Computer Aided Software for No-limit Texas Hold'em Poker

Wen-Hsing Lai, and Zi-Hao Huang

Abstract—No-limit Texas Hold'em Poker, with the features of multiple players, imperfect knowledge, risk and deception management, is a very important platform for implementing complex topics for machine intelligence, and developing computer programs that play poker at human level is considered to be a big challenge. Our goal is to establish a No-limit Texas Hold'em aided software to help players make decisions and gain steady profit. The aided software we built is based on expert rules, which are designed basically on simulated/enumerated win rate. First, we simulated/enumerated the win rate. Based on the win rate, we sort the strength of drawing hands and made hands in every round and build betting strategy rules by an expert from expert experience. The test experiments are performed on three world-renowned online poker games. The result shows that our aided software is very profitable. In 100 hands, averagely, our profit is 3.65 times in no-limit 2 and 3.95 times in no-limit 5 of the money we buy-in.

Keywords—Expert Rules, No-limit Texas Hold'em Poker, Simulation/Enumeration, Win Rate.

I. INTRODUCTION

With well-defined rules and goals, game is a very important platform for implementing complex topics in artificial intelligence. However, most studies focus on two player games, like chess, in which, players always have complete knowledge of the game. That is, it is deterministic zero-sum games with perfect information. This kind of game can achieve high performance with brute-force search of the game trees unless the game tree, for example, of go, is far too large. On the other hand, for imperfect information games, such as multiple player poker, search alone is insufficient to win, because the other players' cards are not known. Hence the traditional game-tree approach can no longer be applied. Poker, with the features of multiple players, imperfect knowledge, risk and deception management, therefore, is a very important research topic for machine intelligence, and developing computer programs that play poker at human level is considered to be a challenge.

No-limit Texas Hold'em is one form of poker. Factors such as seating position, the stage of the tournament and prior bets can intensely influence a player's decision. To make good profit in Texas hold'em is not easy for machines, since it needs statistics, simulation, expert experience, and psychological consideration.

The computer-based approaches to poker can be classified into three architecture descriptions: expert system, game-theoretic optimal play, and simulation/enumeration-based systems [1]. An expert system is essentially a set of specific rules. Building such rules could be very laborious. For a complex game like poker, plus the multi-player environment of No-limit Texas Hold'em, enormous branching factor would make the calculation and storage of the game-theoretic optimal strategy become impractical. Simulation is the method to measure the winning chances by playing the hand out several times with random opponent hands and upcoming community cards. On the other hand, enumeration evaluates each possible condition to get exact probabilities.

However, the assumption made by classical game theory that players always act in a way to directly maximize their wins are often violated. It turns some research of poker to evolutionary methods to resolve the issue [2]-[5]. Besides, with the advances in data processing capability, using the information of past games also becomes a trend, for example, using knowledge of human by copying strategies of the best human players by analyzing past games between them [6], and a data mining approach to mine data gathered from online poker in order to explain what signifies successful play [7].

Nevertheless, just knowing the probability estimates of one's own hand is not enough and making rules or strategies too general would also make the poker program weak and predictable. Nowadays, adjusting strategy according to the estimate of the opponents' strategies and opponents' hand strength, called opponent models, attracts lots of attention [8]-[13].

Our goal is to establish a No-limit Texas Hold'em aided software to help players make decisions and gain steady profit. Since we wish the aided software can be applied to games to earn money, conservative and steady profit is the priority for us. Therefore, high risk manipulation is not in our consideration. For example, opponent models or data mining of past games may include many factors that we cannot totally control or consider, like psychological condition, deception, and bluffing. Besides, for online poker games, it is still difficult to detect emotions of those people behind computer. It makes psychological tactics hard to apply and increases risk. Therefore, the aided software we built is based on safer and more conservative expert rules, which are basically relied on

W.-H. Lai is with the Department and Graduate Institute of Computer and Communication Engineering, National Kaohsiung University of Science and Technology, Kaohsiung 824, Taiwan (phone: 886-7-6011000; fax: 886-7-6011012; e-mail: lwh@nkfust.edu.tw).

Z. -H. Huang received his M.S. degree from National Kaohsiung First University of Science and Technology, Taiwan (e-mail: u0051806@nkfust.edu.tw).

Table I
HAND RANKING OF TEXAS HOLD'EM

Hand Ranking	Meaning	Example
Royal Flush	Five highest cards of one suit	♠A♠K♠Q♠J♠T ♥A♥K♥Q♥J♥T
Straight Flush	All five cards are of the same suit and in numerical sequence	♠A♠2♠3♠4♠5 ♦9♦T♦J♦Q♦K
Four of a Kind	Four cards of one rank, and an unmatched card of another rank	♠A♥A♣A♦A♠K K♠K♥K♣K♦♠J
Full House	Three of a kind and a pair	♥A♣A♦A♣K♦K ♠Q♥Q♣Q♣J♦J
Flush	Five cards of the same suit	♠A♠K♠Q♠J♠9 ♦A♦J♦8♦5♦2
Straight	Five cards of sequential rank, but not all in the same suit	♠A♥K♣Q♦J♠T ♠6♦5♣4♥3♠2
Three of a Kind	Three cards of the same rank and two cards of different ranks	♠A♥A♣A♦K♠Q ♠9♥9♣9♦5♠3
Two Pair	A kicker with two cards of the same rank and two cards of another rank	♠A♥A♣K♦K♠Q ♠8♥8♣7♦7♠A
One Pair	Two cards of the same rank and three cards of different ranks	♠A♥A♣K♦Q♠J ♠Q♥Q♣9♦7♠2
Highest Card	Five unmatched cards	♠A♥K♣Q♦J♠9 ♠A♥K♣J♦9♦5

