A Doppelkopf Player Based on UCT

Silvan Sievers Malte Helmert

University of Basel
Basel, Switzerland

September 25, 2015

Introduction

- Doppelkopf: card game with similarities to skat, but larger state space
- Unique feature: parties usually only revealed during card play!
- UCT: state-of-the-art algorithm for many applications of acting under uncertainty

Outline

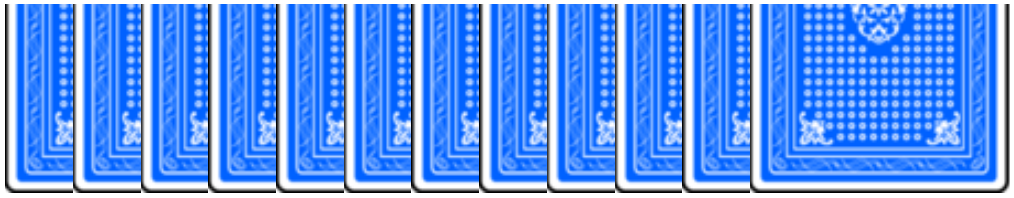
Game Rules

- 4 players, 2 changing parties
- 48 cards: double deck from nines to aces
- Total of 240 card points
- Goal: collect 121 card points

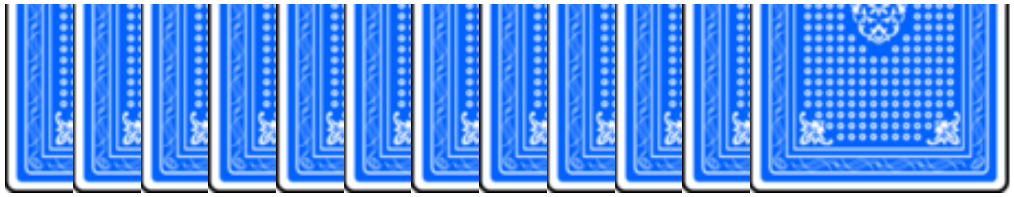
Game Rules

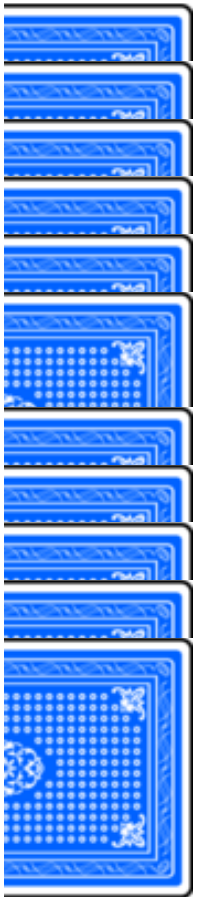
- 4 players, 2 changing parties
- 48 cards: double deck from nines to aces
- Total of 240 card points
- Goal: collect 121 card points
- Normal game:
  - Trump suit: ♡10, queens, jacks, remaining ♢
  - Off suits: remaining ♣, ♠, ♡
  - Two parties: re and kontra (players with and without ♣Q)

