

# Interactive Partner System in Imperfect Information Game

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**Abstract:** This study aims at the construction of the partner system in a poker game called “Seven-Card-Stud”. The system presents tactics to human players. And human players also can get the reasons by the interaction between them and the system why the system presents such tactics. The system takes humanlike comments on some situations in a game which make the system friendly and pleasant. This paper compares the present partner system and the support system only showing tactics in subjects experiments.

## 1. Introduction

A computer is used as a game field or an agent in computer board games or computer card games. The agent system is also used as a support system which gives some advice about game tactics to a human player.

In perfect information games such as chess and shogi, many computer algorithms have won remarkable results [1]. For example, the Deep Blue is noted as the computer program that defeated Kasparov, a world champion of Chess. These games are deterministic[2], and tactics given by the support system using the agent system are usually related to advantage/disadvantage in games directly.

On the other hand, algorithms in imperfect information games have not become so stronger as human grade holder players yet since only imperfect information is used in the assessment of, e.g., opponent hand strength, and uncertainty in the assessment is the bottleneck for developing strong algorithms. Heuristics are also used in order to deal with uncertainty in developing computer programs. Therefore, a support system using the agent system for imperfect information games does not always give good advices to human players. Furthermore, a support system only showing tactics makes human players confused since they don't always know the reason why they should apply the presented tactics in the current situation.

This study tries to construct a partner system that not only gives some advice to a human player but also has interaction with a human player to find a better action and decision in a Seven-card-stud poker game [3], one of imperfect information games. This paper also confirms the usefulness of the present partner system by comparing the support system giving only some advice and the partner system.

## 2. Seven-card-Stud

This paper considers the situation in which two players play the poker game called Seven-card-Stud [3]. In this poker game there are two kinds of cards, upcards and holecards. Upcards are dealt face up, which are seen by both players. Holecards are dealt face down, which can be seen only by the owner of the cards. When cards are dealt, each player makes decisions whether he/she bets or drops a game. This is called round.

Two holecards and one upcard are dealt to each player and then the first round is to be started. When the amount of both players' bet becomes even, the next card is dealt to each player and the next round starts. The fourth, fifth, sixth cards are dealt as upcards. And the seventh card is holecard. After the seventh cards are dealt and the round is ended, each player makes decisions which holecard should be opened. Each player opens one holecard and the next round is started. If neither player drop a game, the processes of opening holecards and the round are continued. If both players continue a game even after the final round, they show their last holecards each other. This is called Showdown and the player with the strongest poker hand is the winner of a game.

## 3. Partner System

### 3.1. System construction

This system consists of three parts: the decision making part, the hand evaluation part and the interaction part as shown in Fig.1.

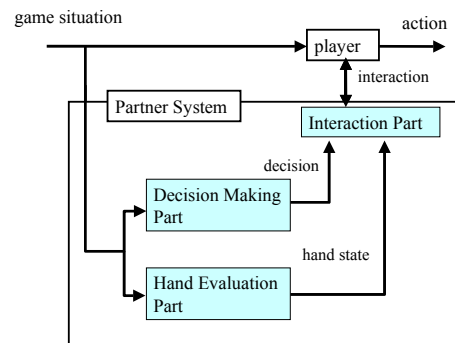


Fig. 1. System construction

The decision making part helps a partner player in making decisions when he/she is in two minds whether to continue/drop a game, how many points to bet, which holecard is opened. The hand evaluation part evaluates a partner player's hand strength and an opponent player's one. The interaction part presents a partner player some pieces of information.

### 3.2. Decision Making Part

The decision making part uses the fuzzy inference [4] for decision making. The flowchart of decision-making is shown in Fig.2.

