# Documentation

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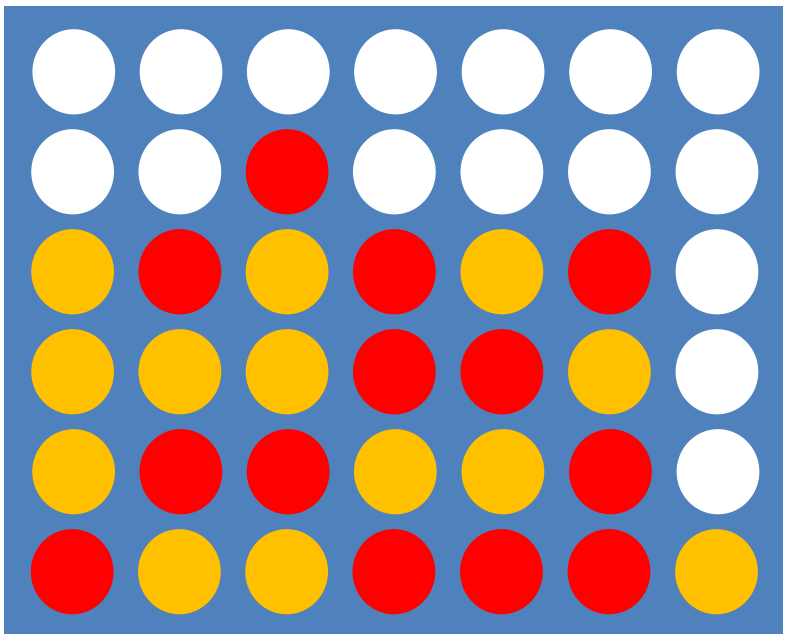

## *An Intelligent Connect 4 Player Using the Minimax Algorithm, Alpha-Beta Pruning, and Heuristic Functions*

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**The source code for the project can be found here:**
https://github.com/TH-Attya/AI310---Project-3.git

**Or via the QR Code:**

# Introduction and Overview

## 1.1 Project Idea

**The goal of this group project is to design and implement an intelligent Connect-Four player, leveraging AI techniques such as the Minimax Algorithm, Alpha-Beta Pruning, and Heuristic Functions.**

**Connect Four is a popular two-player game where the players choose a colour and then take turns dropping coloured discs into a seven-column, six-row vertically suspended grid. The pieces fall straight down, occupying the lowest available space within the column.**

**The objective is to connect four of one's own-coloured discs in a horizontal, vertical, or diagonal row before the opponent does.**

**Connect Four is a solved game. The first player can always win by playing the right moves.**

## 1.2 Main Functionalities

**- User-friendly interface for seamless interaction.**

**- Implementation of Minimax Algorithm with Alpha-Beta Pruning for intelligent decision-making.**

**- Heuristic functions to guide optimal moves.**

**- Adjustable difficulty levels to accommodate varying skill levels.**

## 1.3 Development Platform

**This project was implemented in PyCharm, a Python IDE.**

**The libraries need for this project include:**

**- NumPy: NumPy or Numerical Python is a library that provides a simple yet powerful data structure -> the n-dimensional array.**