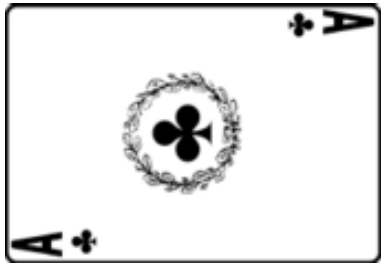
Tricks: Example



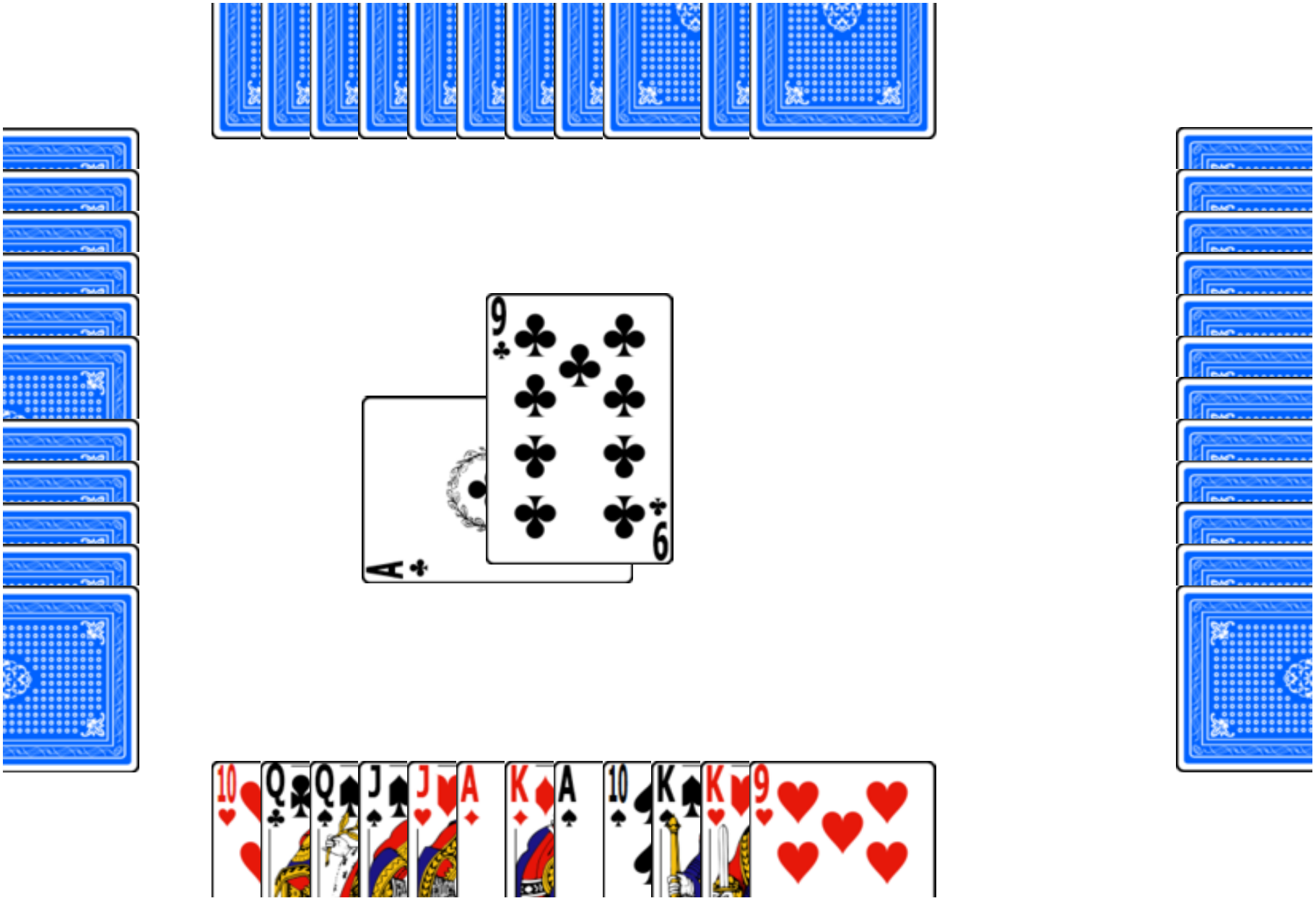
Tricks: Example



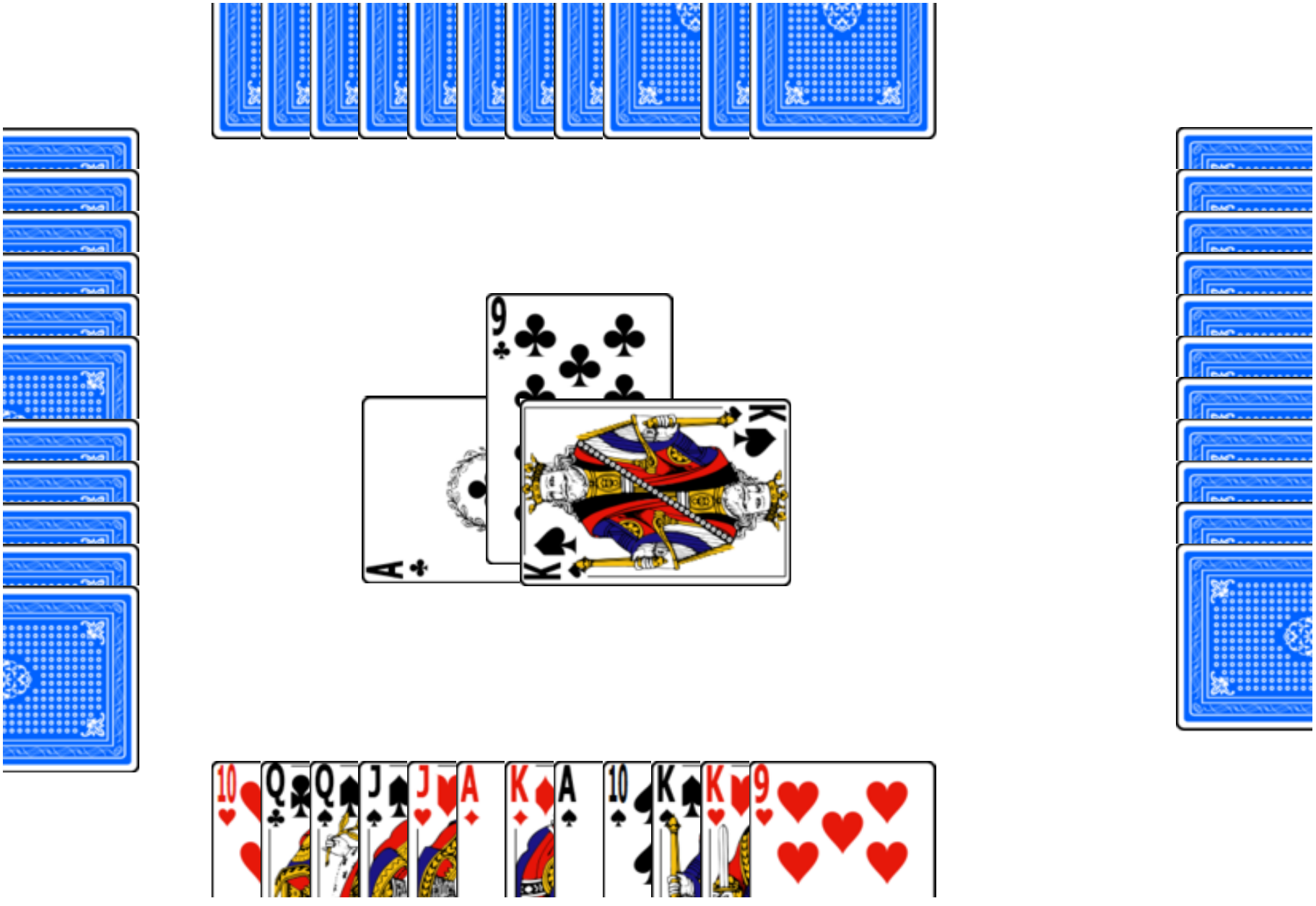




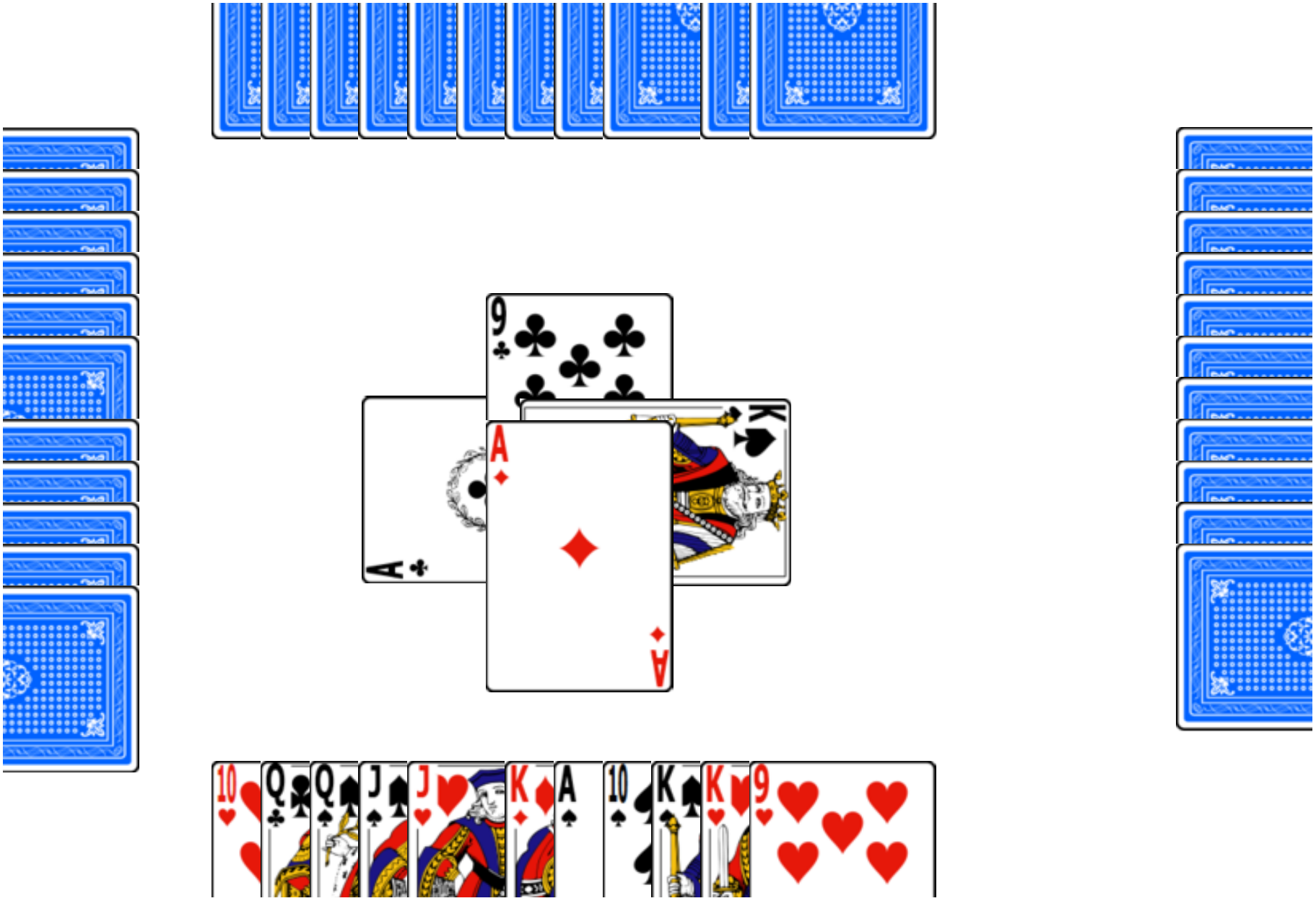
Tricks: Example



Tricks: Example



Tricks: Example



Game Rules

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

Game Rules

- Announcements:
  - All reveal party of the announcing player
  - All increase the game value
  - Some increase card points required for winning
- Game evaluation: score points
  - +1 for winning
  - +2/+1 for different announcements
  - +1 for every 30 card points achieved above the threshold required for winning
  - +1 through winning special tricks

Outline

Why UCT?

