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Abstract

Conspiracy number and proof number are two game-independent heuristics in a game-tree search. The conspiracy number is proposed in Conspiracy Number Search (CNS) which is a MIN/MAX tree search algorithm, trying to guarantee the accuracy of the MIN/MAX value of a root node. It shows the scale of “stability" of the root value. The proof number is inspired by the concept of conspiracy number, and applied in an AND/OR tree to show the scale of “difficulty” for proving a node. It is first proposed in Proof-Number Search (PN-search) which is one of the most powerful algorithms for solving games and complex endgame positions. The Monte-Carlo evaluation is another promising domain-independent heuristic which focuses on the analysis based on random sampling of the search space. The Monte-Carlo evaluation does not reply on any prior knowledge of human and has made significant achievements in complex games such as Go.

In this thesis, we select the conspiracy number search, the proof number search and the Monte-Carlo tree search as three example search algorithms with domain-independent heuristics to study its relations and differences, and finally propose a new perspective of the game tree search with domain-independent heuristics. The relations and differences of the three search algorithms mentioned can be summarized as follows. The Monte-Carlo tree search uses Monte-Carlo evaluations for the leaf nodes to indicate the most promising node for expansion. In other words, the Monte-Carlo evaluation can be regarded as a detector to obtain the information beneath the leaf nodes to forecast the promising search direction in advance. In contrast, the conspiracy number search and the proof number search tend to use the indicators corresponding to the structure or the shape of the search tree that has already been expanded. Therefore, it can be regarded as forecasting the promising search direction according to the information above the leaf nodes. As a natural induction of such understanding of the game tree search using domain-independent heuristics, we may get some improvements by combining the conspiracy number or the proof number idea with the Monte-Carlo evaluation into a search algorithm, which can be considered as a combination of “the information above leaf nodes” and “the information beneath the leaf nodes”.

Our research focuses on applying or refining domain-independent heuristics such as the conspiracy number, the proof number and the Monte-Carlo evaluation to achieve such three purposes: (1) enhancing current search algorithm. For this purpose, we proposed the so-called Deep df-pn search algorithm to improve df-pn which is a depth-first version of PN-search by forcing a deeper search with a parameter. The experiments with Connect6 show a good performance of Deep df-pn. (2) Analyzing and visualizing game progress patterns for better understanding of games and master thinking way, such as showing the analysis of the game progress for learners in Chinese Chess tutorial system. For this purpose, we proposed the so-called Single Conspiracy Number method for long term position evaluation in Chinese Chess and

obtained good results. (3) Studying the relations and differences between the conspiracy number, proof number and the Monte-Carlo evaluation and combining “the information above leaf nodes” and “the information beneath the leaf nodes” to propose a new search algorithm with domain-independent heuristics named probability-based proof number search. A series of experiments show that probability-based proof number search outperforms other famous search algorithms for solving games and endgame positions.

Keyword: combinatorial game, domain-independent heuristic, game solver, Monte-Carlo evaluation, game progress pattern