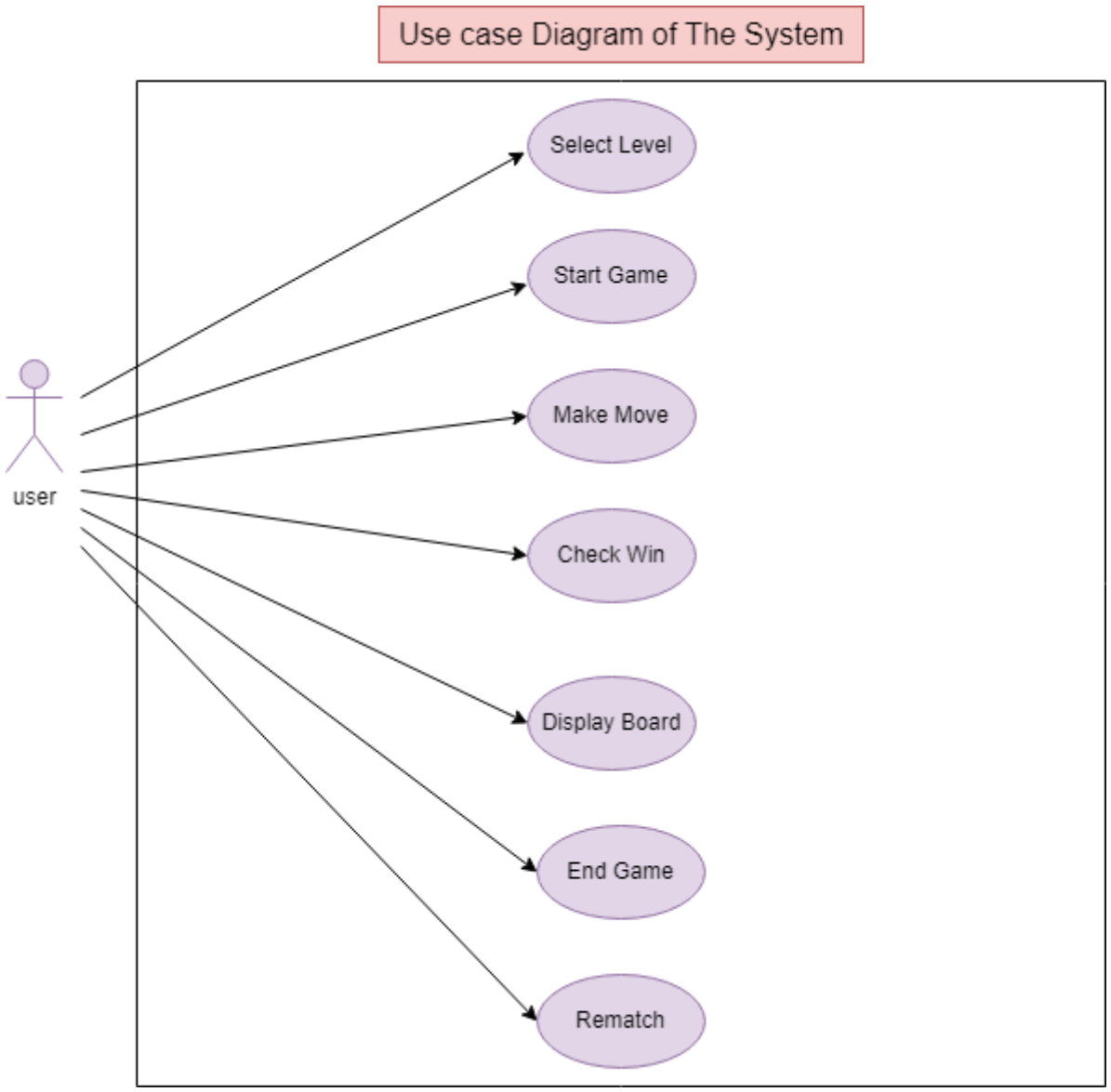
**- Pygame: a library for the development of multimedia applications like video games using Python.**

**- Python SYS Module: provides functions and variables which are used to manipulate different parts of the Python Runtime Environment. It lets us access system-specific parameters and functions.**

**- Python Math Module: some of the most popular mathematical functions are defined in the math module.**

## Proposed Solution

**From the user's perspective, the main functionalities of the game are:**
**- Selecting a difficulty level -> Beginner, Intermediate, Expert, Master.**
**- Starting the game.**
**- Making a move i.e., choosing where to place their discs.**
**- "Checking their win" i.e., evaluating their strategy and acting accordingly**
**- When either player wins, the display board lights up (e.g., Player 1 wins!!)**
**- The game then ends, and the user may go for a rematch and play again.**



## Definitions

### *1.4 Minimax Algorithm*

**Minimax is a decision-making algorithm used in two-player games with perfect information.**

**It evaluates possible moves by simulating the entire game tree and selects the move that minimizes the maximum possible loss.**

### *1.5 Alpha-Beta Pruning*

**Alpha-Beta Pruning is an optimization technique applied to the Minimax Algorithm.**

**It reduces the number of nodes explored in the game tree by eliminating branches that are guaranteed not to impact the final decision.**

