Tic-Tac-Toe & Connect Four Game

FINAL PROJECT

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Abstract – This project focuses on creating a Connect Four game using Monte Carlo Tree Search (MCTS). The report discusses how the idea for the game originated and the challenges encountered during development. It explains the importance of MCTS in the project and how Tic-Tac-Toe served as a model for building the Connect Four game.

PROBLEM DESCRIPTION

In this project, we're tasked with developing our own game using Monte Carlo Tree Search (MCTS), an algorithm for decision-making in certain types of games. MCTS involves four key steps:

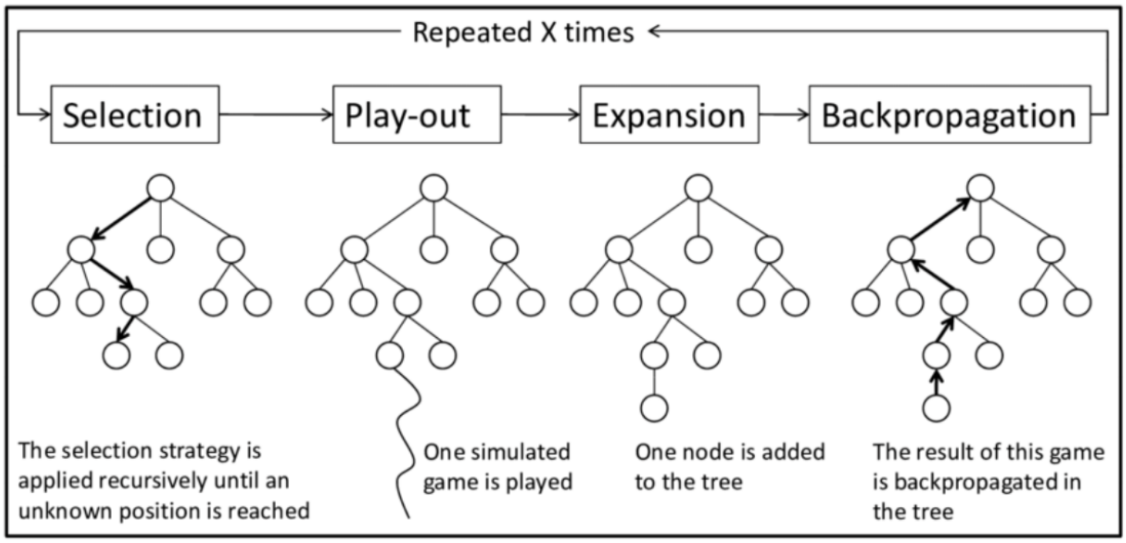
Selection, Expansion, Simulation, and Backpropagation.

Selection begins at the root node and navigates through the tree based on a selection policy until reaching an unexplored node.

Expansion involves adding child nodes to expand the tree.