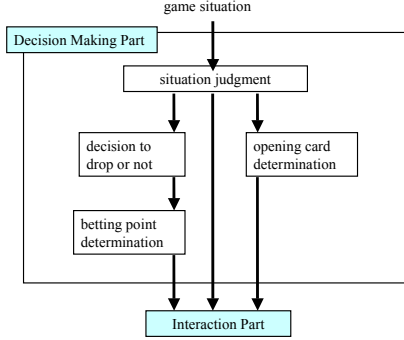


Fig. 2. Decision making part

#### 3.2.1. Situation judgment

Before making decisions, the situation judgment section analyzes the game situation, a partner player's relative hand strength toward an opponent player's one [4], an opponent player's betting points and the tendency of an opponent player's tactics [5]. The analysis results and opponent player's betting points are given to the interaction part in order to present them to a partner player.

#### 3.2.2. Decision to drop or not

When the situation judgment section assesses a partner player's hand at inferiority, the decision making part makes a decision to drop a game or not by the fuzzy inference [4]. The section has the rules meaning that the more the opponent player's betting points and the closer to the end-game, the stronger the tendency to drop a game. If the fuzzy inference result ( $\in [0,1]$ ) on the decision to drop a game or not is larger than a uniformly generated random number ( $\in [0,1]$ ), the section decides to drop a game.

#### 3.2.3. Betting point determination

If the decision making part decides to continue a game, betting point  $C_{bet}$  is obtained by Eq.(1), where *lower* is the lower limit of betting points fixed at 1 and *upper* is the upper limit of total betting points of a partner player and an opponent one, which is dependent on the game situation, and *a* is a parameter shown in Eq.(2). In Eq.(2) *result* is the output of the situation judgment section, and *noise* is a normally distributed random number with the mean value 0 and the variance 0.1.

$$C_{bet} = lower + a(upper - lower) \quad (1)$$

$$a = 0.5 * result + 0.5 + noise \quad (2)$$

When the system assesses a partner player's hand strength at inferiority and takes bluff strategy in and after the fifth round, *a* is obtained by

$$a = 0.5 * (\frac{potential}{9}) + 0.5 \quad (3)$$

where 9 is the fixed number defined as the maximum score of the poker hand [4], and potential is the expected value of the strength of possible poker hands [4].

#### 3.2.4. Opening card determination

When the situation judgment section assesses the partner player's hand at superiority and the hand is hidden in holecards, assuming that one partner player's holecard is opened, possible combinations of cards are assigned to remaining holecards. Then the expected value of the strength of possible poker hands is obtained. The opening card determination section chooses the card at the rate of 80%, of which expected value is the lowest. The section chooses the card at the rate of 20%, of which expected value is the second lowest. When the situation judgment section assesses partner's hand at inferiority, the opening card determination section chooses the card by which the partner player's hand seems to be stronger.

### 3.3. Hand Evaluation Part

It is difficult to explain hand evaluation by only the relative hand strength used in the decision making part. Therefore, the hand strength is evaluated from the viewpoint of each poker hand as shown in Fig.3. This part divides hands into three categories, a completed hand, a likely hand and others. The completed hand is a partner player's completed poker hand or a poker hand that is shown in an opponent player's upcards. The likely hand is the poker hand of which key cards may be hidden in the opponent player's holecards or of which key cards are assessed to be hidden in a partner player's holecards. The former is a opponent player's likely hand and the latter is a partner player's likely hand.

The others are poker hands except for above two kinds of hands. Evaluation results of the hand evaluation part are given to the interaction part.

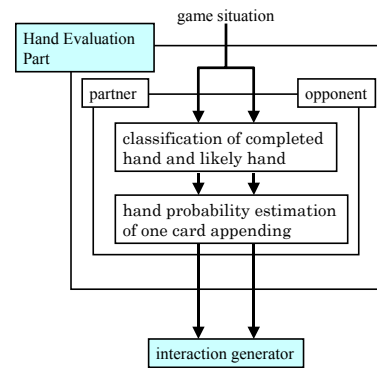


Fig. 3. Hand evaluation part

The evaluation of the likely hand is important from the following point of view. There is a situation in which a player pretends to have some key cards of a strong likely poker hand in the holecards in spite that he/she does not have them, and takes bluff strategy. Or there is also a situation in which a player pretends not to have any key cards of a strong likely poker hand in the holecards in spite that he/she actually have them, and takes slowplay strategy. The decision to take bluff/slow play strategy is based on the evaluation of the likely hand.