**Integrating Alpha-Beta Pruning enhances the efficiency of the Connect-Four player, making it more responsive and capable of handling larger search spaces.**

### *1.6 Heuristic Functions*

**Heuristic functions provide a shortcut for evaluating game states without exhaustively exploring all possible moves.**

**In Connect Four, heuristic functions can assess the current board state based on factors like the number of connected discs and potential winning configurations.**

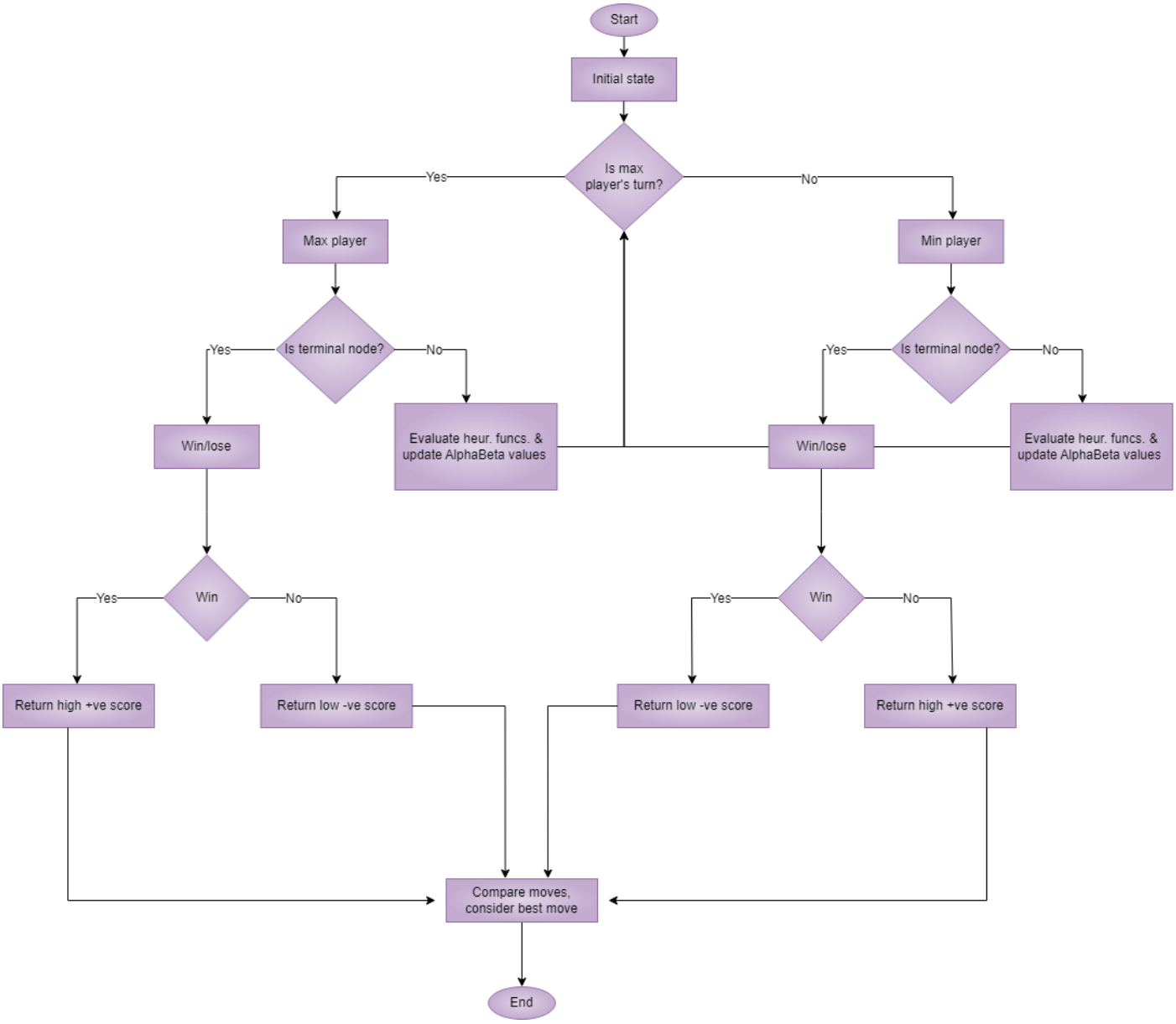
**By incorporating heuristic functions, the AI player can make informed decisions without exhaustively searching the entire game tree.**