- Goal: determine the "best" move
- Problem: computing all possibilites infeasible
- UCT (Kocsis and Szepesvári 2006):
  - Monte Carlo tree search algorithm based on sampling
  - State of the art for scenarios with uncertainty

The UCT Algorithm

- Repeatedly perform rollouts of the game:
  - Assume a fixed card assignment
  - Traverse the game tree, choosing successors by balancing exploration and exploitation
  - From leaf nodes on: Monte Carlo simulation
  - End at terminal game states: compute rewards
  - Propagate back information

Variations

- Varying the number of card assignment used:
  - Single-UCT: regular UCT, each rollout with a different card assignment
  - Ensemble-UCT: several UCT computations, each with a different fixed card assignment

Outline

Problem Statement

The Card Assignment Problem (CAP)

- Given a game state and a player to move:
  - Assign all remaining cards to all other players
  - Respect all available information from the game history

Problem Statement

The Card Assignment Problem (CAP)

- Given a game state and a player to move:
  - Assign all remaining cards to all other players
  - Respect all available information from the game history

- Goal for an unbiased UCT player: compute solutions to the CAP uniformly at random
- Requirement: computing the number of solutions of the CAP, i.e. solving #CAP
- Complexity of #CAP: #P-complete

The Card Assignment Algorithm

While there are cards left to be assigned:

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

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

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

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

Properties of the Algorithm

- Only generates consistent card assignments
- Terminates after at most as many iterations as cards need to be assigned to players
- Solutions not generated uniformly at random:
  - Number of card slots of players not considered
  - Assignment of ♣Q prioritized over other cards
  - Number of possible assignments not considered

Outline

Setup

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

Ensemble-UCT Configurations

- X/Y: number of single UCT computations/rollouts

ensemble-UCT (5/2000)	ensemble-UCT (10/1000)	random
1.67 ± 0.12	$\mathbf{1.83 \pm 0.11}$	(-1.75 ± 0.05)

ensemble-UCT (10/1000)	ensemble-UCT (20/500)	random
$\mathbf{2.10 \pm 0.11}$	1.70 ± 0.10	(-1.90 ± 0.05)

Ensemble-UCT Configurations

- X/Y: number of single UCT computations/rollouts

ensemble-UCT (5/2000)	ensemble-UCT (10/1000)	random
1.67 ± 0.12	$\mathbf{1.83 \pm 0.11}$	(-1.75 ± 0.05)

ensemble-UCT (10/1000)	ensemble-UCT (20/500)	random
$\mathbf{2.10 \pm 0.11}$	1.70 ± 0.10	(-1.90 ± 0.05)

$\rightarrow$ trade-off between the number of different card assignments and the quality of the computation per card assignment

Influence of Announcement Making

ensemble-UCT		random
announcing	no announcing	
$\mathbf{1.70 \pm 0.07}$	0.79 ± 0.05	(-1.25 ± 0.04)

single-UCT		random
announcing	no announcing	
$\mathbf{0.48 \pm 0.06}$	0.19 ± 0.05	(-0.33 ± 0.04)

Influence of Announcement Making

ensemble-UCT		random
announcing	no announcing	
$\mathbf{1.70 \pm 0.07}$	0.79 ± 0.05	(-1.25 ± 0.04)

single-UCT		random
announcing	no announcing	
$\mathbf{0.48 \pm 0.06}$	0.19 ± 0.05	(-0.33 ± 0.04)

$\rightarrow$ making announcements crucial for performance

Ensemble-UCT versus Single-UCT

ensemble-UCT	single-UCT	random
$\mathbf{4.52 \pm 0.11}$	-1.25 ± 0.08	(-1.63 ± 0.05)

Ensemble-UCT versus Single-UCT

ensemble-UCT	single-UCT	random
$\mathbf{4.52 \pm 0.11}$	-1.25 ± 0.08	(-1.63 ± 0.05)

$\rightarrow$ using few, but fixed card assignments better than using many card assignments

Analysis of UCT Players

- Two sets of 24 games human vs. ensemble-UCT:
  - 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

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

Conclusion

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

The End

Thank you!