### 3.3.1. Classification of completed hand and likely hand

The classification of a completed hand is easy since the completed hand is clear. However, the classification of the opponent player's likely hand is not so simple since the key card of the likely hand may be hidden in the opponent player's holecards. The classification of the likely hand is performed as follows. Assuming that a key card is added to some cards shown in the opponent player's upcards, if a poker hand is completed, the poker hand is classified into the likely hand. On the other hand, an opponent player should also consider the partner player's likely hand. That is, a partner player may have some key cards of a likely hand hidden in a partner player's holecards. Therefore, the classification of the partner player's likely hand is performed from the viewpoint of an opponent player in the same way as above mentioned. For example, let us consider card distributions shown in Fig.4, where the upper side shows the opponent player's card distribution and the lower side shows a partner player's one. A partner player's card distribution and an opponent player's card distribution of upcards are also arranged in Table 1, where P means the partner player's card, O means the opponent player's card and a blank means a card which may be dealt to an opponent player as a holecard. The hand evaluation part searches this table in the level direction in order to find the poker hand type of flush. To find other poker hands such as three-of-a-kind, full-house, the hand evaluation part searches this table in the vertical direction. In this example, three-of-a-kind of 6 is an opponent player's completed hand and full-house (three 6's and two 2's) is an opponent player's likely hand. On the other hand a pair of 2 and flush of spade are the partner player's completed hands and, for example, A-high-straight, three-of-a-kind of 2 are the partner player's likely hands. These pieces of information are given to the hand probability estimation section.

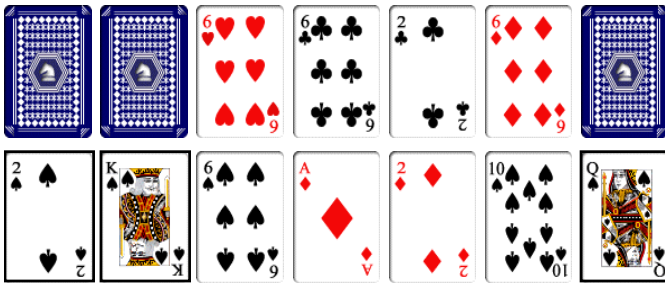


Fig. 4. Example dealt cards

Table. 1. Card map

	2	3	4	5	6	7	8	9	T	J	Q	K	A
S	P				P				P		P	P	
H					O								P
D	P				O								
C	O				O								

### 3.3.2. Hand probability estimation

Assuming that one more card is dealt to each player, there is a situation in which a completed hand becomes other stronger completed hand or a likely hand becomes a completed hand. The probability of the latter situation is obtained by the following.  $appear\_card$  is a number of the partner player's all cards and the opponent player's upcards. And  $k$  is a number of cards which makes completed hand. The probability is obtained by  $k/(52 - appear\_card)$ , where if the completed poker hand that a likely poker hand becomes by adding one more card is not stronger than the already completed other poker hands, the probability is not considered here. The probability obtained here is given to the interaction part.

### 3.4. Interaction Part

The interaction part presents information obtained by the decision making part or the hand evaluation part in the form of linguistic expressions to a partner player. Presented information includes the response to a partner player's inquiry, warning against the game situation, or some comments on the game results.

#### 3.4.1. Response of inquiry

Responses to a partner player's inquiry are based on the output of the decision making part and the hand evaluation part.

##### 3.4.1.1. Decision to drop or not

System's responses to the decision to drop or not are based on betting points obtained by the betting point determination section.

Ex) Let us bet!

You had better drop this game.