Table II
THE CALCULATED PROBABILITY OF HAND RANKING

$$P(Royal\ flush) = \frac{4 \cdot 1}{c_5^{52}} = 0.0000015390771693292702$$

$$P(Straight\ flush) = \frac{4 \cdot 10}{c_5^{52}} = 0.000015390771693292702$$

$$P(Four\ of\ a\ kind) = \frac{13 \cdot 48}{c_5^{52}} = 0.00024009603841536616$$

$$P(Full\ house) = \frac{13 \cdot 12 \cdot \binom{4}{2} \cdot \binom{4}{3}}{c_5^{52}}$$
$$= 0.001440922190201729$$

$$P(Flush) = \frac{\binom{13}{5} \cdot 4}{c_5^{52}} = 0.001968503937007874$$

$$P(Straight) = \frac{10 \cdot 4^5}{c_5^{52}} = 0.003937007874015748$$

$$P(Three\ of\ a\ kind) = \frac{13 \cdot \binom{4}{2} \cdot \binom{12}{2} \cdot 4^2}{c_5^{52}}$$
$$= 0.021276595744680851$$

$$P(Two\ pair) = \frac{\binom{13}{2} \cdot \binom{4}{2} \cdot \binom{4}{2} \cdot 44}{c_5^{52}}$$
$$= 0.047619047619047616$$

$$P(One\ pair) = \frac{13 \cdot \binom{4}{2} \cdot \binom{12}{3} \cdot 4^3}{C_5^{52}} = 0.42256902761104442$$

P(High Card)=1-P(Royal Flush)-P(Straight Flush)-P(Four of a Kind)-P(Full House)-P(Flush)-P(Straight)-P(Three of a Kind)-P(Two Pair)-P(One Pair)≈0.5

simulation/emulation odds. There is a poker expert who is responsible for finding strategies or rules to get high profit expectation value from systematically simplifying the complicated game tree via the probabilistic knowledge and simulation/enumeration results we provided. An aided software based on the strategies and rules is developed to help players make decisions. We tested our poker aided software on popular online poker websites including PokerStars, FULL Tilt POKER, and bet365, and got promising results.

This paper is organized as follows. The next section will introduce no-limit Texas hold'em and its complexity analysis. Then, in section III, the probability of hand ranking, and the win rate of the first two cards in pre-flop (PF) and hand ranking in flop will be calculated or simulated. The fourth section describes the framework of No Limit hold'em aided software and the betting strategies used. Experimental results will be shown in section V. Finally, conclusions and future works will be discussed.

II. NO-LIMIT TEXAS HOLD'EM

No-Limit Texas Hold'em is one of poker's complex deformations. Player's strategies generally depends on many factors, such as player's seating position, opponent's style, the amount of chips in the pot, and the stakes you or your opponent hold, etc. In poker game, for a player, only the first two cards he got can reveal information. Many other factors

during the games, like opponents' styles, skills, attitude (looser or aggressive), fold to 3-bet, check raise or even discarding, will influence the game very much, but they are unsure and not under player's control.

Table III
THE SIMULATED PROBABILITY OF HAND RANKING

Hand Ranking	Percentage
Royal straight flush	0.00015390771693292702%
Straight flush	0.0015390771693292702%
Four of a kind	0.024009603841536616%
Full house	0.1440922190201729%
Flush	0.1968503937007874%
Straight	0.3937007874015748%
Three of a kind	2.1276595744680851%
Two pair	4.7619047619047616%
One pair	42.256902761104442%
High card	50.093186913672372%
Sum	100%

A. How to Play

No-Limit Texas Hold'em is a zero-sum multi-player card games that is typically played as a session consisting of a series of hands or deals. In the beginning, each player holds a certain amount of chips. The goal is to win maximum amount of chips. Players bet that their hand is stronger than the others and all bets go into the pot. The player with the best hand wins. Or player can raise bet to force others to forfeit the hand.

There are four stages in No-Limit Texas Hold'em, namely pre-flop, flop, turn and river. During each round, all active players make a betting decision of Fold, Check/Call, or Bet/Raise [14]. Fold means a player discards his hand. Check/Call means a player invests nothing or the least amount. Bet/Raise is a player chooses to add more money if he can check/call. The game plays in a clockwise around the table.

In Pre-flop, each player is dealt two pocket cards (hole cards) which only the player can see. A round of betting begins. Once the play enters the flop stage, three community cards are dealt. Players use the two hole cards and the three community cards to make their best hand and play the second round of betting. When the game gets into the turn stage, one community card is drawn. Again, make the best hand and play the third round of betting. In the river stage, the final community card is dealt and a final round of betting is proceeding. If there are still two players or more are active, all players reveal their hole cards and the player with the highest ranking hand wins the entire pot. This is called a showdown.

The minimum bet in No-Limit is the big blind (BB), while the maximum bet is the total amount of your chips. Buy-in is the amount money required to join a game in Texas hold'em. For no limit games, it is generally 20 to 50 times BB for low buy-in, and 40-100 BB for standard buy-in, and 100-250 BB for high buy-in.

B. Hand Ranking

A standard deck of 52 cards is used, which contains 4 suits and 13 ranks per suit. For card suits, symbol d or ♦ is for Diamonds, c or ♣ is for Clubs, h or ♥ is for Hearts, and s or ♠ is for Spades. The ranking from high to low is Ace (A), King (K), Queen (Q), Jack (J), Ten (T), Nine (9), Eight (8), Seven (7), Six (6), Five (5) , Four (4), Trey (3), and Deuce (2).

A poker hand consists of five cards, including pocket cards and community cards. Hand ranking, which identifies the strength of cards, determines the winner. Hand ranking is listed in Table I from highest to lowest. The rank of the individual cards (kicker) decides for hands in the same category.

C. Pot Odds and Implied odds

To win No-Limit Texas Hold'em game, pot odds and implied odds are the probability that need to be considered.

Pot odds is the ratio of money in the pot versus the cost or bet to call. If the odds of probability is more than the pot odds, it is right to call, and vice versa. Therefore, it can be considered as the required probability of winning.

On the other hand, implied odds is the ratio between the amount you expect to win, which is more than what is in the pot, versus the amount it will cost to continue playing.

D. Deception and Unpredictability

Deception and unpredictability are important tactics in poker. The strategies may contain [1]:

Changing Styles: Switch styles from time to time. For example, switch styles from tight conservative to looser style.

