Single-suit Bridge Play: computer out-performs humans

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Over the last few years, the public profile of computer game-playing has reached new heights with the feats of the chess computer Deeper Blue. In many other games as well, researchers in industry and academia have produced computer players that can hold their own against the best humans. Until recently, though, computer analysis of Bridge has been far inferior to that of human experts.

Times are changing. Over the last few years, Matt Ginsberg has developed a Bridge program that can compete against good human players on complete deals. At the same time, we have also been working on Bridge, producing a system called Finesse. This system is designed to find lines of play under the toughest possible assumptions of 'best defence', where the defenders always find the best responses to your actions. We formalised the underlying mathematical theory, and investigated what is required to play optimally.

For the task of solving card combinations, Finesse performs very, very well. In fact, it is the first computer program capable of consistently producing optimal play on a significant aspect of Bridge. We demonstrated this by testing Finesse against 650 single-suit problems taken from the ACBL's Official Encyclopedia of Bridge. Finesse gets them all right. This is a substantial advance over any previous computer program. In fact, it is questionable whether any human players could match this performance. For example, Finesse sometimes discovers new lines of play that are better than even the Encyclopedia's. Below, we will give two examples of this, and afterwards describe the Bridge knowledge that Finesse uses to solve such problems.

Two New Lines of Play

Here is problem number 568 from the Encyclopedia, with the Encyclopedia's (incorrect) solution.

A T x x
N
W E
S
9 x x

For two tricks, lead small to the nine. If this loses to West, finesse the ten next. If an honour appears from East on the first round, lead small to the nine again; if East shows out or plays another honour, finesse the ten next; otherwise play to the Ace. Chance of success: 51%

This is one of the Encyclopedia's more complicated lines of play. It succeeds for the 4-2 splits KQJx-xx, Kxxx-QJ, Qxxx-KJ, and Jxxx-KQ, for all 3-3 splits except xxx-KQJ, and also when the cards are split 6-0 or 5-1. Summing the probabilities of these distributions verifies the chance of success given by the Encyclopedia.

To check this solution, we looked up the problem in Jean-Marc Roudinesco's 'Dictionary of Suit Combinations'. Roudinesco gives the same line of play, with the same chance of success. However, when we give this problem to Finesse, we obtain a different solution, which Finesse claims is better. Let's look at this new line of play (described in a similar format to the Encyclopedia's explanations):

> Lead small to the nine. If East plays low and West wins, cash the Ace; if West plays an honour under this Ace, continue the third round by ducking, but if East plays an honour, finesse the ten. If an honour appears from East on the first round, run the nine and then finesse the ten. Chance of success: 57.5%.

The crucial distributions in this problem are the 4-2 splits where West holds any two of the KQJ as well as two low cards. These are the cases KQxx-Jx, QJxx-Kx, and KJxx-Qx. Since the lines of play given by the Encyclopedia and Finesse both recommend starting by leading low towards the nine, these distributions confront East with a choice. Go up with the honour or play low?

Let's consider first what happens if East plays low. The finesse of the nine will then lose to West. In the Encyclopedia's line of play, the continuation is then to finesse the ten, which will lose to East's honour, making two tricks impossible. Finesse's continuation, on the other hand, is to cash the Ace, which drops East's honour (on the third round, the ten is then finessed, which brings in the second trick).

But what happens if East goes up with the honour on the first round? For the Encyclopedia, the continuation will be to lead small to the nine and then to cash the Ace. This again fails to produce two tricks. Finesse, on the other hand, runs the nine and then finesses the ten, which is successful.

So, Finesse's line of play is better than the Encyclopedia's whenever the defenders' cards are split KQxx-Jx, QJxx-Kx, or KJxx-Qx (a probability of 0.1453). But, by cashing the Ace on the second round after East plays low on the first, it will no longer be possible to win two tricks for the distributions KQJx-xx or KQJxx-x (a probability of 0.0848). Overall, then, the probabilities favour Finesse's solution over the Encyclopedia's by $0.1453 - 0.0848 = 0.0605$.

An interesting footnote to this problem is that, in the event that East plays an honour on the first round, there are no down-sides to Finesse's continuation of 'run the nine, then finesse the ten'. That is, the Encyclopedia's 51% chance of success would not be affected if this continuation replaced the more complicated 'lead small to the nine again; if East shows out or plays another honour, finesse the ten next; otherwise play to the Ace'. This appears to be a case where both the Encyclopedia and the Dictionary simply over-complicate the solution.

A second example where Finesse's solution is better than the Encyclopedia's is problem 601.

Q x x x x

N
W E
S

J 9 x

For three tricks, lead small to the Queen. If it loses to East, Finesse the nine next; if an honour appears from West on the first round, lead to the Queen again. Chance of success: 48%

This line of play succeeds for all 2-3 splits of the outstanding cards except Tx-AKx, and all 3-2 splits except ATx-Kx and KTx-Ax (the Encyclopedia introduces a slight rounding error by rounding up the probability of these distributions from 0.4748 to 0.48). Again, the Dictionary of Suit Combinations also gives a chance of success of 47.48% (although it suggests a slightly different line of play). And again, Finesse's line of play is different:

For a chance of success of 50.3%, lead low towards the Jack, and

1. if West wins, lead small from the South hand; if West now plays the ten, finesse the Queen, otherwise duck.
2. if West's ten drops, lead small to the nine,
3. if East goes up with an honour, lead towards the Jack.

This line of play wins three tricks for all 2-3 splits except Kx-ATx and Ax-KTx, and for all 3-2 splits except AKx-Tx. In total, this is the same number of distributions that the Encyclopedia's line wins for. However, Finesse's line of play also manages something that the Encyclopedia's doesn't: to win in a 1-4 distribution, when West holds the singleton ten (a probability of 0.0283).

