs. number of threads/time multiplier for different configurations: single threaded, lock-free, locked, and time-scaled locked to 1-thread vs. 1-thread 1s/move. The graph illustrates trends in performance improvements.]

locked/lock-free/time-scaled-1-thread v 1-thread 1s/move

Arneson  Hayward  Henderson  MoHex: Computer Hex World Champion
exp’s: bridge/AMAF

<table>
<thead>
<tr>
<th></th>
<th>win %</th>
<th>Elo gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>bridge v — AMAF</td>
<td>64.7% ± 1.4%</td>
<td>105</td>
</tr>
<tr>
<td>AMAF + bridge v</td>
<td>73.9% ± 1.3%</td>
<td>181</td>
</tr>
</tbody>
</table>
exp’s: tree knowledge threshold

![Graph showing percentage wins for different knowledge thresholds and thread counts.](chart.png)

Hex
MoHex
experiments

MoHex: Computer Hex World Champion
exp's: opening book

Percentage wins

- no book
- 10k book
- 40k book
- 160k book

MoHex: Computer Hex World Champion
2009: Wolve v MoHex (white)
2009: Six v MoHex (white)
tournaments

2009: Yopt v MoHex (white)
## tournaments

<table>
<thead>
<tr>
<th>Olympiad</th>
<th>gold</th>
<th>silver</th>
<th>bronze</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>MoHex</td>
<td>Wolve</td>
<td>Six</td>
</tr>
<tr>
<td>6-0</td>
<td>3-3</td>
<td>2-4</td>
<td>1-5</td>
</tr>
<tr>
<td>2008</td>
<td>Wolve</td>
<td>MoHex</td>
<td>Six</td>
</tr>
<tr>
<td>9-3</td>
<td>8-4</td>
<td>4-8</td>
<td>3-9</td>
</tr>
</tbody>
</table>

### 242-game rounds

<table>
<thead>
<tr>
<th>2009</th>
<th>solver/book off</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoHex v Six</td>
<td>76.6 ± 3.6</td>
</tr>
<tr>
<td>MoHex v Wolve</td>
<td>49.2 ± 3.2</td>
</tr>
</tbody>
</table>
conclusion

- other games
  - Y
  - Havannah
  - Go
- MoHex todo
  - simulations: connection AMAF
  - tree: solver init’n
- MoHex summary
  - no big surprises