Slow play: Slow play is playing a hand intentionally weakly on one round of betting with the aim of sucking people in for later bets.

Check-raising: A player initially checks with the intention of raising if another player bet.

Bluffing: Over-play to make a profit from weak hands. The false impression may also make your opponent suspects you may be bluffing when you really have a very strong hand. This will increase the profitability of future hands.

Semi-bluffing: A bet with a hand which is not likely to be the best hand at the moment but has a good chance of outdrawing calling hands. Again, false impression may indirectly lead to returns in the future.

E. Complexity Analysis

In Pre-flop, each player is dealt two pocket cards. For a hand of a player, there are C(52,2) possibilities. If there are x players, for the other x-1 players, there are $\prod_{i=1}^{x-1} C_2^{52-2i}$ possibilities. Besides, the basic betting decision is Fold, Check/Call, or Bet/Raise. Each decision has 1/3 probability to be chosen. If there are x players and 1/3 players quit the game every round and the game will be finished about 3 rounds. Therefore, a player has to determine the best strategy after checking $\left(\prod_{i=1}^{x-1} C_2^{52-2i} \right) 3^{3x}$ probabilities [15]. No-Limit Texas Hold'em is a multi-player card games, which makes the search space large.

Table IV
SIMPLIFIED COMBINATIONS OF FIRST-TWO-CARDS (S FOR SUIT AND O FOR OFFSUIT)

AA	AKs	AQs	AJs	ATs	A9s	A8s	A7s	A6s	A5s	A4s	A3s	A2s
AKo	KK	KQs	KJs	KTs	K9s	K8s	K7s	K6s	K5s	K4s	K3s	K2s
AQo	KQo	QQ	QJs	QTs	Q9s	Q8s	Q7s	Q6s	Q5s	Q4s	Q3s	Q2s
AJo	KJo	QJo	JJ	JTs	J9s	J8s	J7s	J6s	J5s	J4s	J3s	J2s
ATo	KTo	QTo	JTo	TT	T9s	T8s	T7s	T6s	T5s	T4s	T3s	T2s
A9o	K9o	Q9o	J9o	T9o	99	98s	97s	96s	95s	94s	93s	92s
A8o	K8o	Q8o	J8o	T8o	98o	88	87s	86s	85s	84s	83s	82s
A7o	K7o	Q7o	J7o	T7o	97o	87o	77	76s	75s	74s	73s	75s
A6o	K6o	Q6o	J6o	T6o	96o	86o	76o	66	65s	64s	63s	62s
A5o	K5o	Q5o	J5o	T5o	95o	85o	75o	65o	55	54s	53s	52s
A4o	K4o	Q4o	J4o	T4o	94o	84o	74o	64o	54o	44	43s	42s
A3o	K3o	Q3o	J3o	T3o	93o	83o	73o	63o	53o	43o	33	32s
A2o	K2o	Q2o	J2o	T2o	92o	82o	72o	62o	52o	42o	32o	22

Table V
CLASSIFICATION RESULTS OF THE FIRST TWO CARDS

Group 1	AA, KK, QQ, JJ, AKs
Group 2	AQs, AJs, ATs, AKo, TT
Group 3	AQo, AJo, ATo, KQs, KJs, KTs
Group 4	KQo, KJo, KTo, QJs, QTs
Group 5	QJo, QTo, JTs, JTo, T9s, 99, 88, 77
Group 6	K9s, Q9s, J9s, A9s, A8s, A7s
Group 7	66, 55, A6s, A5s
Group 8	A4s, 44, 33, 22

Table VI
HAND GROUPING FOR PAIRS

Hand	Group	Hand	Group
AA	1	77	5
KK	1	66	7
QQ	1	55	7
JJ	1	44	8
TT	2	33	8
99	5	22	8
88	5		

Table VII
HAND GROUPINGS FOR NON-PAIRS

Hand	Group		Hand	Group	
	Suited	Not Suited		Suited	Not Suited
AK	1	2	KQ	3	4
AQ	2	3	KJ	3	4
AJ	2	3	KT	3	4
AT	2	3	K9	6	x
A9	6	x	QJ	4	5
A8	6	x	QT	4	5
A7	6	x	Q9	6	x
A6	7	x	JT	5	5
A5	7	x	J9	6	x
A4	8	x	T9	5	x

III. SIMULATION

Win rate is important information in designing our poker aided software. In this section, calculated and simulated probabilistic data will be presented. Instead of using these data directly in our aided software, these data will be provided to a poker expert as a reference guide to draw up the betting strategies and rules applied to our aided software.

A. The Probability of Hand Ranking

First of all, the hand ranking probability is calculated to understand the card strength as in Table II. The lower the probability is, the higher the hand rank is. As shown in Table II, high cards have high chance, about 50%, to happen, so its value is the lowest.

We can also simulate the win rate of hand ranking by program. Frist, shuffle and deal out the cards. Every player holds 2 cards, and 5 community cards are dealt. Then, according to the rule of the game, pick the strongest five cards from seven cards. Make statistics of win rate by counting the number of winning. The program will repeat until convergence to get the final simulated win rate. The result is shown in Table III. It is quiet close to the calculated probability in Table II.

B. Simulation of the First Two Cards in Pre-Flop

No limit Texas Hold'em is composed of four rounds, Pre-flop, flop, turn and river, respectively. The starting round, pre-flop, is the key to the games. The first two cards of the pre-flop would bring C(52,2)=1326 possibilities.

The win rates of the first two cards are important considerations for the strategies used in our aided software. One expert will reference the win rates to formulate the appropriate strategies. We need to consider some important situations and simulate them to decide the win rate. Before that, to simplify the complexity, we know that except in the case of flush, in which the poker suits matter, we won't need to concern the poker suits. Therefore, for example, AdKd and AhKh are classified into the same category and shown as AKs (s means suit or same suits). Another situation like AsKd and AhKd, which are different suits, will be shown as AKo (o means offsuit or different suits). Because the poker suit appears in the flop will influence the possibility of forming a flush, this classification is for per-flop only. By classifying suit and offsuit, we reduce 1326 two-card-combinations to 13*13=169 as shown in Table IV.

