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A work point count system coupled with back-propagation for solving double dummy bridge problem

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ABSTRACT

The game 'contract bridge' is one of the most widely known card games comprising many fascinating aspects, such as bidding, playing and winning the trick including estimation of hand strength, the additional input data based on the human knowledge of the game to improve the quality of results. The game classified under a game of imperfect information is to be equally well-defined, since the decision made on any stage of the game is purely based on the decision that was made on the immediate preceding stage. The incompleteness of information, the real spirit of the card game in proceeding further deals of the game are taking into many forms especially during the distribution of cards for the next deal. One among the architectures of the Artificial Neural Network is considered by training on sample deals and used to estimate the number of tricks taken by one pair of bridge players is the key idea behind the Double Dummy Bridge Problem, implemented in this paper. The Cascade Correlation Neural Network architecture with supervised learning implemented to train data and hence to test it is coupled along with Work point count system.

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1. Introduction

Contract bridge is a trick-taking card game where, on each of several deals, the opposing side first competes in a bidding auction for the right to establish the contract for that deal, the side winning the auction being known as the declaring side. The contract is an exchange of the right to establish which suit, if any, is a trump for an undertaking to win at least the number of tricks specified by the highest bid [1]. After the contract has been established, the play of the cards proceeds as in most trick-taking card games until all 13 tricks have been played. One side may claim a stated number of the remaining tricks and concede the balance if any, during the play.[1] The declaring side will have either succeeded or failed in fulfilling the contract is based on the actual number of tricks taken. If successful, the declaring side scores the points, otherwise the defending side scores the points.

The overriding objective is to win the contest by accumulating more points than the opponent. Although each variant of bridge has its own particular scheme for awarding and accumulating points, all are based upon whether or not the contract for each deal was made or defeated and the total number of tricks played in the game. It can sometimes be advantageous to bid a contract that one does not expect to make and to be defeated, thus losing some points, rather than allow the opposing side to bid and make a contract which would score them still greater number of points. In the standard 52-card deck used in bridge, the ace is ranked the highest followed by the king, queen, and jack and the spot-cards from 10 down through two. The suit denominations also have a rank order with No-trump being the highest followed by Spades, Hearts, Diamonds and Clubs.

A key feature of bridge is the concept of vulnerability, since on each deal, each side is said to be either vulnerable or not vulnerable depending upon whether or not it has won a game. The scoring points that are won on a deal as a result of making a contract, and the points which are lost when failing to make a contract, are both significantly increased for the side that is vulnerable. Accordingly, whether one's side is vulnerable affects its strategy for both bidding and play [2]. In certain situations, if one pair of players has made the most recent bid, in turn the other pair of players may double the stakes. i.e., if the said pair makes a contract at this stage, then they win double the number of points, but the risk is also correspondingly greater. Any pair between the two can then redoubles and since three passes end every auction, it is quite possible for the final contract to be doubled or redoubled, increasing the score.

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[1] www.wikihow.com/play-Bridge.

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Artificial Neural Networks (ANN) are based on non-linear activation function approximations which make them suitable for most of the applications especially games, since the outcome of the game could only be foreseen, but cannot be stated earlier at any stage. The focus of the paper is mainly on verification of ANN's abilities to learn the evaluation function to solve the Double Dummy Bridge Problems (DDBP) rather than finding the solution to the problem. There are many Feed Forward Neural Networks (FFNN) available which are trained in bridge game [3–5] and have been formalized in the best defense model, which also presents the strongest possible assumptions about the opponent [6,7]. This is used by human players because modeling the strongest possible opponents provides a lower bound on the pay off that can be expected when the opponents are less informed. Of the two methods known as a work point count method (WPCM) [8,13] and a distributional point method (DPM) [9,13] to evaluate the hand strength during the game is an exclusive and a popular system used to bid a final contract in bridge game. The knowledge of the game of bridge acquired by an individual player over a period of time is also considered and it is supplied to the neural network architecture in the form of input neurons by multiplying the card values by the appropriate numbers defined in WPCM. The sum of these values is given in the network model thereby making it to imbibe the expertise of the players along with the usual definition in the input process.