##### 3.4.1.2. Betting points

System's responses to a partner player's inquiry about betting points are based on the range which the partner player's betting points are correspondent to. The range of betting points is divided into 5 classes: (1) too few (2) few (3) fair (4) much (5) too much, where their meanings are expressed by fuzzy sets shown in Fig.5. In Fig.5, the horizontal line is normalized by  $upper$  in Eq.(1),  $D_p = C_{bet}/upper$  and the value in the horizontal line is defined as the relative value to  $D_p$ .

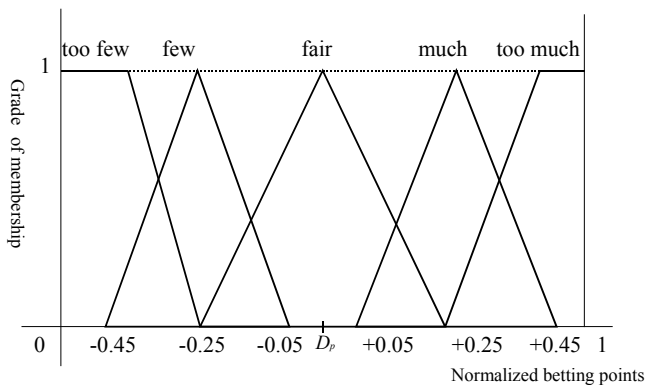


Fig. 5. Membership functions about a partner player's betting points

Ex) Let us bet much points !  
You can bet 160 points at most.

#### 3.4.1.3. Opening card determination

System's responses to a partner player's inquiry about opening card are based on the decision by the opening card determination section. If there is no possibility to take bluff or slow-play strategy even if any card is opened, the message as shown in the second example is presented.

Ex) The most left card is best.  
Any card is O.K.

Above explanations are related to responses to the partner player's inquiry about betting points, opening card, etc., and support systems usually have these functions. The present partner system has following functions to explain reasons of system's decision or comments to a partner player.

#### 3.4.1.4. Comments on an opponent player's hand

The partner system gives comments on an opponent player's hand to a partner player from the following three viewpoints: (1) the opponent player's likely poker hand of which key cards may be hidden in the opponent player's holecards, (2) completed poker hands which are shown in the opponent player's upcards, (3) the strongest poker hand opponent player's among likely poker hands and the opponent player's completed poker hands. The presented comments are based on the probabilities of ((1) or (2)) and (3) which are obtained by the way mentioned in 3.3.2.

Ex) An opponent player's hand seems to be a pair very well.

#### 3.4.1.5. Comments on a partner player's hand

The present system gives comments on a partner player's hand to a partner player from the following three viewpoints: (1) a partner player's hand which an opponent player seems to take notice of, (2) completed hands which are shown in a partner player's upcards, (3) the strongest poker hand among a partner player's likely poker hands and completed poker hands. The presented comments are based on the probabilities

of ((1) or (2)) and (3), which are obtained by the same way mentioned in 3.3.2.

Ex) Comparing our poker hands with the opponent player's ones, our hand is a little stronger.

#### 3.4.1.6. Comments on relative hand strength

The range of the relative hand strength is divided into 5 classes: (1) much inferior, (2) inferior, (3) even, (4) superior, (5) much superior, where their meanings are expressed by fuzzy sets shown in Fig.6, and the horizontal line shows a normalized relative hand strength, which is normalized by the maximum score of the poker hand.

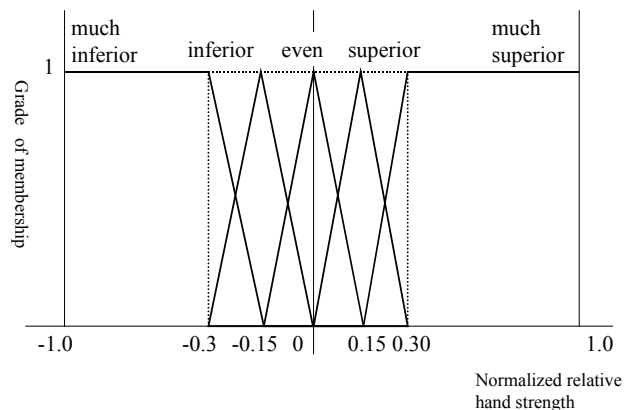


Fig. 6 Membership functions about relative hand strength

Ex) Our hand seems to be superior to an opponent player's hand.