## Applied Algorithms

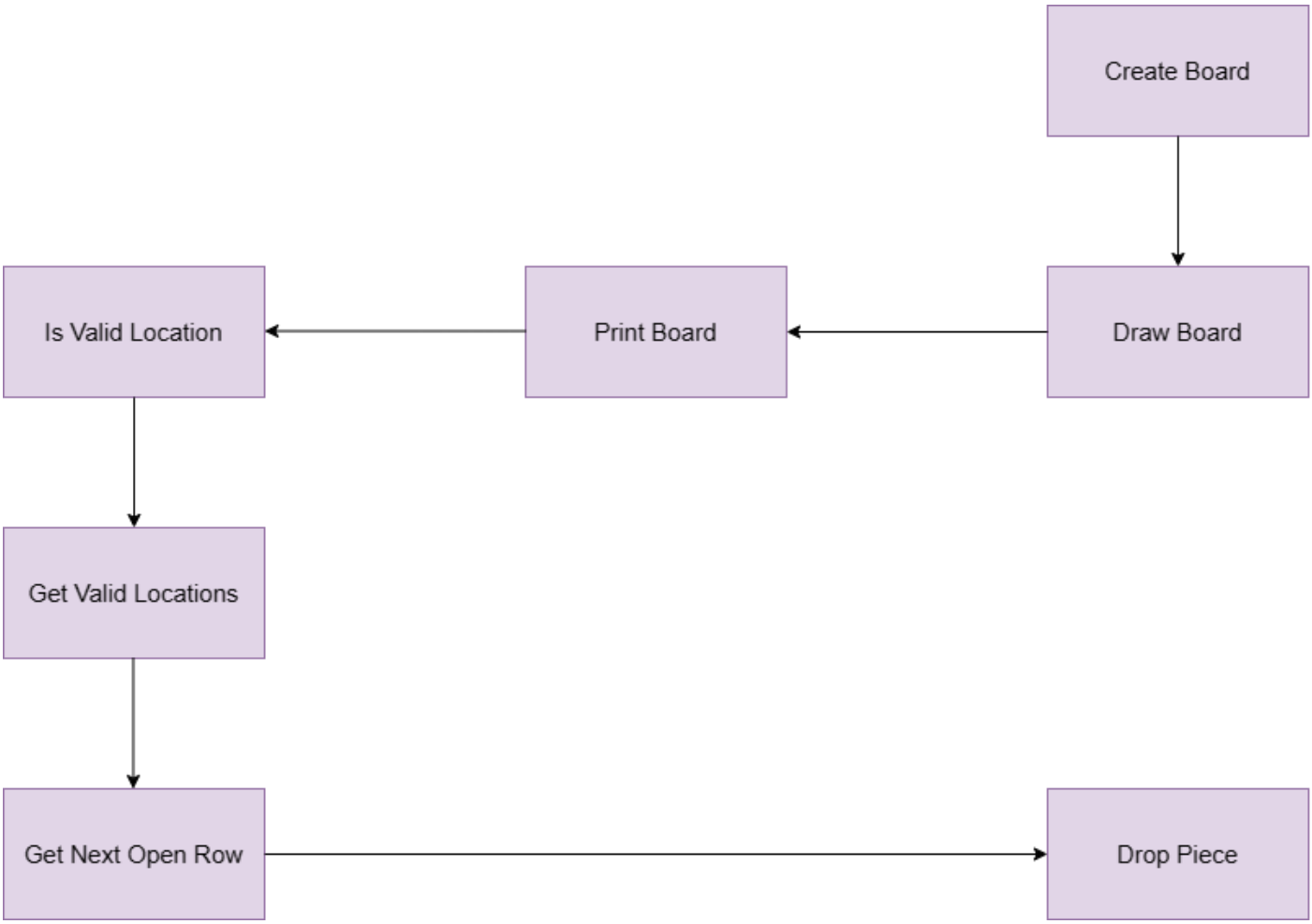
### *1.7 Heuristic Function 1 -> Beginner Level*
### *1.8 Heuristic Function 2 -> Intermediate Level*
### *1.9 The Minimax Algorithm -> Expert Level*
### *1.10 The Minimax Algorithm with Alpha-Beta Pruning -> Master Level*

