Report 5

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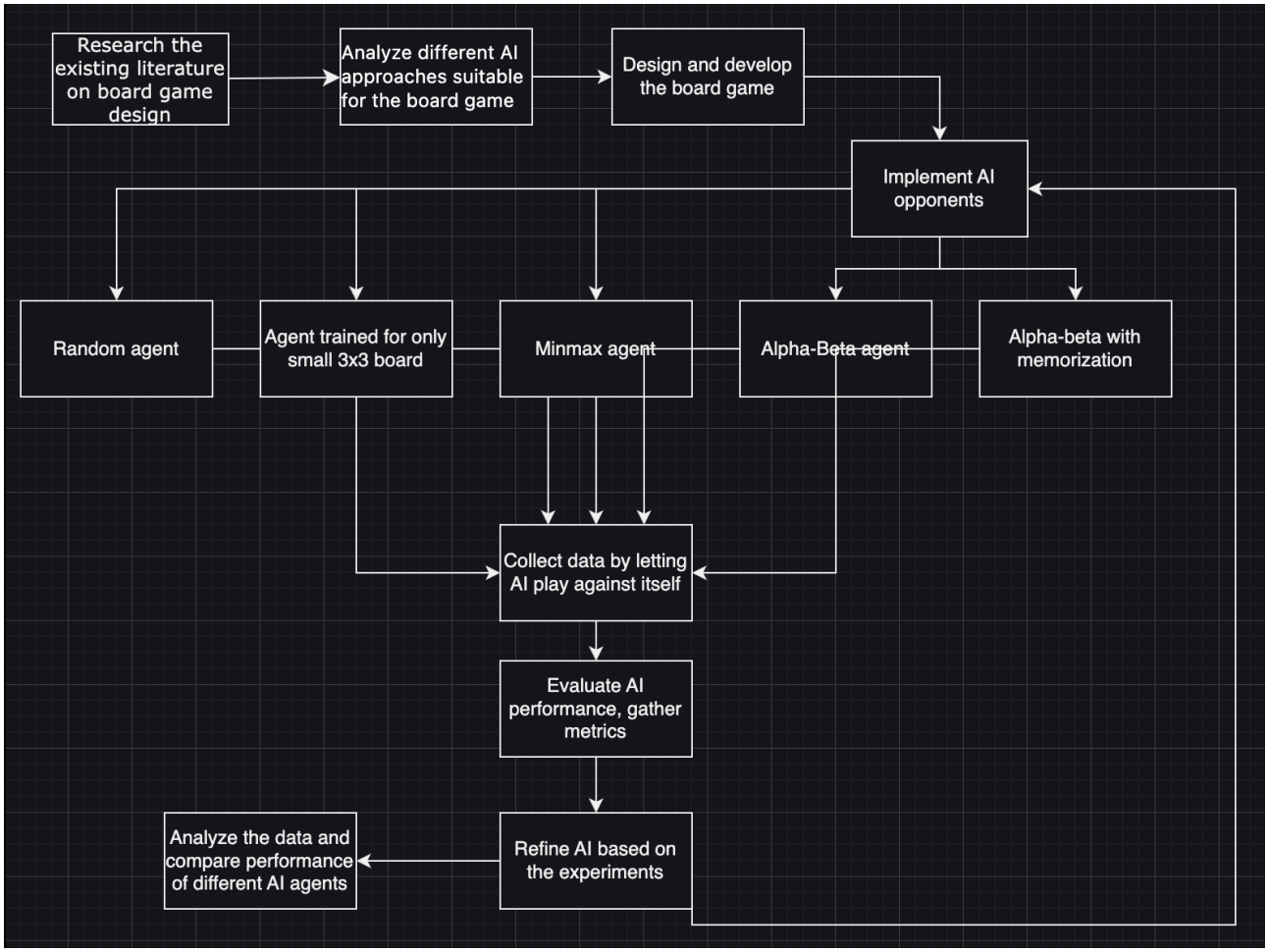
Project Title:

Design and development of a board game that incorporates elements of tactical decision-making and strategic planning
What are you going to do?
I am going to design and develop a board game that enables players to play against one another and most importantly play against AI. I want to analyze different AI approaches such as heuristics, tree- traversal algorithms - minimax, alpha-beta pruning, adversarial search algorithms, and other techniques to improve performance such as memorization.