#### 3.4.1.7. Comments on an opponent player's betting points

An opponent player's betting points are important information for the decision to drop a game or not, for the evaluation of the opponent player's poker hand strength and for the assessment of the opponent player's tactics. The range of the opponent player's betting points obtained by the situation judgment section in the decision making part is divided into 3 classes: (1) a few, (2) moderate, (3) many, where their meanings are expressed by fuzzy sets shown in Fig.7, and the horizontal line shows normalized betting points, and normalized by *upper* in Eq.(1).

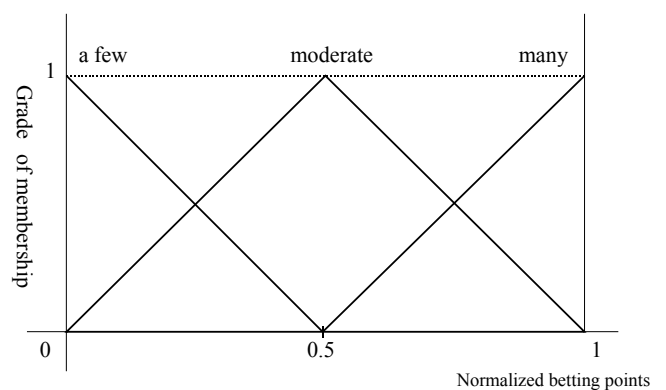


Fig. 7. Membership functions about an opponent player's betting points

Ex) Opponent betting points are many!

#### 3.4.1.8. Additional comments on card to be opened

A partner player does not necessarily understand the reason why the instructed card is opened even if comments on the card to be opened are given. Therefore, the partner system explains that how our hands are evaluated by an opponent player and that the current tactics are loss or gain for us. If a partner player shows the card to be opened, the hand evaluation part evaluates the following points assuming that the shown card is opened. (1) Which poker hand does an opponent player take notice of? (2) Is it loss or gain for us to open the shown card.

#### 3.4.2. Other Remarks

##### 3.4.2.1. Change in poker hands

When changes in poker hands are observed, for example, when (1) a partner player and/or an opponent player comes to have a stronger poker hand, (2) a partner player and/or an opponent player comes to have a stronger likely hand or (3) it is found that a partner player's expected poker hands and/or an opponent player's ones cannot be completed, the partner system gives some comments on these changes to a partner player.

Ex) It seems that the opponent player's hand cannot be flush.

##### 3.4.2.2. Opponent's betting points are suspiciously few or much

When an opponent player's betting points are suspiciously few or much, an opponent player usually considers some tactics. Therefore, the partner system gives a partner player some comments on an opponent player's betting points in order that partner player takes notice of the opponent player's tactics.

Ex) The opponent player's betting points are few.

#### 3.4.3. Remarks on showdown

When a game is over and both players' hands are shown, the system makes some comments on the game according to the following.

- 1) Which player is the winner.
- 2) The game is over by drop or showdown.
- 3) If the game is over by drop, which player's hand is stronger.
- 4) The system's decisions and/or comments and a partner player's decisions are the same or not.
- 5) There is significant difference between a partner player's hand and an opponent player's one, or not.

## 4. Experiments

Subjects experiments are performed in order to evaluate the usefulness of the present system. In the experiments the present system is compared with the support system which makes only comments on game situations. The playing system developed in [4] is used as the an opponent player. The subjects are 5 students who are all beginners of poker

players. They play 30 games with the present partner system and play other 30 games with the support system, where card distributions in 15 games out of 30 games are the same. These 15 games are called common games here.