But we still lack the information of card strength, and we need to do some simulations. Through observing Table IV,

Table VIII
THE ODDS TABLE FOR BASIC DRAWING HANDS IN FLOP

Type	Drawing Hands	Number of Outs	odds	Example
1	Open-ended Straight Flush	2	2/47 ≒ 4%	PF: ♣Q♣J Board:♣K♣T♥6
2	Gut shot Straight Flush	1	1/47 ≒ 2%	PF: ♠A ♠J Board: ♠K♠T♥8
3	Open-ended Straight	8	8/47 ≒ 17%	PF: ♠9♦8 Board: ♠A♣7♥6
4	Gut shot Straight	4	4/47 ≒ 8%	PF: ♠Q♦T Board: ♣7♠K♥9
5	Flush	9	9/47 ≒ 19%	PF: ♦8♦9 Board: ♣7♦K♦2
6	Two over cards	6	6/47 ≒ 12%	PF: ♥A♦K Board: ♣7 ♠T♦2
7	One over cards	3	3/47 ≒ 6%	PF: ♥A♦T Board: ♣7 ♠Q♦2

according to hand ranking, 169 (=13*13) combinations can be divided into three categories, pocket pair, suit connect, and two high cards. We, therefore, simulate 6 major situations and their sub-situations as follows.
1. pocket pair versus pocket pair (e.g. AA vs. KK)
2. pocket pair versus two high cards:
  This situation is further divided into four sub- situations:
  a. top pair versus top two high cards (e.g. AA vs. AKo)

b. second pair versus top two high cards (e.g. KK vs. AKo)
c. over pair versus lower two high cards (e.g. AA vs. KQo)
d. lower pair versus over two high cards (e.g. QQ vs. AKo)
3. suit connect versus pocket pair:
  This situation is further divided into four sub-types:
  a. top suit connect versus top pair (e.g. AKs vs. AA)
  b. top suit connect versus second pair (e.g. AKs vs. KK)
  c. lower suit connect versus over pair (e.g. KQs vs. AA)
  d. over suit connect versus lower pair (e.g. AKs vs. QQ)
4. two high cards versus two high cards:
  This situation is further divided into three sub-types:
  a. High kicker dominates (e.g. AK vs. AQ)
  b. Low kicker dominates (e.g. AK vs. KQ)
  c. Dominate (e.g. AK vs. QJ)
5. Two high cards versus Suit connect (e.g. AKo vs. AKs)
6. Suit connect versus Suit connect

The same experiment was performed a large number of times until convergence defined by error below +- 1%. Basically, it needs eight millions to ten millions times to converge. According to the law of large numbers (LLN), the average of the results obtained from a large number of trials should be close to the expected value. Through the win rate, we could know the strength and hidden-value of different combinations, and do the right decision to make positive returns.

From simulation results, in pre-flop, pocket pair has the highest value. Aic (AA), also called over pair, is the highest in pocket pairs, because AA has formed top one pair before entering flop. Holding a pocket pair in pre-flop round usually puts players in the lead.

C. Classification of the First Two Cards

We have already known the 169 kinds first two card combinations in pre-flop, and got the simulation results of their card strength by considering the 6 major situations and their sub-situations in section III.B. To make the expert to observe the card strength more conveniently, the first two cards (starting hands) are sorted into groupings [16]. Most of the hands in each grouping can be played roughly the same before the flop stage in many, but not all situations [16]. Our rankings are in Table V, arranged from strong hand to weak hand, from 1 to 8. Others are valueless cards that we can fold. Tables VI and VII provide hand grouping for pairs and non-pairs for each starting hand.

D. Simulation of Hand Ranking in Flop

In section III.B, we simulate 6 major situations and their sub-situations which usually appear in pre-flop. From the results, we know the win rate, the strength and the hidden-value of the first two cards. Then, in section III.C, we remove the weaker cards and keep the cards with high win rate. Then, the cards are sorted from strong to weak, and further divided into eight groups according to its strength, as show in Table V. In this section, we will discuss the follow-up situations after entering flop. Again, the results in flop will be provided to our poker expert as a reference to draw up the betting strategies and rules applied to our aided software.

Table VIII presents the odds table for 7 basic drawing hands in flop and Table IX is for extended drawing hands. Table X is the odds table of made hands in flop. The numbers

Table IX
THE ODDS TABLE FOR EXTENDED DRAWING HANDS IN FLOP

Type	Drawing Hands		Number of Outs	odds	Example
8	Flush	+ Open-ended Straight	15	15/47≒31%	PF: ♦Q♦J Flop: ♠K♦T♦3
9		+ Two over cards	21	21/47≒44%	PF: ♦Q♦J Flop: ♠T♦9♦3
10		+ One over cards	18	18/47≒38%	PF: ♦Q♦T Flop: ♠J♦9♦2
11	Flush	+ Gut shot Straight	12	12/47≒25%	PF: ♣Q♣T Flop: ♥K ♣9 ♣3
12		+ Two over cards	18	18/47≒38%	PF: ♣K♣Q Flop: ♥T ♣9 ♣3
13		+ One over cards	15	15/47≒31%	PF: ♣K♣T Flop: ♥Q♣9♣3
14	Open-ended Straight	+ Two over cards	14	14/47=29%	PF:♥Q♣J Flop: ♦9♣4♠T
15		+ One over cards	11	11/47=23%	PF:♥Q♣9 Flop: ♦J♣4♠T
16	Gut shot Straight	+ Two over cards	10	10/47=21%	PF:♥Q♣J Flop: ♦9♣2♠8
17		+ One over cards	7	7/47=14%	PF:♥Q♣9 Flop: ♦J♣2♠8
18	Flush	+ Two over cards	15	15/47=31%	PF:♥A♥K Flop: ♥J♥5♠8
19		+ One over cards	12	12/47=25%	PF:♥A♥T Flop: ♥Q♥5♠8

of outs are also shown in these tables. An out is any hidden card which will improve a player's hand to likely to win if it is drawn. For example, if your hand was ♥A♦K, and open ♦2 ♣7 ♠T in flop, only three A cards and three K cards can help to make one pair. On the other hand, card 2, card 7, and card T cannot help to make one pair. So, the probability of hitting one pair is 6/47=12.7% for type 6 in Table VIII.

