

Creating a Hand Solver for the Card Game Bridge

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Bridge: A Walkthrough

Bidding Phase

- 4 player game board
- Suit rankings
- Partner bidding & no-communication
- Trump suits

Playing Phase

- Dummy player
- Tricks
- Card counting



A sample bidding box.

The Problem

- Bridge is very difficult
- Lack of information
- Silent communication
- Multiple phases



The Problem (cont.)

- Inference of bid meanings for play
- Lack of gameplay modeling for incomplete states
- Extreme complexity



Double Dummy Solver and the Fundamental Flaw

- DDS: A powerful solver of games given current full state
- Revisit: Complexity of modeling all states
- Estimate game state using hand solver
- **Core assumption:** Focus on the relevant cards



A sample play state. Note that we do not have access to all the information.

Novelty

Bid-aware heuristic



SIMPLE SCORING READY RECKONER (Non Vul)

**CONTRACT DEFEATED :- 50 pts per trick short
(regardless of denomination).**

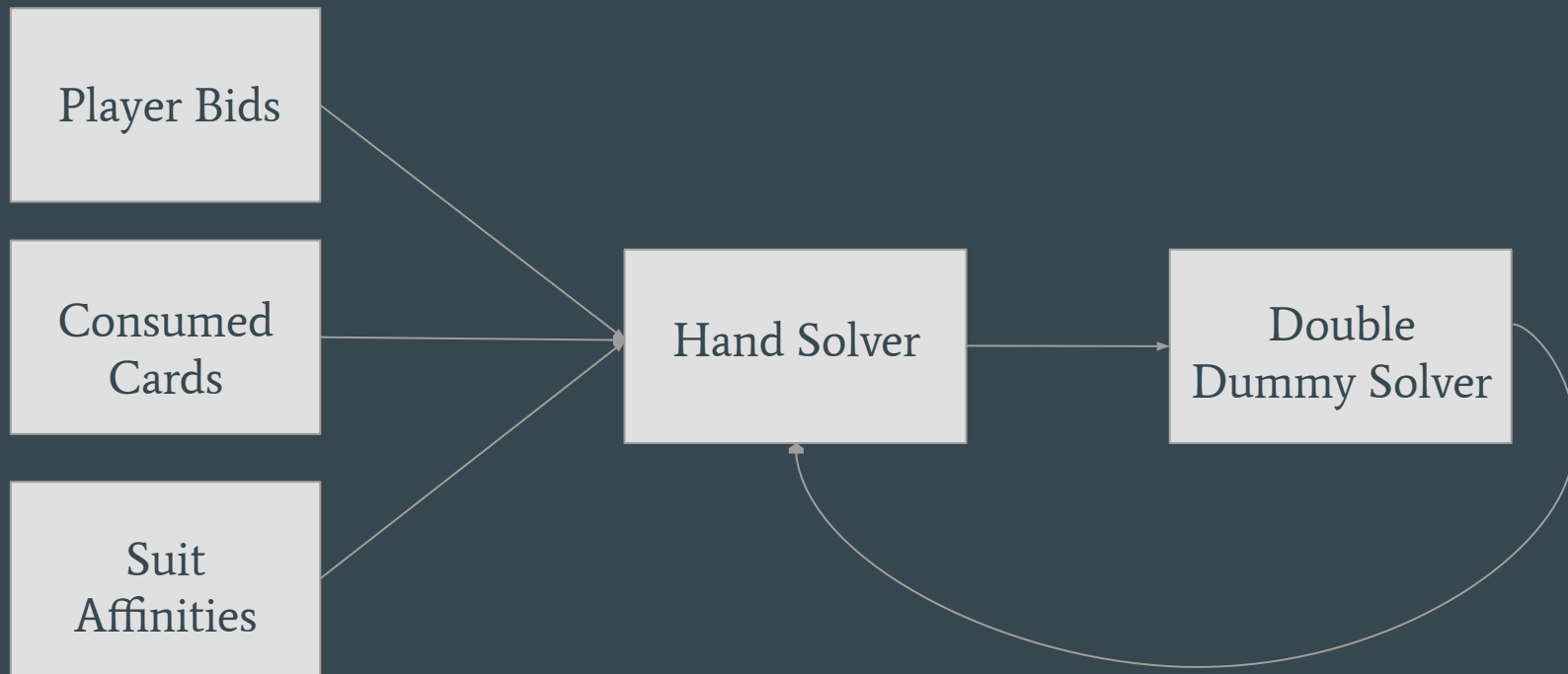
Contract Made			Contract Made			Contract Made			Contract Made						
BID	TRKS	SCORE	BID	TRKS	SCORE	BID	TRKS	SCORE	BID	TRKS	SCORE				
1♣	7	70	2♣	8	90	3♥	9	140	5♣	11	400				
	8	90		3♠	10		170	5♦		12	420				
	9	110			3NT		11			200	5♥	13	440		
	10	130					3NT			12		230	5♥	11	450
	11	150								3NT		13		280	5♥
12	170	3NT	9			400			5♥			13		510	
13	190		3NT	10		430		5♥				13		510	
7	80			2♥	11	460					5NT	11		460	
8	110				2♠	12	490					5NT	12	490	
9	140					2♠	13			520			5NT	13	520
10	170	2NT					10		130	6♣				12	920
11	200		2NT				11	150	6♦					13	940
12	230			2NT			12	170			6♥			12	980
13	260				2NT		13	190				6♥		13	1010
7	90					2NT	10	420					6NT	13	1020
8	120	2NT					11	450		6NT				12	990
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12	240				2NT		13	520				6NT		13	1020
13	270					2NT	10	430					6NT	1	