### 4.1. Game records

The overall points of each subject against an opponent players in the common games with the partner system and those with the support system are shown separately in Table 2. It is found that subjects with the partner system do not always get more points than those with the support system. The usefulness of the partner system is not mentioned by overall points in the common games.

The betting points of each subject in the common games with the partner system and those with the support system are shown separately in Table 3. It is found that except for subject A, four subjects with the partner system bet more points than those with the support system.

Table. 2. Subjects' amount of gain

	support	partner
A	49231	8882
B	4604	14796
C	-6634	-48102
D	-32779	-36213
E	-27443	95

Table. 3. Subjects' amount of betting points

	support	partner
A	52767	21962
B	6788	17224
C	59584	71572
D	62115	100437
E	34967	46105

Table. 4. Subject A's betting points

game	support	partner
1	75	1406
2	105	753
3	206	85
4	171	109
5	261	230
6	47920	9360
7	299	218
8	195	461
9	2517	4656
10	198	272
11	45	2956
12	337	280
13	68	195
14	66	274
15	304	707
sum	52767	21962
*	4847	12602

The bottom of Table 4 shows the sum total of betting points except for game6.

Table4 shows subject A's betting points in each game with the partner system and those with support system. It is found that except for game 6, subject A with the partner system bets more points than he with the support system on average. These mean that subjects with the partner system have more confidence in betting points than subjects with the support system.

#### 4.2. Subjects' answers in questionnaire

After the experiments, subjects are asked to answer questionnaire: Which system do you want to play the game with? Or do you want to play the game by yourself? Four subjects out of five answer that they prefer to play the game with the partner system. Only subject D answers that he would like to play the game by himself. Examples of the reasons for their preferring the partner system are as follows.

- (1) When I play a game with the partner system, its advice is obvious to me. However, when I play a game with the support system, I often miss the meaning of support system's comments.
- (2) When I get the comments from the support system in the situation that I have not confidence in my decision, I am confused more since the meaning of the comments is not clear for me.

A subject, who answers that he prefers to play a game by himself, answers the questionnaire as follows: He wants to make decisions by himself even in every situation. He has the playing style which does not need any help from other people in games. He does not need the partner system. Answers of the questionnaire show that four subjects except for subject D feel familiarity to the partner system more than the supports system. The usefulness of the partner system is also confirmed by the answers of the questionnaire of impressions of the two systems, the partner system and the support system.

- (1) I feel humanity and familiarity in the partner system's responses.
- (2) The partner system gives some pieces of information that I am hardly aware of.
- (3) Although the partner system is more kind to subjects in game than the support system, the partner system sometimes gives some advices of which meanings are not clear.
- (4) The support system often gives some advises of which meanings are not clear at all.

(5) The support system has no familiarity since it does not encourage or praise subjects.

(6) Subjects feel that that support system plays a game by itself rather than the subjects play games with it.

These answers show that humanlike linguistic expressions of partner system's comments help subjects to adapt to the partner system and that although both systems have problems concerning to the meaning of some advices, the partner system reduces unclearness of comments by the interaction with subjects.

## 5. Conclusions

This paper mentions the interactive partner system in the poker game of Seven-card-Stud, which is a kind of imperfect information games. The system takes some comments on tactics, both players' hand and betting points, the reasons why the system takes comments, games results, etc. This paper also performs subject experiments to confirm the usefulness of the presented system by the comparison of the partner system and the simple support system. It is found that subjects can understand the poker game of Seven-card-Stud by the use of the partner system and that subjects have better impressions of the partner system than those of the simple support system since the partner system takes clearer and more humanlike comments than the simple support system. It is also found that the partner system cannot take all comments which make the partner player satisfied. In a future the system is improved so that the partner player can play the game more pleasantly in cooperation with the partner system.

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