Games of No Chance
MSRI Publications
Volume **29**, 1996

Tutoring Strategies in Game-Tree Search

(Extended Abstract)

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Introduction. According to the analysis of grandmaster-like strategies in Shogi [Iida and Uiterwijk 1993], it is important for a teacher, at the beginning stages of teaching, to intentionally lose an occasional game against a novice opponent, or to play less than optimally in order to give the novice some prospects of winning, *without this being noticed by the opponent.* Such a strategy is called a *tutoring strategy* in game-tree search.

In this work we consider a *loss-oriented search strategy* (*LO-search* for short), by which a player attempts to lose a game, and we show an algorithm for LO-search based on the minimax strategy and OM-search (opponent-model search; see [Iida et al. 1993]). We further describe characteristics of LO-search, including the concept of *intentional error.* We next discuss the situation in which a player will notice such an intentional error. We then describe a *tutoring search* (*TU-search* for short) by which a player attempts to lose a game without this being noticed by the opponent.

LO-search is based on OM-search, since LO-search also takes the opponent model into account. OM-search is predicated on the assumption that one has complete knowledge of the opponent's strategy and that this strategy is completely contained in the opponent's evaluation function. In OM-search, two values are computed for all positions in a search tree. For clarity, the players are distinguished as a max player and a min player.

Loss-Oriented Search. In order to play games, the minimax strategy or variations thereof have been used by many game-playing programs. The minimax strategy will choose the best move according to the program's look-ahead, using some evaluation function. OM-search will also choose the best move while taking the opponent model into account. Note that these strategies back up the best

The full version of this article, including algorithms, example search trees and characteristics of the search strategies, will be published in the *ICCA Journal* vol. **18**, No. 4 (December 1995).

successor at any internal max node in a search tree. Thus, in order to lose a game against an opponent, it may be reasonable to choose a move at a max node that leads to a successor whose value is not the best. A definition of LO-search now is the following:

> a search strategy that chooses a move taking the opponent model into account at a min position and *maximizing* the value by OM-search at a max position, provided that the latter is less than the value by the minimax strategy from the max player's point of view. If there is no such successor at a max position, a move *minimizing* the value by OM-search is chosen.

LO-search thus plays an *intentional error*, provided that it exists, whose value by OM-search is maximal among intentional errors. When there are no intentional errors, that is, when every move leads to a better result than minimax due to the opponent's errors, LO-search plays a move whose value by OM-search is the minimum among the legal moves.

Note the difference between LO-search and misère play. In misère play, the goal for both players is to lose, whereas in LO-search the main goal for one player, called the *max player*, is to lose (or give the opponent some prospect of winning), while the *min player* is striving to win. Again we assume that the max player, who will adopt LO-search, has complete knowledge of the min player's evaluation function.

It is evident that, the worse the score of the move played, the higher the potential to lose. However, LO-search should not play moves that are too stupid, such as giving up a queen for free in chess. Therefore, it is important to examine at a given position whether LO-search is to be used or not.

Many variations on LO-search are possible. The above definition seems to be one of the most reasonable variations for playing an intentional error, since LO-search often plays only a little weaker than the program's real strength. But, in many tactical situations, the second-best move may be just as bad as the worst—for example, failing to recapture a piece or making the wrong response to a mate threat in chess. In such cases, an LO-search move will be very poor. A solution to this problem is to recognize when a non-optimal move should be played and when not.

An additional problem with LO-search is that the min player can be aware of an intentional error played by the max player.

Tutoring Search. To tackle the problems just mentioned, we define the concept of *loss* as the difference between the value of the move chosen and that of the optimal move in the OM-search sense, and the notion of *loss limit* ε, a bound for the loss beyond which the min player probably will be aware of the max player's intentional error. The value of ε should be small when the two players have comparable strength. When the min player's evaluation function is identical to the max player's, ε must be set to 0: the max player cannot play any move by TU-search other than the best move from his point of view. A definition of TU-search now is the following:

> a search strategy that chooses a move taking the opponent model into account at a min position and *minimizing* the value by OM-search at a max position, provided that an intentional error will be unnoticed by the opponent.

Contrary to LO-search, tutoring search only will play an intentional error when this will be unnoticed by the opponent. It will not consider very stupid moves (from both player's point of view). On the other hand, since very dumb moves are avoided, it will be possible to choose the *lowest*-valued one among the candidate intentional errors.

References

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