The amount of outs appears in extended-types is more than it in basic types, and the odds also increases. For example: The type 9 in Table IX has outs up to 21.

We can simulate the odds for different types of drawing hands and made hands. The results will be provided to our

Table X
THE ODDS TABLE FOR MADE HANDS IN FLOP

Type	Made hands	Number of Outs	odds	Example
20	Set	7	7/47=14%	PF: ♥T♠T Board:♣T♦7♠K
21	Two pair	4	4/47=8%	PF: ♠Q♠T Board: ♣T♦Q♣6

poker expert as a reference to draw up the betting strategies and rules applied to our aided software.

IV. AIDED SOFTWARE

The purpose of this paper is to develop an aided software for no limit Texas Hold'em, which combines betting strategies, probabilities, and expert experience to make better in-game decisions and maximize profit. So, the user can run this aided software to help them make decisions when they are playing poker games. In this section, the details of the aided software will be presented.

A. Framework for the Aided Software

First, choose the number of players from two to nine. Next, select a seat from dealer, Sb, Bb, Utg, Utg+1, Utg+2, Utg+3, Utg+4, and Cut off, which are arranged around the table clockwisely. Different default VPIP (Voluntary Put Money in the Pot) value will be set by system according to the seat superiority. The VPIP can be adjusted by user according to his personal style or opponent's strength. Generally, VPIP measures how often the player voluntarily added money into a hand. That is, this percentage indicates how often he called, bet, or raised. We can use VPIP to determine if a player is loose or tight. The lower the VPIP is, the tighter the player is. Conversely, the higher the VPIP is, the looser the player is. Table XI shows the default values of VPIP and the number of first two cards considered corresponding to each seat, which are basically based on experience. The number of first two cards considered is the number of those card combinations that we consider valuable and our software will have corresponding strategies. For the other combinations, we just fold. Basically, the higher the VPIP is, the looser the player is, and the larger the number of first two cards considered is. As shown in Fig. 1, a screen shot from the poker aided software we developed, when the VPIP is 19%, the card number for consideration is 33. From Table XI, it is easy to see dealer has the biggest VPIP, because final betting has its advantage.

Then, the software will enter pre-flop stage. The first two cards are classified into groups according to expert rules and different betting strategies are applied. Next, user will enter flop. Considering the odds of the possible hand rank from the

simulation results in section III.D, the corresponding betting strategies are practiced. Accordingly, the software will enter turn and river and betting strategies of these stages are applied. User can fold and return to pre-flop for restarting at any time.

B. Betting Strategies

In our software, the betting strategies are designed by an expert by considering the simulated results, pot odds and implied odds, to assist users to get long-term positive expectation. The strategies used in our aided-software include slow play, check-raising. We did not apply changing styles, semi-bluffing and bluffing in our software, because changing styles has high degree of complexity, while semi-bluffing and bluffing are high-risk behaviors if you cannot predict the reaction of your opponent.

We classified our betting strategies into pre-flop, flop, turn and river stages according to different hands.

In pre-flop, based on the simulated win rate in section III, a poker expert designs different betting strategies corresponding to each group of first two cards to bet, hopefully, to gain positive expectation of profit. These betting strategies or rules are applied to our aided software. The first two cards are classified into 12 groups as in Table XII and bet with four betting strategies P1 to P4. Figs. 2 - 5 are the flowcharts of betting strategies P1 to P4 in pre-flop. For branches, if there is any front player raise, which may mean he has strong hand, then choose the lower branch, otherwise, take the upper branch. Sometimes we also need consider how big the bet is to decide our next move as in Figs. 3 – 5.

In flop stage, more hand combinations need to be considered, which makes the branches of betting strategies more complex. In Table XIII, we show the betting strategies in each stage corresponding to the first two cards {KK, or QQ, or JJ, or TT} and {99, or 88, or 77} as an example. These are expert rules based on the simulation results in section III.D. They are basically considering the odds of what kind of hand rank you may have, and decide the best betting strategy based on the odds.

In Table XIII, when the first two cards are {KK, or QQ, or JJ, or TT}, the consideration of hand rank can be divided as two phases. For example, if the player got the first two cards KK, firstly, consider if there is Ace or not. If there is Ace, basically, it is possible to lose to Ace Pair, so, use betting strategy F5 (Fig. 10), otherwise, consider the situation of getting straight draw, flush draw, set or quads, trips, or lower cards and use the corresponding betting strategies.

Figs. 6 - 10 show the betting strategies F1 to F5 in flop. Again, in Figs. 6 - 10, if there are front players bet, then choose the lower branch, otherwise, take the upper branch.

V. EXPERIMENTAL RESULTS

To test the performance of our aided software and see how much profit the player will gain by the help of the software, we experiment three most popular online poker, PokerStars (www.pokerstars.com), FULL Tilt POKER (www.fulltilt.com) and bet365 (poker.bet365.com), on no-limit 2 (NL2) and no-limit 5 (NL5) by the help of our aided-software. We buy-in 2 USD in NL2 and buy-in 5 USD in NL5 and recorded

