Doppelkopf: Game Information
- Trick based card game for four players
- 48 cards: double deck from nine to ace
- Two parties: re and kontra
- Solo and normal games
- Unique feature: parties not known in advance during normale games
- Goal: collect 121 (re) or 120 (kontra) card points

Doppelkopf: Game Rules

Announcements
- All reveal party of the announcing player
- All increase game value
- Some claim to win the game
- Some increase card points required for winning

Game Evaluation: Score Points
- +1 for winning
- +1/+2 for announcements
- +1 for every 30 card points achieved extra
- Extra score points for special tricks

The UCT Algorithm (Kocsis and Szepesvári 2006)
- Monte Carlo tree search algorithm based on sampling
- State of the art for many problems of acting under uncertainty

High Level Description
- Repeatedly perform rollouts starting in the current state
- Balance exploration and exploitation
- Incorporate rewards from rollouts into a game tree

Variations of the UCT Algorithm

Single-UCT
- One UCT computation
- Each rollout with a different card assignment

Ensemble-UCT
- Several UCT computations
- Fix a card assignment for each UCT computation

The Card Assignment Problem (CAP)
- Goal for unbiased players: compute solutions to the CAP uniformly at random
- Requirement: solve #CAP (#-complete) → infeasible

The Card Assignment Algorithm
While there are cards left to be assigned:
- If a card can be assigned to exactly one player: Assign that card to that player
- If a player requires as many cards as he can have: Assign those cards to that player
- If a player requires a ♠ Q: Assign a ♠ Q to that player
- Otherwise: Assign a random card to a random player

Experiments: Setup
- Two UCT players against two random players
- 1000 games with random card deals
- Repeat every game in every possible permutation of positions
- Total of 10000 rollouts for every decision
- Results: average score points per game with 95% confidence interval

Experiments: Ensemble-UCT Configurations
- X/Y: number of single UCT computations/rollouts

<table>
<thead>
<tr>
<th></th>
<th>ensemble-UCT (5/2000)</th>
<th>ensemble-UCT (10/1000)</th>
<th>random</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1.67 ± 0.12</td>
<td>1.83 ± 0.11</td>
<td>−1.75 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>2.10 ± 0.11</td>
<td>1.70 ± 0.10</td>
<td>−1.90 ± 0.05</td>
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</tbody>
</table>

→ trade-off between the number of different card assignments and the quality of the computation per card assignment

Experiments: Influence of Announcement Making

<table>
<thead>
<tr>
<th></th>
<th>announcing ensemble-UCT</th>
<th>no announcing ensemble-UCT</th>
<th>random</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.70 ± 0.07</td>
<td>0.79 ± 0.05</td>
<td>−1.25 ± 0.04</td>
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<tr>
<td></td>
<td>0.48 ± 0.06</td>
<td>0.19 ± 0.05</td>
<td>−0.33 ± 0.04</td>
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</tbody>
</table>

→ making announcements crucial for performance

Experiments: Ensemble-UCT versus Single-UCT

<table>
<thead>
<tr>
<th></th>
<th>ensemble-UCT</th>
<th>single-UCT</th>
<th>random</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.52 ± 0.11</td>
<td>−1.25 ± 0.08</td>
<td>−1.63 ± 0.05</td>
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→ using few, but fixed card assignments better than using many

Experiments: Playing Against a Human
- 24 games human vs. ensemble-UCT

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<thead>
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<th>human ensemble-UCT</th>
<th>random</th>
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</thead>
<tbody>
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<td></td>
<td>43</td>
<td>−9</td>
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<td></td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>

→ Analysis of ensemble-UCT playing style:
- Too many solos (works well against random players)
- Always makes announcements when playing solo, but rarely in normal games
- The fewer options remaining, the stronger the game play (not a surprise)

Possible Improvements
- Separate hand evaluation algorithm
- Analyze and reduce bias of card assignment algorithm
- Domain specific knowledge for simulation phase of rollouts
- Drop assumption that opposing players behave like UCT players
- Reuse information from decisions at previous game states

Contributions
- Doppelkopf as a benchmark problem
- Baseline UCT players
- Card assignment algorithm
- Ensemble-UCT for more stable UCT performance