Diagram 1



Report:

This is the final weekly report focused mainly on the results of the research, conclusion and the future work. Here is the overall technical approach used through the research:

Up until this week, I have focused on building the best agent with the various heuristics for the game. However, this week new kind of agents are built to test and compete against our agent(the final boss). New agents:

1)Random agent

Random agent is developed to perform stochastic moves on the board. It still obeys the game rules meaning it can perform only on the set playground and picks a move among the available moves of the board.

2) Partially genius agent

From early stages of development, the first agent developed and tailored was the agent playing on simple 3x3 TicTacToe board. This agent was genius in the small board and in the worst case scenario games ended in draw if they were not a win. Algorithm used minimax algorithm with alpha-beta pruning and improved with memorization techniques. There are 2 types of heuristics that this agent uses.

Heuristic - 1

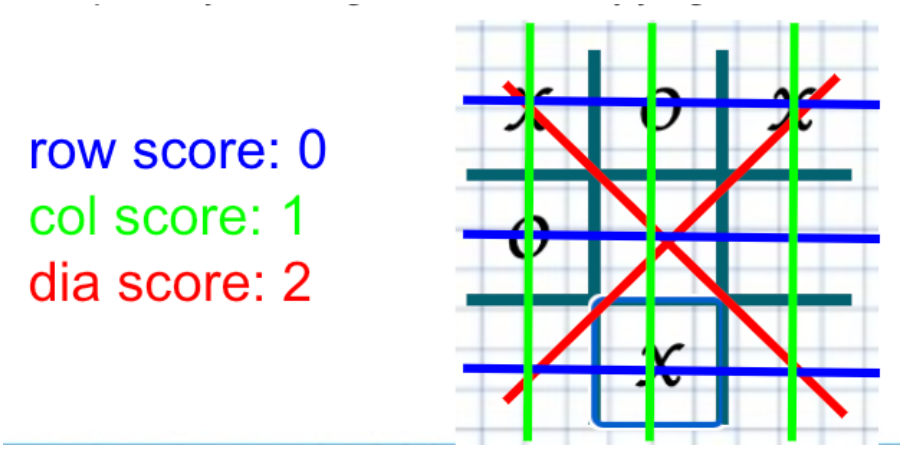
The scoring of a board is determined by analysing the presence of a certain pattern, denoted as 'X' for player 1 or 'O' for player 2, in rows, columns, and diagonals. The use of memoization is employed in order to keep previously calculated board evaluations inside a memory dictionary, hence enhancing the efficiency of subsequent computations.

- Strengths
- Customizable Target - The target parameter allows the algorithm to evaluate the board for different players (e.g., 'X' or 'O'), making it flexible and adaptable for both players in a two-player game.
- Weaknesses
- simplistic: The algorithm's heuristic evaluation is based solely on the occurrence of the target pattern in rows, columns, and diagonals. It

does not take into account other aspects, such as board control, potential threats, or blocking moves, which may limit its strategic depth.

- Lack of Context: The algorithm analyses the board position without considering the game circumstances, opponent's actions, or future ramifications. In complicated game settings, it may overlook chances or make bad judgements.
- Lack of Weighting: The method treats all target pattern occurrences in rows, columns, and diagonals identically. It does not distinguish between crucial and less important positions, possibly resulting in unsatisfactory judgements for the big board.

