CHAPTER 5
CONCLUSIONS AND FINDINGS

5.1 INTRODUCTION

The chapter focuses on delivering concluding remarks and findings of the board games of Game of Reversi and Game of Checkers as test bed for the thesis. The conclusion is basically derived from the results collected based on various genetic parameters. The results are positive proof of evolutionary genetic process and machine learning.

5.2 CONTRIBUTION

The undertaken thesis research work contributes in the field of board game study and it evolutionary implementation using genetic approach to the branch of machine learning for two board games Checkers and Reversi.

5.2.1 Game of Checkers Conclusion

Game of Checkers is in the category of two-player, zero sum, deterministic, perfect information and alternate move board games. Since four decades, many researchers and game program developers have contributed heavily to make computer programs which play the game very effectively by making “intelligent” moves using various game analysis methods and processes.

There are many game versions of Checkers available worldwide. The thesis takes standards game of Checkers of 8x8 boards into consideration with simple game playing rules for moves and captures. This thesis makes a novel approach in this domain by making a genetic string which represents board game positions which are significant for move making and capturing. This chromosome string of 32 bit contains one bit for one
board position and linear evaluation function has fitness values and game feature centric weight as its constituent in dot product. Linear evaluation function provides simple mathematical equation representing weights $W$ and functional features $F$ in simple dot product. Each “parent” created an off springs by varying all of the accompanying weights and related square values. All parents and offspring contested for survival by playing games of checkers and receiving points for the results of their play.

Each game gets played using a min-max alpha-beta search of the associated game tree that results from observing ahead over a nominated number of moves. The ply depth of the search, $d$, was set to three to permit for reasonable number of generations with specified size of populations. The best move to make was chosen by iteratively minimizing or maximizing over the leaves of the game tree at each ply according to whether it was the opponent’s or the player’s move.

Linear evaluation function is mathematically simple and perfect match for genetic string representing board positions. They both help in finding evolved value of weights and enhancing genetic weight values by iterative process cycle of genetic operators. Each board game has very typical features of mobility, stability, capture patterns, parity and various patterns on game board. These features and their strategic significance is duly identified by game experts and represented very well by value $F$ in evaluation function.

For a given game board position next move is decided based on exploring all move possibilities of varying ply depth up to three. These move possibilities are explored using min-max search algorithm and if leaf nodes are very large in number than alpha beta pruning is used. To check move that is maximum benefiting from available nodes various Genetic operators’ selection-crossover and mutation with varying percentages are used for various population sizes and generation span.

Evolutionary genetic operators in parallel are applied onto them and these weights get evolved resulting in finding better moves for that specific generation. Better move are selected to be applied on the available board configuration to achieve winning board
positions. These move making process based on above mentioned parameters give one of the very effective machine learning policy for such kind of problem domains.

Various graphs are formulated based on various collected results of games, game generations and game populations. These fitness charts measure learning process efficiency by collecting maximum and minimum fitness values for various board positions. These values positively progresses as game passes through various generations. Better fitness values are indicative of good or better move selection and slump or drop in fitness present picture of average move. Average move results due to mutation effect or less ply depth.

These results are clearly indicative of the positive learning impact of genetic parameters in evolving the game play and positive increment of fitness values. These results clearly envisage and justify the effect of evolutionary genetic approach on all the game of checkers. This search depth is reasonably good and evolving games are taking more time to finish which is due to better move selection evolution.

It is found that for many board game domains, 50-100 generations are good enough to find near-optimal good solutions. This is better than an exhaustive search based on some simple game heuristics. The collected results show very clear fitness function improvement in Max. and Min. values in each of the generations. The Checkers program implementation concludes the right and mature choice of genetic algorithm as evolutionary optimization technique and selected genetic parameters for the specified board game.

5.2.2 Game of Reversi Conclusion

Game of Reversi is second board game under implementation using evolutionary game playing approach with genetic optimization. The game is also two-player, zero sum, deterministic, perfect information and alternate move board game. Though it is popularly known as Othello, the thesis uses ancient Japanese name Reversi because of its basic
game playing rule of flipping opponents rule by bracketing it. This board Game can be perfectly described by a well-known caption as “A minute to learn and a life time to Master”.

The thesis’ Reversi playing program demonstrates “human-like” approach to artificial game playing by evolving game playing parameters using genetic approach. The program took ten board square positions to make its genetic string as the Reversi board is symmetric and these ten disc families, which cover entire categories of board discs. The main research contribution of the thesis is Disc family based genetic string and its parameter evolving using genetic approach.

Each set of board squares was allocated a multiplying coefficient based on the importance of that particular set. This group coefficient of ten functions sets go through coefficient (weight) change as genetic operators were applied on them. These Weight results are collected and analyze using fitness graphs for almost all disc families’ members. The program also uses the Power Rate equation which clearly defines the strength of board position captured or through that winning percentage of one player compared to all games played including draws.

Weight value graphs shown in chapter 4 indicate that various firmness support of discs sets as per their stability and mobility feature. Corners discs shows highest degree of stability as it is taken once cannot be revert back by opponent at least for that particular game. The weight graphs of various generations reveal the feature of building and learning by slowly developing good playing and move making in initial generations of the game.

Slowly developed fitness values positively increases and stabilizes with passing generations of games. It proves the success of genetic optimization. Based on the results of the experiment and collected–analyzed for different disc sets, the thesis concludes that GAs enriches the authority of the board game-playing computer program by increasing
the potentiality of better move selection. This results in providing a reasonable chance to play the game of Reversi more competently and meritoriously.

After this real-world test on specific board games, it evidences that evolutionary learning through genetic algorithm projected in this thesis paves a new way to use it for a group of problem spheres which requires optimization as its one of the vital area. Genetic evolution enhances the efficiency of learning greatly. The optimization of the genetic algorithm can improvise fitness functions in order to calculate the board state accurately and make significant progress to improvise the computer Game of Checkers and Game of Reversi.

5.3 CLOSING REMARKS

- One nice feature about genetic algorithms is that it explores a large number of points simultaneously. This permits us to escape poor local optima quickly. Rather than getting stuck (as in local search) or doing a laborious stochastic climb, it already has other points generated for further exploration.
- By coding a given Othello problem into a GA framework, these smart algorithms are able to "evolve" solutions to real world problems.
- For many problems domains, genetic algorithms can often find good solutions (near-optimal) in around 50-100 generations. This can be many times faster than an exhaustive search.
- The range of the weightings is very high for each set of discs which shows the impact of Genetic Approach on them. It gets betterment of linear Evaluation Function as a result of this.
- Above Result shows that Genetic Approach has a subtle positive effect in Board game playing and machine learning by computer. It gives better and stronger genetic game playing programs.
- This board game domain implementation shows a novel path of evolutionary learning through genetic algorithm for other group of problem domains also where optimization is one important domain to arrive at a better solution. Evolutionary algorithm enhances the effectiveness of learning momentously.