Table XI

DEFAULT VALUES OF VPIP AND THE NUMBER OF FIRST TWO CARDS CONSIDERED CORRESPONDING TO EACH SEAT

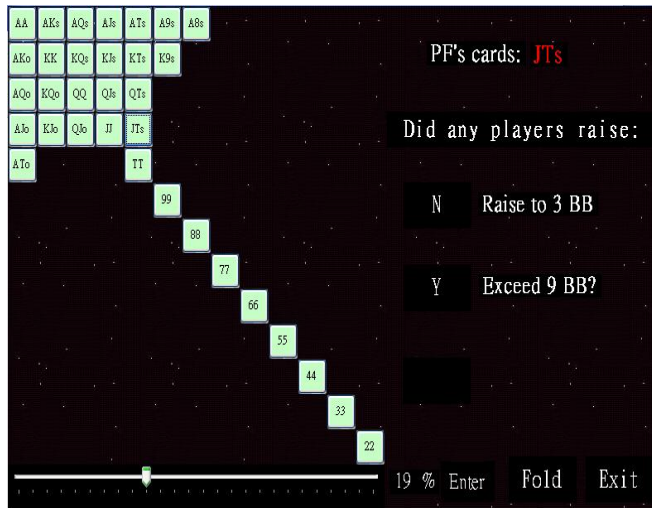|	Dealer	SB	BB	UTG	UTG+1	UTG+2	UTG+3	UTG+4	Cut-off
VPIP	25%	14%	16%	17%	18%	19%	20%	21%	22%
No. of First Two Cards	43	26	28	30	32	33	35	37	39

Fig. 1. A screen shot from the poker aided software developed.

Table XII

THE 12 GROUPS OF FIRST TWO CARDS AND THEIR CORRESPONDING FOUR BETTING STRATEGIES P1 TO P4 IN PRE-FLOP

First two cards	Betting strategy
AA	P1
KK, QQ, JJ, TT	P1
99, 88, 77	P3
66, 55, 44	P3
33, 22	P3
AQs, AJs, ATs, KQs, QJs, JTs	P2
KJs, KTs, QTs	P4
AKs	P1
J9s, T9s	P4
AQo, KQo, AJo, KJo, QJo, ATo, KTo, QTo, JTo	P4
AKo	P2
A9s, A8s, A7s, A6s, A5s, A4s, K9s, Q9s	P3

The bankroll of one hundred hands.

In PokerStars, our profit in NL2 is (8.71-2)/2=3.35 and (20.6-5)/5=3.12 times in NL5. In FULL Tilt POKER, our profit is (9.91-2)/2=3.95 in NL2 and (22.74-5)/5=3.54 times in NL5. In bet365, our profit is (30.9-5)/5=5.18 times in NL5. Bet365 does not provide NL2, so the data is NA (Not Available) in Table XIV. The result of Table XIV shows that our aided software is very profitable. In 100 hands, averagely, our profit is 3.65 times in no-limit 2 and 3.95 times in no-limit 5 of the money we buy-in. Figs. 11 – 15 record the detailed

one hundred hands of profit or loss in NL2 and NL5 on PokerStars, FULL Tilt POKER and bet365.

The profit greatly depends on the tactics and experiences of the opponents we met. When we met strong opponents, fixed tactic is too easy for opponents to see through and fight back. In general, the higher BB is, the stronger opponents we will encounter. Therefore, the profit we got from NL5 is generally less than NL2. From Figs. 11 - 15, it is also easy to see that the profit curve of NL5 is less stable than NL2. However, as a whole, our aided software is proved to be very profitable.

VI. CONCLUSION AND FUTURE WORK

The purpose of our poker aided-software focuses on helping players in complex No-limit Texas Hold'em game to make decision and get profit. From our experiment on the three most popular online poker, PokerStars, FULL Tilt POKER and bet365, by the help of our aided-software, the result shows that our aided software is very profitable. In 100 hands, averagely, our profit is 3.65 times in no-limit 2 and 3.95 times in no-limit 5 of the money we buy-in.

Compared with professional poker players, there is still room for improvement. First, the software makes decision basically based on expert rules, and the expert rules are based on expectation value. If we encounter experienced opponents, more complex betting strategies should be used. Besides, there are too many factors influencing the game, e.g., opponent's strength, player's habit, human emotion, etc. Among them, one very critical factor is bluffing. Poker, like many other games, uses psychological tactics. Due to human's anxiety, greed and fear is difficult to hide, players also use human weakness to defeat human. For computer, it is still difficult to detect human's emotion, not to mention detecting emotions of those people behind computer if it is an online game instead of a face-to-face game. Considering the human factors will be the future work.

But for beginners, our poker aided-software is still very useful. The biggest advantage of using the auxiliary software is to help users stay calm and guide users to win during the game. The experimental results of our aided-software applying on online pokers have demonstrated that the software can help beginner players get stable profit.
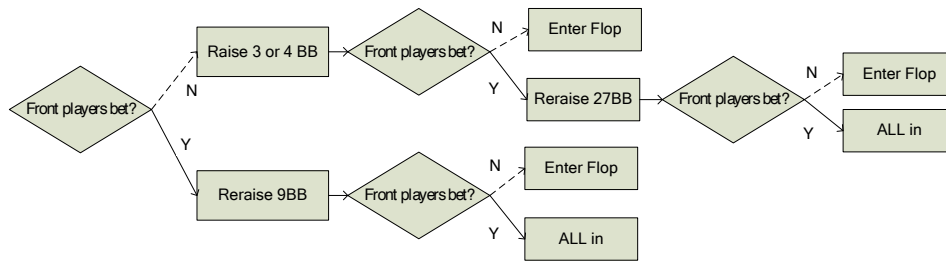
Fig. 2. The flowchart of betting strategy P1 in pre-flop.
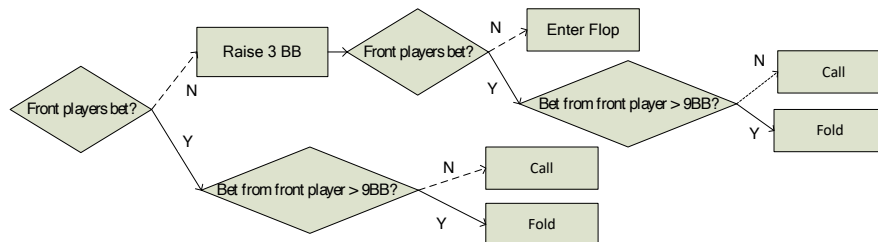