Of particular interest here is how Finesse proceeds when the first-round finesse loses, and West then follows the lead from the South hand with a low card. The question then is 'Finesse the Queen, or duck?' Finesse's solution (duck, unless you see the ten) illustrates something interesting about the system: Finesse realises that each card played by the defenders changes the probabilities, and that the best line of play will generally be conditional on the cards the defenders have revealed so far. What is remarkable, though, is that this is one of only two examples out of the 650 where the card played by the first defender on a trick changes the probabilities to the extent that the declarer's next play (finesse, cash or duck) should be altered. We demonstrated this by testing a second version of Finesse that only calculates probabilities after every completed trick, not every card play. This program solved all the Encyclopedia examples except for this problem and one other (number 622).

How Does the Computer Do It?

In designing computer programs to play games, the challenge is to avoid being swamped by the overwhelming number of possible moves: at any point in the game there are many possibilities, and the consequences of any of these may be important. Yet in Bridge (as in many other games) human players do not exhaustively consider all possible sequences of moves. Instead, they plan their play using higher-level concepts and chunks of knowledge gained from experience. For example, one possible type of Bridge knowledge is a familiarity with common tactics such as taking finesses and cashing winners.

The incorporation of high-level knowledge was a guiding principle behind our design of Finesse. We first codified knowledge about Bridge as precise high-level tactics, and then constrained the computer to construct lines of play using only these tactics. We then implemented our mathematical theory so that Finesse could pick out the best line of play from among the alternatives it investigated for any card combination.

To produce our tactics, we generalised from examples of card play we found in Bridge books. As we mentioned in the introduction, the tactic set we produced in this way is sufficient to generate optimal solutions for all the problems in the Encyclopedia of Bridge. What is perhaps surprising, though, is that just seven tactics were all that was needed. Although the tactics represent knowledge that human players usually learn through experience, we are not aware of any Bridge text that explicitly presents the required knowledge in such a compact and manageable way.

Finesse's tactics are easy to explain to Bridge players. The two simplest tactics are ‘cash’ and ‘duck’. These correspond to cashing a master and ducking a round. Another relatively simple tactic is one we call ‘sequence’. This tactic handles situations where there are enough high cards to play one on each trick and there is no element of manoeuvre. For example:

K Q J	Q 8 3
N W E S	N W E S
9 5 2	K J 5

The most interesting tactics are the remaining four, which are for finessing. In describing these tactics, we will call a ‘finesse card’ a card with which declarer tries to win a trick, even though it is not a master. Also, the ‘lead card’ is the card that declarer leads in order to initiate the finesse. And a ‘cover card’ is a card in the third hand capable of beating at least one of the outstanding cards above the finesse card. The four types of finesse are then:

Type 1. The finesse card and cover card are in the same hand (i.e., they are a tenace), opposite the lead card.

A Q 10	A J 10
N W E S	N W E S
9 4 2	8 6 5 3

Type 2. The finesse card is also the lead card, and the opposite hand contains the cover card, and also a duck card. Furthermore, the finesse card must belong to a sequence (two or more cards with no outstanding cards between them) held by the declarer.

A Q x x	A x x
N W E S	N W E S
J x x	Q J

Type 3. The finesse card and a duck card are opposite the lead card. No cover card is necessary.

K Q 2	A 6 4
N W E S	N W E S
8 5 3	Q 7 5

Type 4. The finesse card is the lead card and is run to the third hand, which holds a cover card. The card directly below the finesse card is held by the defence, and the card directly below this is held by North or South. There must be a continuation for the next trick that uses this card as a finesse card for a Type 1 or Type 2 finesse.

K 5 2	A 9 8
N W E S	N W E S
A J 9	K J 4

Building in knowledge about these tactics takes time, but also provides some valuable paybacks. In addition to helping FINESSE *find* solutions, FINESSE's tactics also help it to *explain* its solutions to humans. This is in contrast to most game-playing programs. For instance, ask a typical chess-playing program why it made a move and you are lucky to get back a screenful of numbers. FINESSE is different. It can automatically produce explanations like 'Finesse the Queen. This leads to two tricks if West holds the King.' The explanations produced by FINESSE are easily understandable because the lines of play themselves are built using Bridge concepts.

What Lies in the Future?

Solving Bridge problems is hard. It is maybe less surprising that humans make mistakes than that they can do as well as they do. For instance, the total number of outright errors discovered by FINESSE in the Encyclopedia is just nine. Of these, one is a simple typo (number 609), and two are cases where the probability calculation is slightly wrong (numbers 31 and 430). For the remaining six errors, FINESSE's line of play actually has a better chance of success than the Encyclopedia's (numbers 289, 477, 543, 568, 601, and 622), but the two problems we have described in this article are the only ones for which the Dictionary of Suit Combinations is also wrong.

Although FINESSE already does very well on the Encyclopedia problems, work on the system continues. For example, one thing our program won't do is try to take advantage of mistakes by the defence. The Encyclopedia attempts to deal with this aspect of the game, often including extra explanations such as 'This line offers extra chances if West is tempted to win with the KTxxx.' This can be a tricky problem, though. FINESSE identifies a total of seven problems where the Encyclopedia's given solution actually makes unstated assumptions about the defence playing sub-optimally (numbers 437, 459, 541, 548, 590, 591, and 595).

In the long-term, we are looking at how our use of tactics can be extended to produce accurate solutions for complete deals. Our short-term goal, though, is to create a powerful tutor for single-suit play. This will be a tutor that knows about Bridge; a tutor that can explain in simple English; a tutor that never gets tired. Also, it will be a tutor that teaches you to play as well as the best humans. And, sometimes, even better.