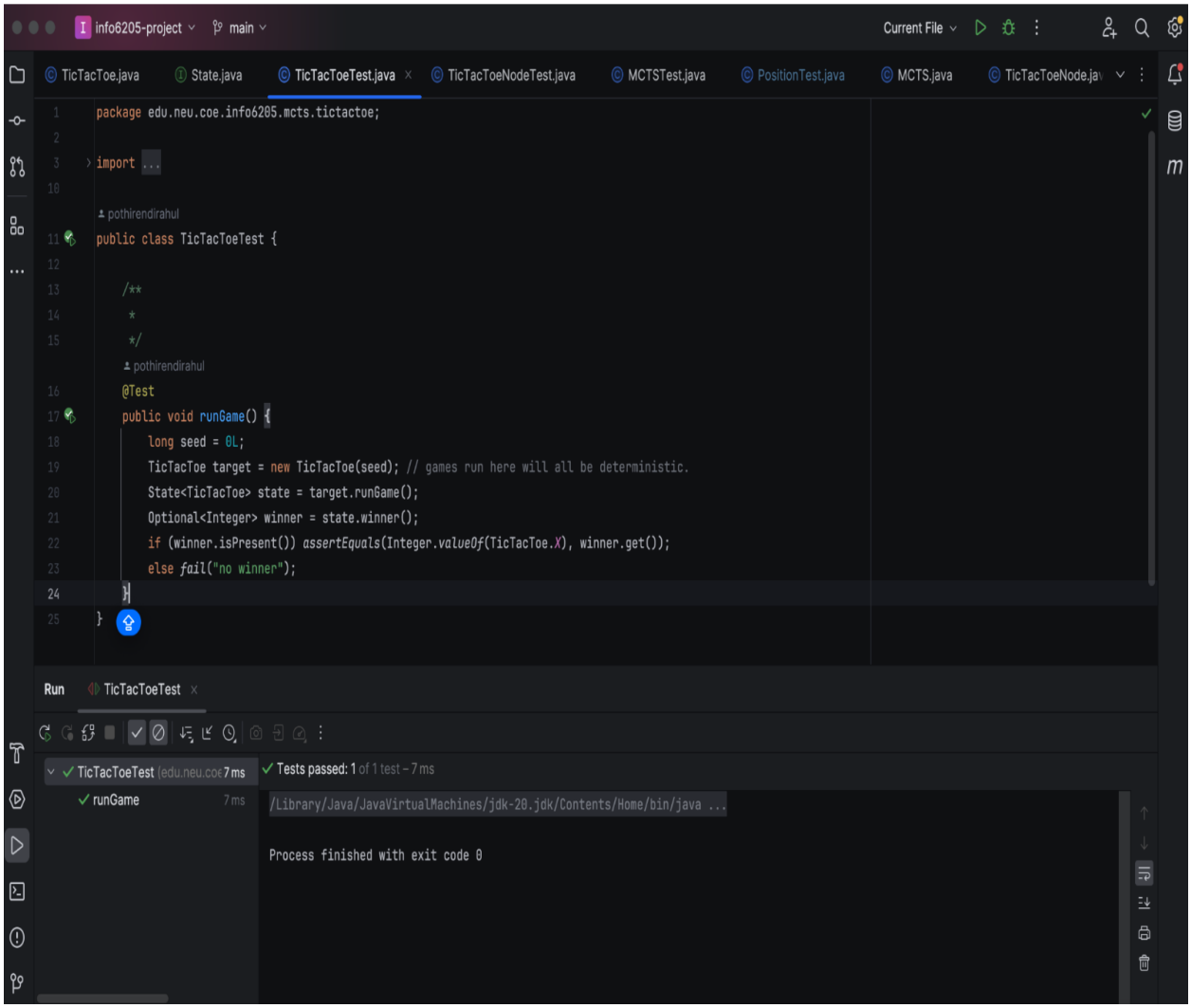
Simulation entails playing out the game from the current node to the end, recording results for all possible outcomes, and selecting the best solution.

Backpropagation involves updating the information stored in the nodes traversed to reach the terminal node. Understanding and implementing these four steps are essential for the search algorithm to function effectively.