Fig. 3. The flowchart of betting strategy P2 in pre-flop.
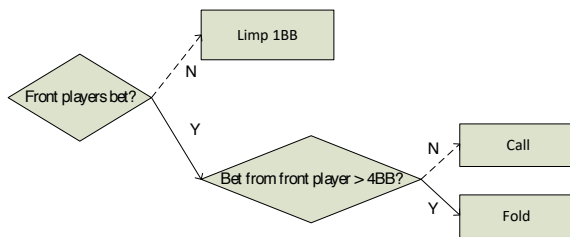

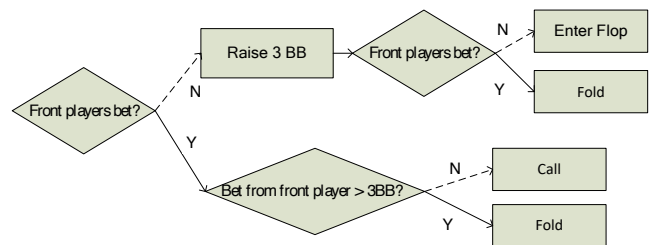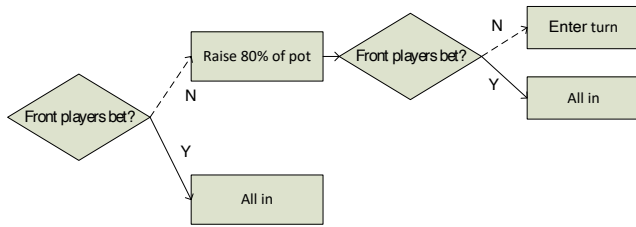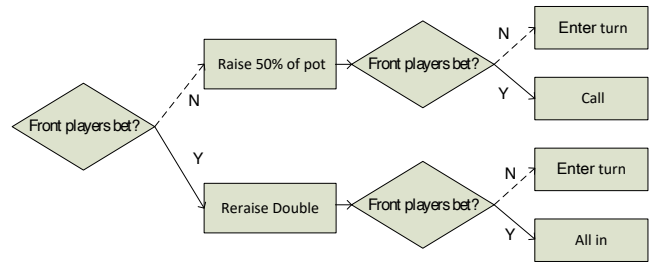
Fig. 4. The flowchart of betting strategy P3 in pre-flop.

Fig. 5. The flowchart of betting strategy P4 in pre-flop.

Table XIII
STRATEGIES CORRESPONDING TO DIFFERENT FIRST TWO CARDS IN EACH STAGE

First two cards	Strategy in Pre-flop	Hand in Flop		Strategy in Flop	Hand in Turn	Strategy in Turn	Strategy in River
KK, QQ, JJ, TT	P1	Have Ace		F5	Have High cards	Check/Fold	Check/Fold
					No High cards	All in	
		No Ace	Straight draw, Flush draw	F1	Have Straight	Check/Call	Check/Fold
					No Straight	All in	
			Set or Quads	F2		All in	
			Trips	F3		All in	
			Lower cards	All in			
99, 88, 77	P3	Over pair		F1	Have High cards	Check/Fold	Check/Fold
					No High cards	All in	
		Set		F2		All in	
		Quads		F2		All in	
		Straight draws		F4	Draw complete	Check/Fold	Check/Fold
					No complete	All in	
		Lower cards		All in			

Fig. 6. The flowchart of betting strategy F1 in flop.

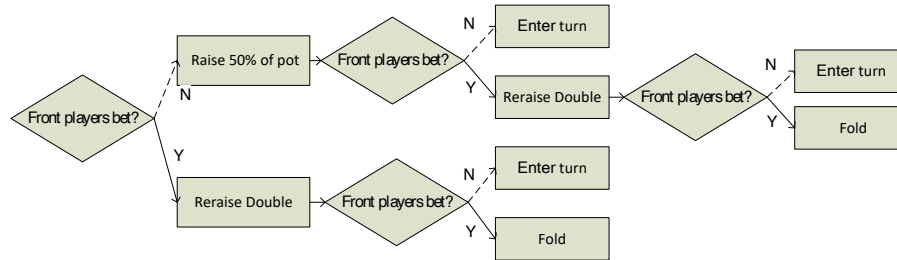Fig. 7. The flowchart of betting strategy F2 in flop.

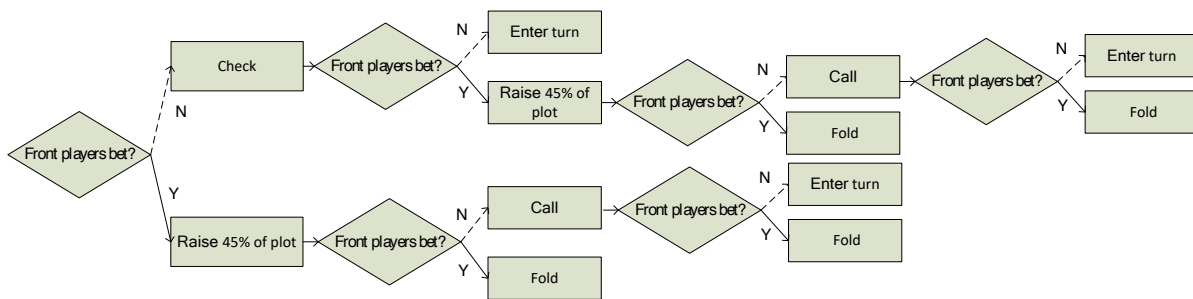Fig. 8. The flowchart of betting strategy F3 in flop.

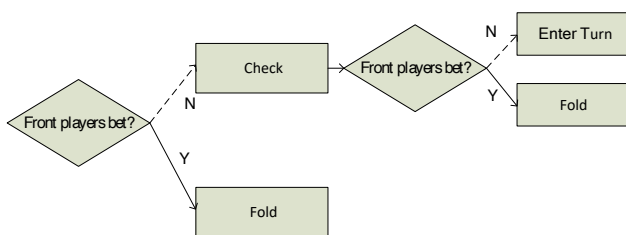Fig. 9. The flowchart of betting strategy F4 in flop.

Fig. 10. The flowchart of betting strategy F5 in flop.