Image 1



Heuristic - 2

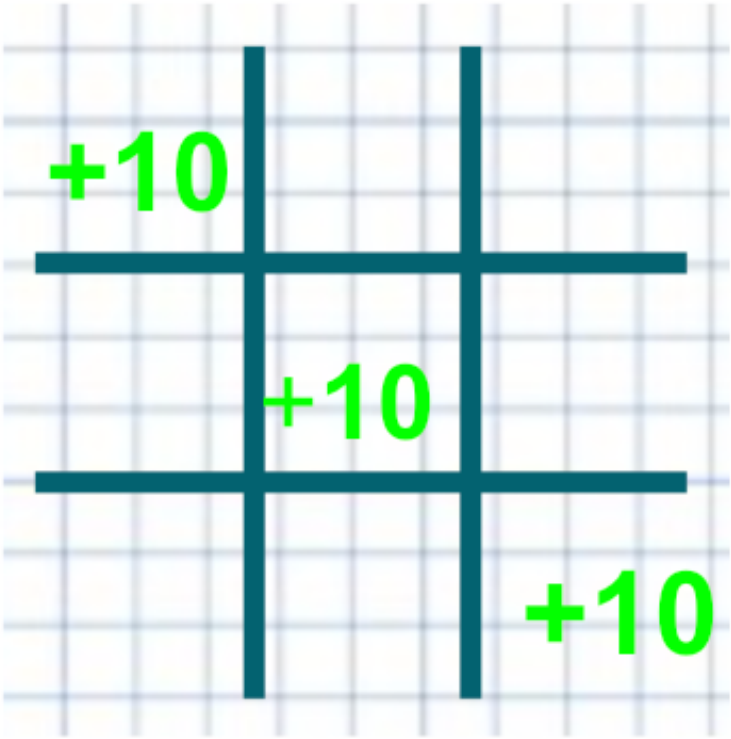
The scoring also based on occurrences of player and opponent symbols in rows, columns, and diagonals. But, the heuristic assigns scores of +10 for player winning patterns and -10 for opponent winning patterns. The score is used to assess the board's desirability for the player.

- Strengths
- Quick Evaluation: The algorithm swiftly checks rows, columns, and diagonals for winning patterns to make heuristic judgements during gaming.

- Simplicity: The heuristic is basic, understandable, and implementable, making it suited for simple applications and rapid prototyping.

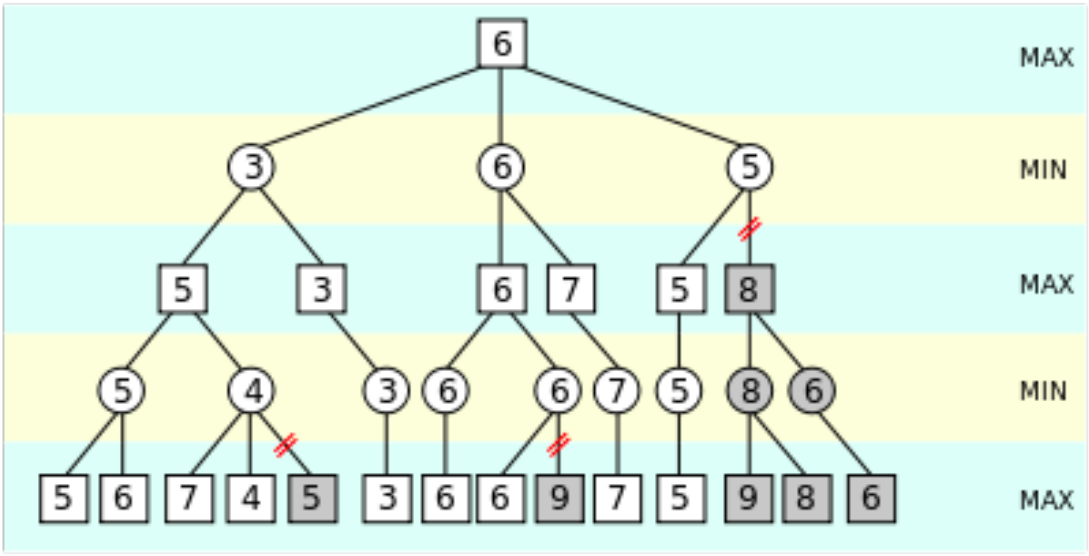
- Weaknesses
- Lack of Depth: The heuristic only analyses immediate winning rows, columns, and diagonals. It does not include preventing opponent threats or generating winning possibilities.
- No Board Control: The algorithm does not consider board control or strategic placement, which might provide an advantage in the game.
- Overemphasis on Immediate victories: The heuristic gives immediate player victories a high score of 10, which may lead to concentrating primarily on short wins rather than longer-term methods that might generate greater outcomes.
- Lack of Weighting: All winning patterns—rows, columns, and diagonals—are equally weighted, which may lead to poor judgements in complicated game circumstances.

Image 2



3-4) Minmax and alpha-beta agents

Image 3



Considering they both use the same type of heuristic, these 2 agents will play exactly the same moves on the board, but alpha-beta agent will be much more quick agent to make the move because of the cutting the unused branches of the tree and saving calculation time. As you see in the Image 3 from the left corner, in the lowest parent node, we are trying to minimize the result and since the value 5 is already bigger than our current value we do not evaluate that part of the tree and its children.
There are 4 types of heuristic written for this agent.
Heuristic - 3

The heuristic evaluates winning patterns differently for smaller and bigger boards, considers player control over the next small board move, and employs memorization to speed up future computations. Especially strong in the free zone stage of the game.

