Artificial intelligence and knowledge engineeringList 2

Jan Jakubik, Piotr Syga

March 18, 2023

1 Purpose of the list

The aim of the exercise is to get acquainted with the algorithms for playing two-player games - the Minimax algorithm and its improvement using alpha-beta cuts.

2 Theoretical introduction

Below is information to help you complete your to-do list. It is assumedthat after the performance the student has mastered the theoretical issues.

2.1 Definitions

Definition 1(Decision tree). A directed tree in which each node represents a problem state and each edge represents an action or choice that leads to the next state is called a decision tree.

The decision tree can be used to model problems in whichdecisions must be made considering the many possible options.

For games, decision trees are often used to represent possible moves in a game. Each node in the tree represents a state of the game, and the edges correspond to possible moves or decisions that the player can make. It is therefore easy to see that the degree of a vertex corresponds to the number of possible tomake movements,and thus need not be constant at one level of the tree. When a player makes a move, we move up the tree to the node corresponding to the new game state. The game ends when you reach the leaf. The length of the path (corresponding to the number of rounds) may be different for different leaves.

Definition 2(Zero-sum game). A game is an ordered three G = (N, S, U), where N is the number of players, S = S1, S2, . . . , SN denotes the set of finite sets of strategies of players from 1 to N , and U = u1, u2, . . . , uN is a set of utility (payoff) functions that assign an outcome value to each

possible combination of player actions. I mean ui: $S_1 \times \cdot\cdot\cdot \times S_n$R is the player's payoff*andbased on player strategy.*
If$\forall p \in S_1 \times \cdot \cdot \cdot \times S_{n, and \in n} at_{and}(p) = 0$, then the game is called a zero-sum game.

2.2 Minimax algorithm

The Minimax algorithm is a game tree search strategy that is used to make decisions in two-player zero-sum games such as chess,checkers or him. Algorithmthis one seeks to minimize the maximum possible loss a player can suffer given the opponent's moves. The Minimax algorithm is based on traversing the game tree, where each vertex of the tree represents a game state, and the edges between them represent the players' moves. The leaves will be vertices representing the end of the game with one of the players winning. In practice, due to the number of vertices increasing exponentially with depth, we use a depth limit and game state heuristics that allow us to evaluate an unfinished game when this limit is reached.

MainMinimax algorithm steps:

1. Search the game tree starting from the root.
2. If we have reached a leaf or a given depth, we return the value for the player who is currently making a move. For a leaf, it is the result of the game, and when reaching the limit of the search depth - the value of the evaluation heuristic.
3. Otherwise, being in the current state of the game, we calculatethe value of each of the children of the vertex recursively calling Minimax (from step 2).
4. We assign the current vertex the maximum or minimum value among its descendants, depending on which playershows this vertex.

The Minimax algorithm can be optimized by alpha-beta chopping, which consists in stopping the recursive traversal of a certain part of the tree when certain conditions allow it to be concluded that there is no further traversingsense.

2.3 Alpha-beta cut

The alpha-beta pruning algorithm is an extension of the Minimax algorithm, which allows you to omit the consideration of unnecessary nodes in the game tree and thus shorten the search time. The alpha-beta pruning algorithm works by eliminating branches of the tree, which are clearly not optimal because they contain only moves that will not improve the value of the value function for a given node. This algorithm allows you to significantly reduce the number of nodes that need to be looked at when searching the game tree.

Mainalgorithm steps:

1. Run the Minimax algorithm on the game tree by searching them recursivelyfrom the root.
2. Store two values: alpha and beta, initially set, corresponding tonio, minus and plus infinity.
3. For the current tree vertex, if it is a maximizing level vertex, follow steps 4-6. Otherwise, follow the steps7.-9.
4. For each vertex child, call the alpha-beta re-cut algorithmcuratively (from step 3).
5. If the value returned by the algorithm is greater than alpha, update the alpha value with the returned value.
6. If beta is less than or equal to alpha, stop traversing the descendants and return alpha.
7. For each vertex child, call the alpha-beta re-cut algorithmcuratively (from step 3).
8. If the value returned by the algorithm is less than beta, update the beta with the returned value.
9. If beta is less than or equal toalpha, stop traversing descendants and return beta.

3 Tasks

Reversi is a board game for two players, played on an 8x8 board. The game uses discs of two colors. The board at the beginning of the gameis empty.Players take turns placing the discs of their color on the board in such a way as to create a straight line with the current player's pieces at both ends and the opponent's pieces in between. When a player forms such a line, he knocks over all the opponent's pucks in the middle of the line. The game continues until the board is completely filled with discs. The player with the most tiles of his color on the board at the end of the game wins.

Using messageson this list and those given in the lecture, write a program that plays Reversi. The standard input of the program should be 8 lines consisting of 8 numbers separated by spaces - 1 means the first player's disc, 2 means the second player's disc, 0 means an empty field. Assume that the number '1' and '2' are equal on the input, it is player '1''s turn. On the standard output, the program should return 8 lines consisting of 8 numbers - 1 is the first player's disk, 2 is the second player's disk, the 9th line should contain information about the number of rounds and which player won. The standard error output should return the number of visited nodes of the decision tree and the running time of the algorithm. Punctation:

1. correct definition of the game state and function generating possible moves forper state and player (10 points)
2. building a set of heuristics for assessing the state of the game for each of the players, eachof players should have at least 3 different strategies (20 points)
3. implementation of the Minimax method from player 1's point of view (30 points)
4. implementation of alpha-beta z-point cutplayer 1 view (40 points)
5. modification of the program so that it makes only one move (from the point of view of the player whose turn it is) which will enable the game to be played between two programs (e.g. two calls to the same application) and the use of heuristics adaptively changing the player's strategy in order tovictory achievements (additional 20 points).

For the task, prepare a report containing a theoretical description of the method, a formal formulation of the problem with constraints, the state of the game and the decision tree, and a description of the idea of the solution along with a short example. In the report, indicate the source materials used and briefly describe the libraries used in the implementation. In the summary of the report, additionally describe the implementation problems encountered while performing the task. Send the report to the leaderat least 24 hours before submitting the list.

4 Literature

- reverse
- Description of Reversi rules
- JF Nordstrom - Introduction to Game Theory
- M. Maschler et al., Game Theory
- N. Nisan et al., Algorithmic Game Theory
- MJ Osborne, An Introductionit's Game Theory