Table XIV
THE PROFIT WE GOT FROM THREE ONLINE POKER, POKERSTARS, FULL TILT POKER AND BET365, ON NL2 AND NL5

	NL2	NL5
PokerStars	3.35	3.12
FULL Tilt POKER	3.95	3.54
bet365	NA	5.18
Average	3.65	3.95
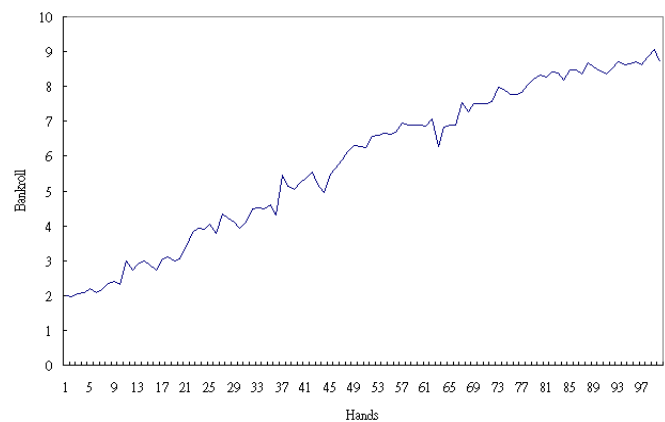
Fig. 11. The one hundred hands of profit or loss in NL2 on PokerStars.
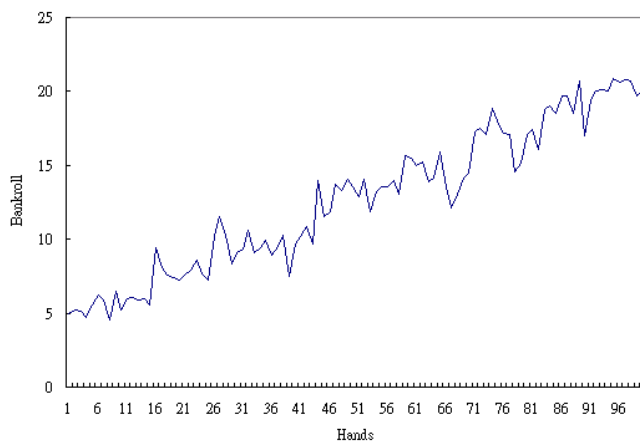
Fig. 12. The one hundred hands of profit or loss in NL5on PokerStars.
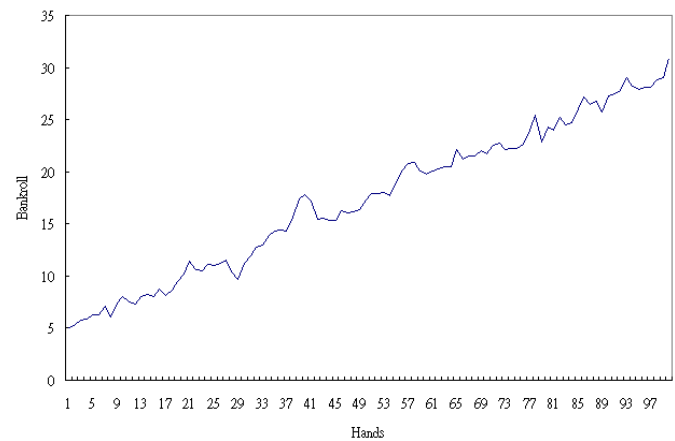

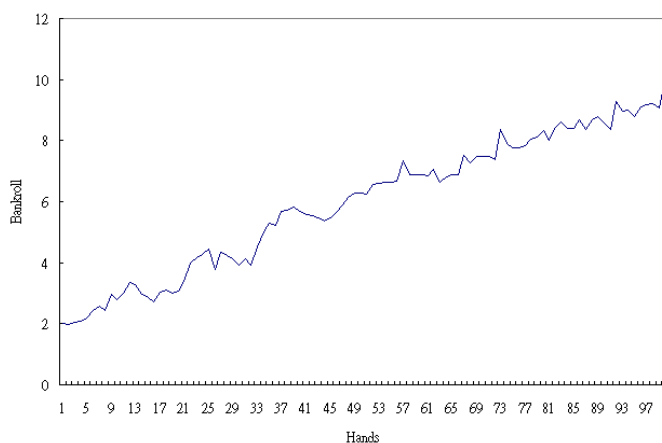Fig. 15. The one hundred hands of profit or loss in NL5 on bet365.

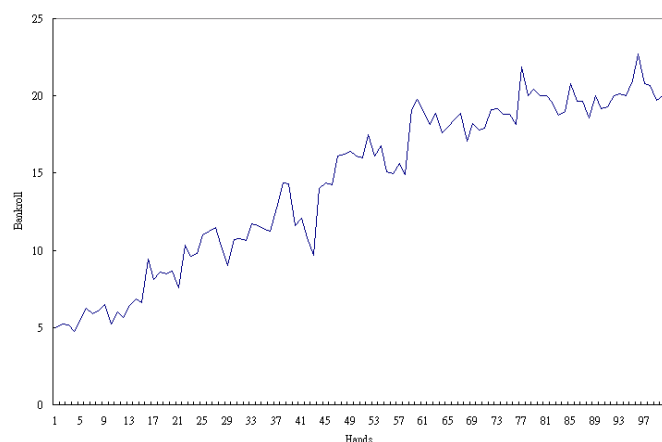Fig. 13. The one hundred hands of profit or loss in NL 2 on FULL Tilt POKER.

Fig. 14. The one hundred hands of profit or loss in NL 5 on FULL Tilt POKER.

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Wen-Hsing Lai received the Ph.D. degree in communication engineering from National Chiao Tung University, Hsinchu, Taiwan, in 2003.

She is an Assistant Professor at the Department and Graduate Institute of Computer and Communication Engineering, National Kaohsiung University of Science and Technology, Taiwan.

Zi-Hao Huang received the M.S. degree in Computer and Communication Engineering from National Kaohsiung First University of Science and Technology, Taiwan, in 2013.