- Strengths
- Comprehensive Evaluation: The algorithm considers player and opponent winning patterns, player control over the next tiny board move, and smaller and bigger boards. This gives a fuller board evaluation.

- Memoization: The method memorises board evaluations to minimise unnecessary computations and improve performance.

- Weaknesses
- Player Control Consideration: The algorithm considers the player's next little board move, which may reveal strategic posture and possible benefits.
- Board Position Analysis: The algorithm ignores the location of the smaller boards inside the Ultimate Tic-Tac-Toe board, which might affect strategic choices.
- Lack of Depth: Although the heuristic examines numerous aspects, it does not include more advanced methods like strategic blocking or trapping the opponent.

Moreover, other 3 agents were used together in the agent to strengthen the evaluation.

Heuristic - 4&5&6

Combination of 3 heuristics:

1. Evaluates the winning position of the large board
2. Evaluates the whole board in the domain of the small board
3. “Forward chaining” -considers next evaluation and the state of the next playground and adds it to the overall score

- Strengths
- Comprehensive Evaluation: The heuristics evaluate winning sequences, centre movements, and corner moves for both players on the bigger board (heur4) and each smaller board (heur5).
- Balanced Scoring: Winning sequences and smart movements relatively get lower incremental points for more nuanced assessments:
    - capturing center cell/board
    - capturing corner cell/board
    - capturing the cell resulting in the sequence of cells
- Player-Controlled Sequences: Heuristics reward player-controlled winning sequences, promoting strategic play.

- Weaknesses

- Fixed Incremental Scoring: The heuristic scores may not appropriately represent the strategic value of various plays or winning sequences.
- Lack of Evaluation Depth: The heuristics do not include advanced strategic factors like opponent blocking or long-term planning, which might lead to poor decision-making.

Depth

Up until this point, I have used a fixed depth(3) for all of the tree-traversing agents. However, the significance of depth varies over various phases of the game. During the first phases of the game, the search space remains very expansive. During the endgame phase, the available search area becomes much reduced, hence amplifying the significance of movements that might lead to a favourable outcome.

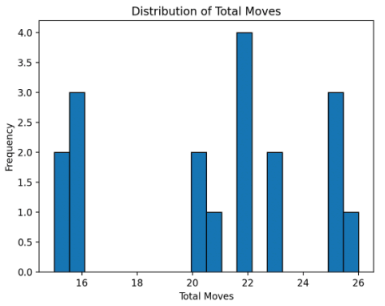
The significance of speed is noteworthy; nonetheless, it is crucial to acknowledge that as the depth increases, the number of nodes in the tree increases exponentially, thus leading to a corresponding exponential growth in the time required to traverse the tree.

Results

There are various records for the different games played by different agents in both directions(they take turns when it comes to who will start first). There are every combination of these 4 agents playing with each other(less important ones excluded from the presentation):

- Random
- Part genious agent
- Minimax
- Alpha-Beta(with memorization)

When it comes to heuristics, strength level also follow the upward direction as in their names:
6+5+4>3>2>1



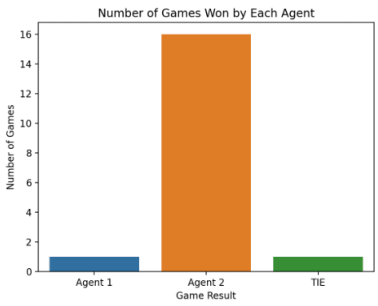
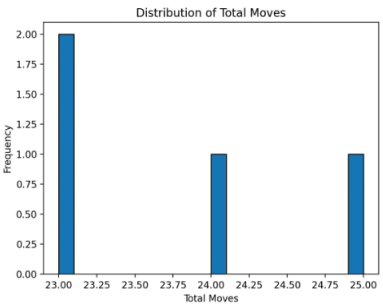