# Diagrams

## 1.11 Flowchart



## 1.12 System Block Diagram



## Similar Applications

### *1.13 Score Four*

**Score four is a "three dimensional" abstract strategy game, similar to Connect Four (Milton Bradley, 1974). It was first sold under the name "Score Four" by Funtastic in 1968. Lakeside issued 4 different versions in the 1970s. Later Hasbro sold the game as "Connect Four Advanced" in the UK.**

**Gameplay:**

**The object of score four is to position four beads of the same colour in a straight line on any level or any angle. As in Tic Tac Toe, Score Four strategy centres around forcing a win by making multiple threats simultaneously, while preventing the opponent from doing so.**

**Source: https://en.wikipedia.org/wiki/Score_four**

### *1.14 3D TIC-TAC-TOE*

**3D tic-tac-toe, also known by the trade name Qubic, is an abstract strategy board game, generally for two players. It is similar in concept to traditional tic-tac-toe but is played in a cubical array of cells, usually 4×4×4. Players take turns placing their markers in blank cells in the array. The first player to achieve four of their own markers in a row wins. The winning row can be horizontal, vertical, or diagonal on a single board as in regular tic-tac-toe, or vertically in a column, or a diagonal line through four boards.**

**Gameplay:**

**On the 4×4×4 board, there are 76 winning lines. On each of the four 4×4 boards, or horizontal planes, there are four columns, four rows, and two diagonals, accounting for 40 lines. There are 16 vertical lines, each ascending from a cell on the bottom board through the corresponding cells on the other boards. There are eight vertically oriented planes parallel to the sides of the boards, each of these adding two more diagonals (the horizontal and vertical lines of these planes have already been counted). Finally, there are two vertically-oriented planes that include the diagonal lines of the 4x4 boards, and each of these contributes two more diagonal lines—each of these including two corners and two internal cells.**

**The 16 cells lying on these latter four lines (that is, the eight corner cells and eight internal cells) are each included in seven different winning lines; the other 48 cells (24 face cells and 24 edge cells) are each included in four winning lines.**

**Source: https://en.wikipedia.org/wiki/3D_tic-tac-toe**

### *1.15 Teeko*

**Teeko is an abstract strategy game invented by John Scarne in 1937 and rereleased in refined form in 1952 and again in the 1960s.**

**Teeko was marketed by Scarne's company, John Scarne Games Inc.; its quirky name, he said, borrowed letters from Tic-tac-toe, Chess, Checkers, and Bingo.**

**Gameplay:**

**The Teeko board consists of twenty-five spaces arranged in a five-by-five grid. There are eight markers in a Teeko game, four black and four red. One player, "Black" plays the black markers, and the other, "Red", plays the red. Black moves first and places one marker on any space on the board. Red then places a marker on any unoccupied space; black does the same; and so on until all eight markers are on the board.**

**The object of the game is for either player to win by having all four of their markers in a straight line (vertical, horizontal, or diagonal) or on a square of four adjacent spaces. (Adjacency is horizontal, vertical, or diagonal, but does not wrap around the edges of the board.)**

**If neither player has won after the "drop" (when all eight pieces are on the board), then they move their pieces one at a time, with Black playing first. A piece may be moved only to an adjacent space.**

**Source: https://en.wikipedia.org/wiki/Teeko**

## References and Literature Reviews

**- Evaluation of the Use of Minimax Search in Connect-4:**
https://www.scirp.org/pdf/am_2023061214362735.pdf

**- AI: Connect Four Agent:**
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**- Using Game-Theory and Demonstrations to Learn the Win Conditions of a Connect Four Game:**
https://cpb-us-e1.wpmucdn.com/sites.psu.edu/dist/2/117852/files/2020/05/Ayub-ICSR2018-v4.pdf

**- Adaptive Agents in the Context of Connect Four:**
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**- Generic Heuristic Approach to General Game Playing:**
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