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AIES ASSIGNMENT 2

MINIMAX ALGORITHM - TICTACTOE

Code

```
#include <array>
#include <iostream>
#include <limits>

typedef std::array<std::array<char, 3>, 3> matrix;

void miniMax(matrix &gameBoard, char currentPlayer);
int maxValue(matrix &gameBoard);
int minValue(matrix &gameBoard);
bool checkFilledBoard(const matrix &gameBoard);
std::pair<char, bool> checkWinCondition(const matrix &gameBoard);

void miniMax(matrix &gameBoard, char currentPlayer) {
  int bestValue = (currentPlayer == 'X')
                      ? std::numeric_limits<int>::min()  // -2147483648
                      : std::numeric_limits<int>::max(); // 2147483647

  int bestMoveRow = -1, bestMoveCol = -1;

  // Traverse all cells to find the best move
  for (int i = 0; i < 3; i++) {
    for (int j = 0; j < 3; j++) {
      if (gameBoard[i][j] == '\0') {
        gameBoard[i][j] = currentPlayer; // Apply move X or O
        int moveValue =
            (currentPlayer == 'X') ? minValue(gameBoard) :
maxValue(gameBoard);
        gameBoard[i][j] = '\0'; // Reset

        // Choose the best move for X or O
        if ((currentPlayer == 'X' && moveValue > bestValue) ||
            (currentPlayer == 'O' && moveValue < bestValue)) {
          bestMoveRow = i;
          bestMoveCol = j;
          bestValue = moveValue;
```

```
        }
      }
    }
  }

  // Apply the best move
  if (bestMoveRow != -1 && bestMoveCol != -1) {
    gameBoard[bestMoveRow][bestMoveCol] = currentPlayer;
    std::cout << "Best move for " << currentPlayer << ": (" << bestMoveRow
              << ", " << bestMoveCol << ")\n";
  }
}

// Maximizer
int maxValue(matrix &gameBoard) {
  auto [winner, isWin] = checkWinCondition(gameBoard);
  if (isWin) {
    if (winner == 'X')
      return 10;
    if (winner == 'O')
      return -10;
  }
  if (checkFilledBoard(gameBoard))
    return 0;

  int bestValue = std::numeric_limits<int>::min();
  for (int i = 0; i < 3; i++) {
    for (int j = 0; j < 3; j++) {
      if (gameBoard[i][j] == '\0') {
        gameBoard[i][j] = 'X'; // Maximizer's move
        bestValue = std::max(bestValue, minValue(gameBoard));
        gameBoard[i][j] = '\0'; // Undo the move
      }
    }
  }
  return bestValue;
}

// Minimizer
int minValue(matrix &gameBoard) {
  // returns a pair <char, bool>
  auto [winner, isWin] = checkWinCondition(gameBoard);
  if (isWin) {
    if (winner == 'X')
      return 10;
    if (winner == 'O')
      return -10;
  }
```

```
  if (checkFilledBoard(gameBoard))
    return 0;

  int bestValue = std::numeric_limits<int>::max();
  for (int i = 0; i < 3; i++) {
    for (int j = 0; j < 3; j++) {
      if (gameBoard[i][j] == '\0') {
        gameBoard[i][j] = 'O'; // Minimizer's move
        bestValue = std::min(bestValue, maxValue(gameBoard));
        gameBoard[i][j] = '\0'; // Undo the move
      }
    }
  }
  return bestValue;
}

// Function to check if the board is filled
bool checkFilledBoard(const matrix &gameBoard) {
  for (int i = 0; i < 3; i++) {
    for (int j = 0; j < 3; j++) {
      if (gameBoard[i][j] == '\0')
        return false;
    }
  }
  return true;
}

// Helper function to check if a line is complete
bool checkLine(const matrix &gameBoard, int x1, int y1, int x2, int y2, int
x3,
               int y3) {
  return gameBoard[x1][y1] == gameBoard[x2][y2] &&
         gameBoard[x1][y1] == gameBoard[x3][y3] && gameBoard[x1][y1] != '\0';
}

// Function to check if someone has won
std::pair<char, bool> checkWinCondition(const matrix &gameBoard) {
  // Check rows, columns, and diagonals
  if (checkLine(gameBoard, 0, 0, 0, 1, 0, 2))
    return {gameBoard[0][0], true};
  if (checkLine(gameBoard, 1, 0, 1, 1, 1, 2))
    return {gameBoard[1][0], true};
  if (checkLine(gameBoard, 2, 0, 2, 1, 2, 2))
    return {gameBoard[2][0], true};

  if (checkLine(gameBoard, 0, 0, 1, 0, 2, 0))
    return {gameBoard[0][0], true};
  if (checkLine(gameBoard, 0, 1, 1, 1, 2, 1))
```

```
    return {gameBoard[0][1], true};
  if (checkLine(gameBoard, 0, 2, 1, 2, 2, 2))
    return {gameBoard[0][2], true};

  if (checkLine(gameBoard, 0, 0, 1, 1, 2, 2))
    return {gameBoard[0][0], true};
  if (checkLine(gameBoard, 0, 2, 1, 1, 2, 0))
    return {gameBoard[0][2], true};

  return {'\0', false};
}

int main() {
  matrix gameBoard{};
  bool gameEnded = false;
  char currentPlayer = 'X'; // First player X

  while (!gameEnded) {
    // Display the board
    std::cout << "Current board state:\n";
    for (int i = 0; i < 3; i++) {
      for (int j = 0; j < 3; j++) {
        std::cout << (gameBoard[i][j] == '\0' ? '-' : gameBoard[i][j]) << " ";
      }
      std::cout << std::endl;
    }

    miniMax(gameBoard, currentPlayer);

    // Check for a win condition
    auto [winner, isWin] = checkWinCondition(gameBoard);
    if (isWin) {
      std::cout << "Player " << winner << " wins!\n";
      gameEnded = true;
      break;
    }

    // Check for a draw
    if (checkFilledBoard(gameBoard)) {
      std::cout << "It's a draw!\n";
      gameEnded = true;
      break;
    }

    // Switch players: 'X' -> 'O', 'O' -> 'X'
    currentPlayer = (currentPlayer == 'X') ? 'O' : 'X';
  }
```

```
  return 0;
}
```