Figure 1. Random_vs_AB



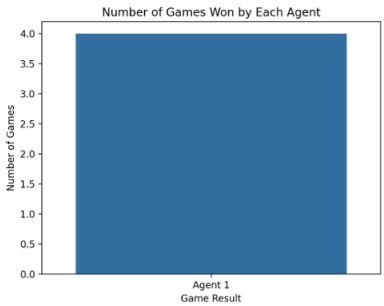
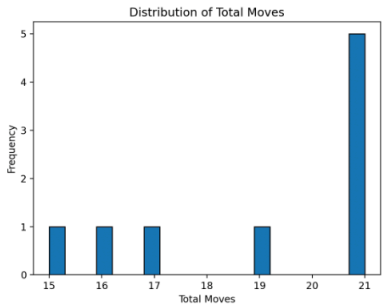


Figure 2. AB_vs_random



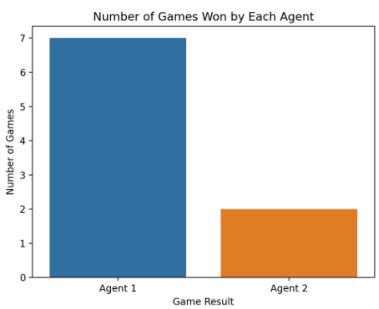
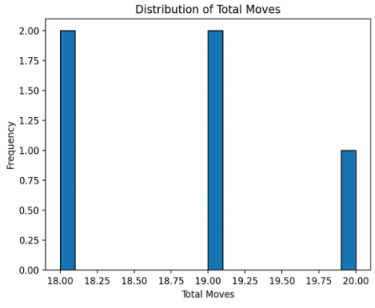


Figure 3. AB_vs_Part_geni



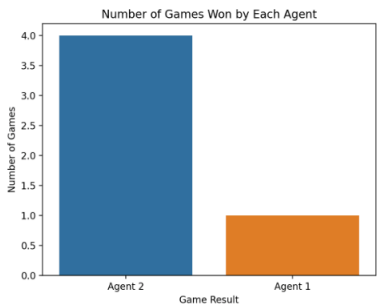
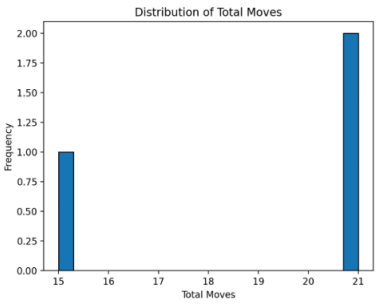


Figure 4. Part_geni_vs_AB



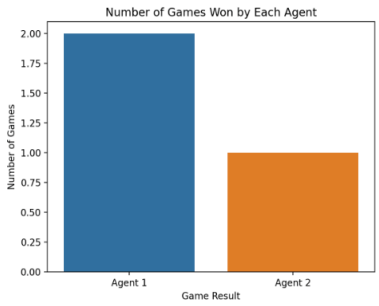
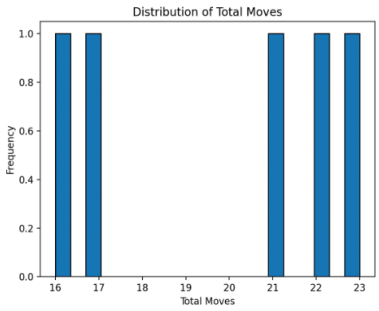


Figure 5. Part_geni_vs_minmax



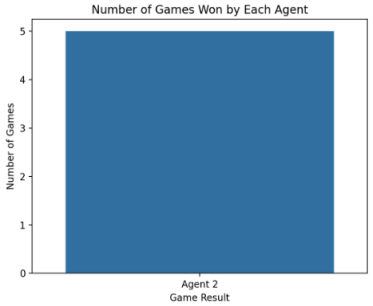
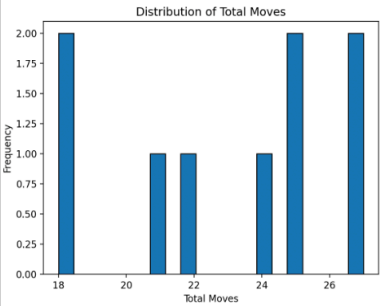