Partnership Learning

Methods: High Level Overview

- Use bids to determine relative hand biases towards suit
- Hand solver creates hand replicas based off of played cards & previous hand bids
- Evaluate using DDS to solve state, determine move

Methods: Systems Architecture



Methods: Hand Solver Heuristics

- Consider each suit to have a “weight” indicating how many cards the player has in that suit
- Prioritize highest bids of each suit as indicator for suit strength
- “Persistence” of bids on a certain suit => higher weight
- Normalize to cap to highest bid strength + persistence to prevent overload
- Weight against bidding player to provide harshest outcome

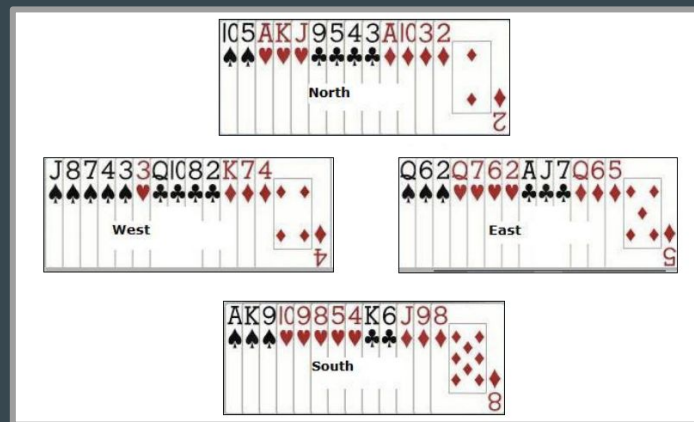
Methods: Double Dummy Solver Algorithm

- As mentioned before, searching all possible states is unviable
- DDS uses “quick tricks” and trump orders to limit unneeded searches
- It follows this with a brute-force evaluation of a state to determine all possible winning cards
- When order does not matter, it transposes into other possibilities to avoid searches
- Overall goal: limit branching ratio to quickly evaluate possible paths

Playing Phase: Hand Solver

- Attempt to address incomplete information issue
- Hand predictor based off of game state
- Evaluates cards used in game state and bids
- Fed into DDS to find ideal move

A hand with final bid of 2 Hearts.



<p>Optimum: NS 3N+2; +460</p>	<p>♠ Q 8 7 6 4 ♥ A ♦ K Q 10 2 ♣ Q 10 7</p>	<p>Bridge Solver Online: John Goucher</p> <p>Double Dummy Solver Module: Bo Haglund</p>																														
<p>♠ 10 5 3 2 ♥ J ♦ A 6 5 4 ♣ A J 4 3</p>		<p>♠ J ♥ K Q 7 6 3 2 ♦ 7 3 ♣ 9 8 5 2</p>																														
<p>13 6 10 11</p>	<p>♠ A K 9 ♥ 10 9 8 5 4 ♦ J 9 8 ♣ K 6</p>	<table><tr><th></th><th>♠</th><th>♥</th><th>♦</th><th>♣</th><th>NT</th></tr><tr><td>N</td><td>1</td><td>4</td><td>1</td><td>5</td><td>5</td></tr><tr><td>S</td><td>1</td><td>4</td><td>1</td><td>5</td><td>5</td></tr><tr><td>E</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr><tr><td>W</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr></table>		♠	♥	♦	♣	NT	N	1	4	1	5	5	S	1	4	1	5	5	E	-	-	-	-	-	W	-	-	-	-	-
	♠	♥	♦	♣	NT																											
N	1	4	1	5	5																											
S	1	4	1	5	5																											
E	-	-	-	-	-																											
W	-	-	-	-	-																											

The predicted version of that same hand.