The paper is organized as follows. Section 2 provides a brief description of the game of bridge followed by a definition of the Double Dummy Bridge Problem and the nature of the source data and how they are mapped to each card. In Section 3 the literature survey pertaining to previous efforts of applying neural networks in game of bridge are mentioned along with the data used in the game obtained from GIB library which includes possible combinations of deals for each of the tricks and the number of tricks taken by the appropriate pair during the game. Section 4 details about cascade-correlation architecture and the way in which the neurons are added in the hidden layer one after another based on the convergence of error both in the training phase with a diagrammatical representation. Section 5 summarizes the back-propagation algorithm implemented in the cascade-correlation architecture. Though many methods are explained to assign values to hand strength, a factor which reflects the individual players' expertise in the game of bridge is assigned through the work point count method and it is illustrated in Section 6. The bridge game, implemented through cascade-correlation network model with number of input neurons equivalent to the number of cards used in the game say 52, the required number of hidden neurons and one output neuron is explained in Section 7. The representation of results with the defined architecture is discussed with a sample of data in Section 8. Also, the architecture illustrated with sample data is compared with state of the art architecture with a complete different algorithm to establish its accuracy with respect to convergence of results.

2. Problem description

The game of bridge is one of the well known card games played worldwide with randomly dealt cards, which makes it also a game of chance, or more exactly, a tactical game with inbuilt randomness, imperfect information and restricted communication. The randomness and imperfect information built-in the game are drawing attention of many of the researchers and Computational Intelligence (CI) methods are applied to focus mainly on the aspect of learning in the game playing systems [10]. The bridge is a partnership game requiring four players, each player sits opposite to his partner and it is traditional to refer to the players according to their position at the table as North, East, South and West, so North and South are partners playing against East and West. It is played with a standard deck of 52 playing cards, where one of the players deals all of the cards, 13 to each player, in clockwise rotation, beginning with the player to the left of the dealer. In bridge games, basic representation includes value of each card as (Ace (A), King (K), Queen (Q), Jack (J), 10, 9, 8, 7, 6, 5, 4, 3, 2) and suit as (♠ (Spades), the highest, ♥ (Hearts), ♦ (Diamonds), ♣(Clubs), the lowest) for assignment of cards into particular hands and into public or hidden subsets, depending on the game rules. The ranking is for '*bidding*' purposes only and in '*play*' all suits are equal, unless one suit has been named as '*trumps*', then it beats all the other cards. The cards are shuffled by the player to dealer's left and cut by the player to dealer's right.

The first card played to each trick is called the '*lead*' and one may play any card in hand on *'lead'* as the next three players have an obligation to follow the suit and if it is not possible, they may play any card in hand. After four cards have been played, the trick is complete and the winner of a trick is determined. The bidding determines the declarer, which suit will be trumps and the number of tricks declarer must win. The dealer is the one who deals the cards and any of the players may become the declarer. The player to the left of declarer makes the first lead, which is called the opening lead. The hand held by declarer's partner is then displayed face up for all to see called the dummy and the player who held it does not participate in the play. The declarer must play both the dummy and his own hand, although each in proper turn. After the opening lead, the hand that wins each trick must lead to the next trick. If a trick contains a trump card, it is won by the highest trump played; otherwise it is won by the highest card of the suit led. After each trick, one player of the side that wins it should collect the cards, arrange them neatly so that the number of tricks won can be counted easily and the play continues the same way for all 13 tricks [11]. The concept of exposing one of the hands for all to see is the hallmark of bridge. The dummy should be arranged neatly, separated into suits and the cards in each suit should be in order of rank and overlapped, with the rank of each card clearly visible. If there is a trump suit, it is placed on dummy's right side, viewed by declarer, trumps are on the left. The purpose of bidding is just to determine which player will be the declarer and how many tricks must be won with the chosen suit as trumps.

2.1. The game of contract bridge

In contract bridge, the four players in two fixed partnerships as pairs facing each other [12] and referred according to their position at the table as North (N), East (E), South (S) and West (W), so N and S are partners playing against E and W is illustrated as below in Fig. 1 as an arrangement in the game. The team who

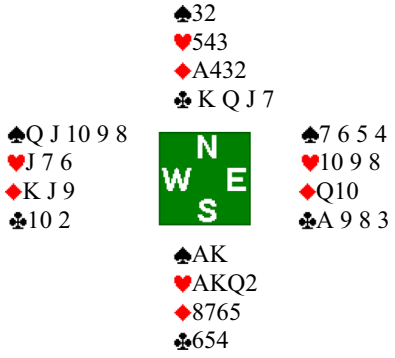

Fig. 1. The arrangement in bridge game.

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