Figure 6. Random_vs_Part_geni



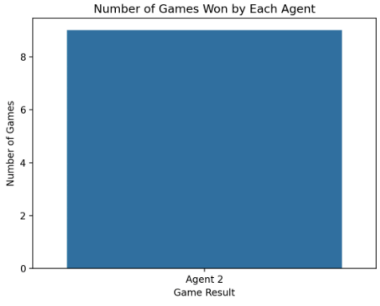
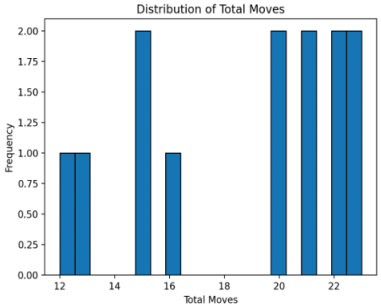


Figure 7. Random_vs_minmax



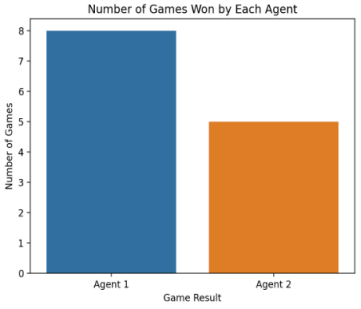


Figure 8. Part_geni_vs_Random

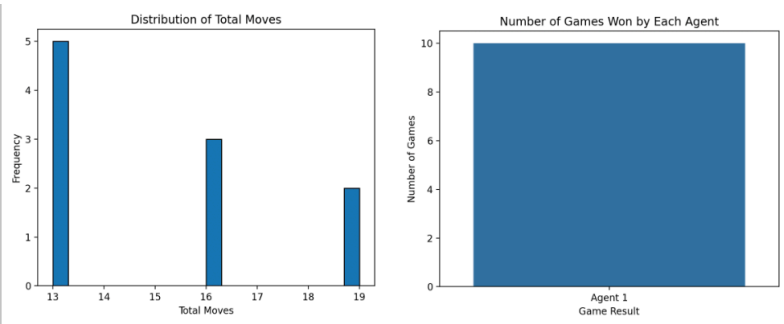


Figure 9. AB_vs_minmax

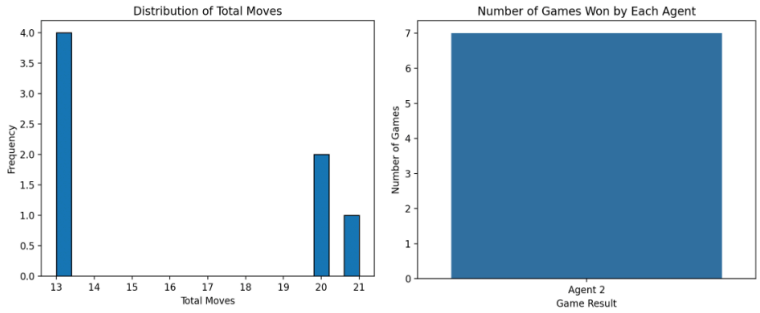


Figure 10. Minmax_vs_AB

Efficient Memorization: In some of the heuristic algorithms used, the project leverages memoization to store previously computed board evaluations. This approach speeds up subsequent evaluations, optimizing the game's performance during real-time gameplay.

The project evaluates various AI algorithms' performance and provides valuable insights into which AI strategies are most suitable for particular game scenarios, leading to informed decisions for future development and improvements.

CONCLUSION

In conclusion, project on the design and development of a board game incorporating tactical decision-making and strategic planning has been a success. Comprehensive exploration of various AI approaches, game mechanics, and data-driven analysis were embarked. Key findings from the research include the implementation of diverse AI algorithms, such as heuristics, minimax, alpha-beta pruning, and adversarial search. These strategies have transformed the game into an engaging and challenging experience, prompting players to think critically and plan strategically. The introduction of the innovative "Strategic Tic-Tac-Toe" board added complexity and excitement, elevating the gameplay to new heights. Preliminary play-testing confirmed the effectiveness of the approach, motivating to further refine and expand the game.

Future Work

The project identifies areas for future research, including investigating adversarial search algorithms(finding better and more detailed heuristics) and memory-based techniques. It's possible to remember the whole history of a game and use it during the play. This not only expands the research

horizons but also indicates a willingness to continuously improve the game and its AI components. Additionally, researching deep into various techniques used behind the AlphaZero, Stockfish, Deep Blue(IBM100). Implementation of AI agent into playable multi platform apps.