Output

```
(base) PS C:\repo\Uni\AIES> .\a.exe
Current board state:
- - -
- - -
- - -
Best move for X: (0, 0)
Current board state:
X - -
- - -
- - -
Best move for O: (1, 1)
Current board state:
X - -
- O -
- - -
Best move for X: (0, 1)
Current board state:
X X -
- O -
- - -
Best move for O: (0, 2)
Current board state:
X X O
- O -
- - -
Best move for X: (2, 0)
Current board state:
X X O
- O -
X - -
Best move for O: (1, 0)
Current board state:
X X O
O O -
X - -
Best move for X: (1, 2)
Current board state:
X X O
O O X
X - -
Best move for O: (2, 1)
Current board state:
X X O
O O X
X O -
Best move for X: (2, 2)
It's a draw!
```

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Title

Implementation of Minimax algorithm.

FAQs

1. Compare informed search and adversarial search.

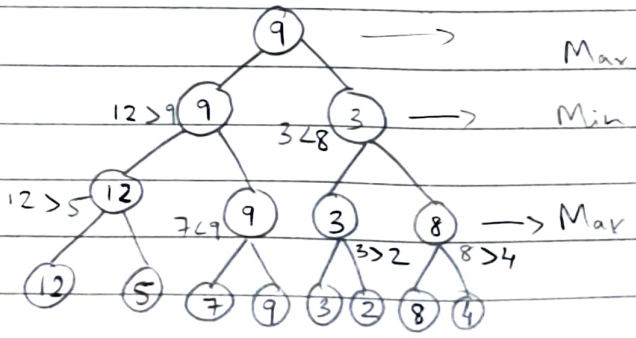
Informed search, also known as heuristic search, uses problem-specific knowledge (heuristics) to find solutions more efficiently. The goal is typically to find the optimal path to a solution in problems like pathfinding, puzzle-solving etc. E.g. A* search, Greedy Best First Search. These searches use a heuristic function (e.g. estimated distance to goal) to guide the search process.

Adversarial search is used in situations where there are two or more agents with conflicting goals. The goal is to maximise one's own outcome while minimising the opponent's outcome. E.g. Minimax algorithm and Alpha-Beta pruning. These algorithms consider the possible actions of the opponent, anticipating their moves and countering them.

2. Explain Minimax algorithm with example.

The Minimax algorithm is used in two-player, turn-based games to determine the optimal move for a player assuming that the opponent also plays optimally.

The algorithm explores all possible moves and their outcomes, assigning a value to each state.



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3. Explain Alpha - Beta Pruning.

It is an optimisation technique for the Minimax algorithm that reduces the number of nodes evaluated in the game tree.

Alpha (α): Represents the best value that the maximising player can guarantee at that point.

Beta (β): Represents the best value that the minimising player can guarantee at that point.

It works on the condition that if $\alpha \geq \beta$ then there is no need to explore the child node, and it can be pruned.

In practice, Alpha-Beta pruning can speed up the search process, especially in large game trees, by ignoring moves that won't be selected by rational players.

Pawkar
30/08