Playing Phase: DDS

- A pre-crafted state solver
- Takes used cards, all hands and solves game state
- Works off of “double dummy” assumption necessitating hand solver

<p>Optimum: NS 4S; +420 LoTT: 18-18 = 0</p>	<p>♠ A₅ K₅ 10₃ 9₃ 7₃ ♥ Q₄ 10₄ 9₄ 6₄ ♦ A₅ ♣ A₄ 10₅ 9₅</p> <p>1</p>	<p>Contract: 2♦ by W</p> <p>NS Tricks: 0 EW Tricks: 0</p>																														
<p>♠ 8 ♥ A J 7 5 4 3 ♦ J 10 6 ♣ Q 8 4</p>		<p>♠ Q 6 5 4 ♥ ♦ K 9 8 7 4 3 2 ♣ 7 3</p>																														
<p>□ KR ?</p> <p>17 8 5 10</p>	<p>♠ J 3 2 ♥ K 8 2 ♦ Q 5 ♣ K J 6 5 2</p>	<table><tr><td></td><td>♠</td><td>♦</td><td>♥</td><td>♣</td><td>NT</td></tr><tr><td>N</td><td>4</td><td>-</td><td>3</td><td>4</td><td>-</td></tr><tr><td>S</td><td>4</td><td>-</td><td>3</td><td>4</td><td>-</td></tr><tr><td>E</td><td>-</td><td>2</td><td>-</td><td>-</td><td>-</td></tr><tr><td>W</td><td>-</td><td>2</td><td>-</td><td>-</td><td>-</td></tr></table>		♠	♦	♥	♣	NT	N	4	-	3	4	-	S	4	-	3	4	-	E	-	2	-	-	-	W	-	2	-	-	-
	♠	♦	♥	♣	NT																											
N	4	-	3	4	-																											
S	4	-	3	4	-																											
E	-	2	-	-	-																											
W	-	2	-	-	-																											

An example of a DDS interface solving a hand.

Playing Phase: DDS (Continued)

Bridge Solver Online:

Input Hand OR browse to a PBN, DLM, or bridge base online LIN file : No file chosen

Optimum:
NS 4S; +420
LoTT: 18-18 = 0

♠ A K 10 9 7
♥ Q 10 9 6
♦ A
♣ A 10 9

Bridge Solver Online:
John Goacher
Double Dummy Solver Module:
Bo Haglund

♠ 8
♥ A J 7 5 4 3
♦ J 10 6
♣ Q 8 4

1

♠ Q 6 5 4
♥
♦ K 9 8 7 4 3 2
♣ 7 3

☐ KR ?

17
8 5
10

♠ J 3 2
♥ K 8 2
♦ Q 5
♣ K J 6 5 2

	♠	♦	♥	♣	NT
N	4	-	3	4	-
S	4	-	3	4	-
E	-	2	-	-	-
W	-	2	-	-	-

- DDS portal of choice: Bridge Solver Online
- Offers PBN importation for transfer
- Provides visuals for optimum trick and hand directions that DDS creates

Results

- Matches bid to power in 80% of cases
 - Occasionally undershoots
 - Heuristic weights to worst case
- Models state to -1 trick potential in all test cases
 - Can do better, but pessimistic algorithm avoids unreasonable weighting

Optimum:
EW 5Dx; +500

♠ A K 9
♥ 10 9 8 5 4
♦ J 9 8
♣ K 6

Bridge Solver Online:
John Goacher

Double Dummy Solver Module:
Bo Haglund

♠ 8 5
♥
♦ 7 6 5 4 3 2
♣ A Q 10 4 3

♠ Q 10 6 4
♥ A 6
♦ K Q 10
♣ 9 8 7 2

6 11 11
 12

♠ J 7 3 2
♥ K Q J 7 3 2
♦ A
♣ J 5

	♠	♦	♥	♣	NT
N	-	-	4	2	-
S	-	-	4	2	-
E	1	2	-	-	-
W	1	2	-	-	-

Optimal cards:

card	=>	score
4S		7
8S		7
QS		7
KD		7
AH		7
2D		7
TD		7
7C		7

Optimum:
EW 5Dx; +500

♠ A K 9
♥ 10 9 8 5 4
♦ J 9 8
♣ K 6

Contract: 2♦ by W

NS Tricks: 0
EW Tricks: 0

♠ 8 5
♥
♦ 7 6 5 4 3 2
♣ A Q 10 4 3

♠ Q 10 6 4
♥ A 6
♦ K Q 10
♣ 9 8 7 2

6 11 11
 12

♠ J 7 3 2
♥ K Q J 7 3 2
♦ A
♣ J 5

	♠	♦	♥	♣	NT
N	-	-	4	2	-
S	-	-	4	2	-
E	1	2	-	-	-
W	1	2	-	-	-

Optimal solutions found by the DDS, with visual representation of those solutions.

Next Steps, Limitations & Future Work

- Implement as a single GUI so that all solutions are considered
- Further development of hand solver
 - Deeper consideration of opening trick
 - Trick dynamics between cycles
 - More consideration of no-trump bids
 - Would likely lead to higher accuracy and smaller required compromises

Conclusion

- Hand solver for resolving incomplete information problem
- Learning through rounds and affinities towards bids
- Novel DDS implementation with predictive hand generation

Thank you for listening!

Credits and References

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