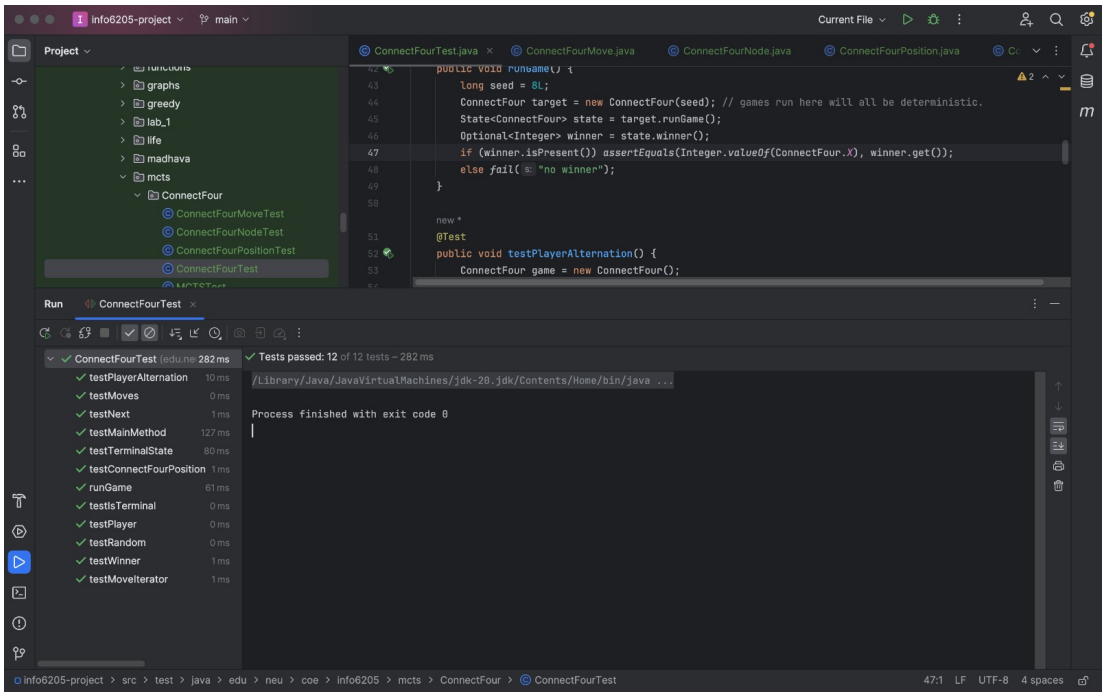


ANALYSIS

Before starting our main project, we practiced with Tic-Tac-Toe to understand how Monte Carlo Tree Search (MCTS) works in a game. In Tic-Tac-Toe, we focused on managing the game's state using a 3x3 grid. We defined empty spaces as -1, 'O' as 0, and 'X' as 1. We wrote code to generate possible moves and check for winning combinations in rows, columns, and diagonals.



Unit test for TicTacToe


info6205-project
main
Current File
Project
graphs
greedy
lab_1
life
madhava
mcts
ConnectFour
ConnectFourMoveTest
ConnectFourNodeTest
ConnectFourPositionTest
ConnectFourTest
ConnectFourTest.java
ConnectFourMove.java
ConnectFourNode.java
ConnectFourPosition.java
public void runGame() {
long seed = 8L;
ConnectFour target = new ConnectFour(seed); // games run here will all be deterministic.
State<ConnectFour> state = target.runGame();
Optional<Integer> winner = state.winner();
if (winner.isPresent()) assertEquals(Integer.valueOf(ConnectFour.X), winner.get());
else fail(s: "no winner");
}
new *
@Test
public void testPlayerAlternation() {
ConnectFour game = new ConnectFour();
Run
ConnectFourTest
Tests passed: 12 of 12 tests – 282 ms
/Library/Java/JavaVirtualMachines/jdk-20.jdk/Contents/Home/bin/java ...
Process finished with exit code 0
testPlayerAlternation 10 ms
testMoves 0 ms
testNext 1 ms
testMainMethod 127 ms
testTerminalState 80 ms
testConnectFourPosition 1 ms
runGame 61 ms
testIsTerminal 0 ms
testPlayer 0 ms
testRandom 0 ms
testWinner 1 ms
testMoveIterator 1 ms
info6205-project › src › test › java › edu › neu › coe › info6205 › mcts › ConnectFour › ConnectFourTest
47:1 LF UTF-8 4 spaces

ConnectFourTest

ConnectFour Unit Tests Summary

testMainMethod: Tests the main method of the ConnectFour class. It checks the output to ensure it contains either "ConnectFour: Winner is:" or "ConnectFour: Draw".

runGame: Tests the runGame method of the ConnectFour class. This test runs a deterministic game and verifies if the winner is player X.

testPlayerAlternation: Verifies if player alternation is correctly implemented. It checks if the player changes after making a move.

testTerminalState: Checks if the game reaches a terminal state after running.
testConnectFourPosition: Tests the ConnectFourPosition class. It ensures correct initialization and checks the grid for expected values.

testIsTerminal: Validates if the game state is correctly identified as terminal.

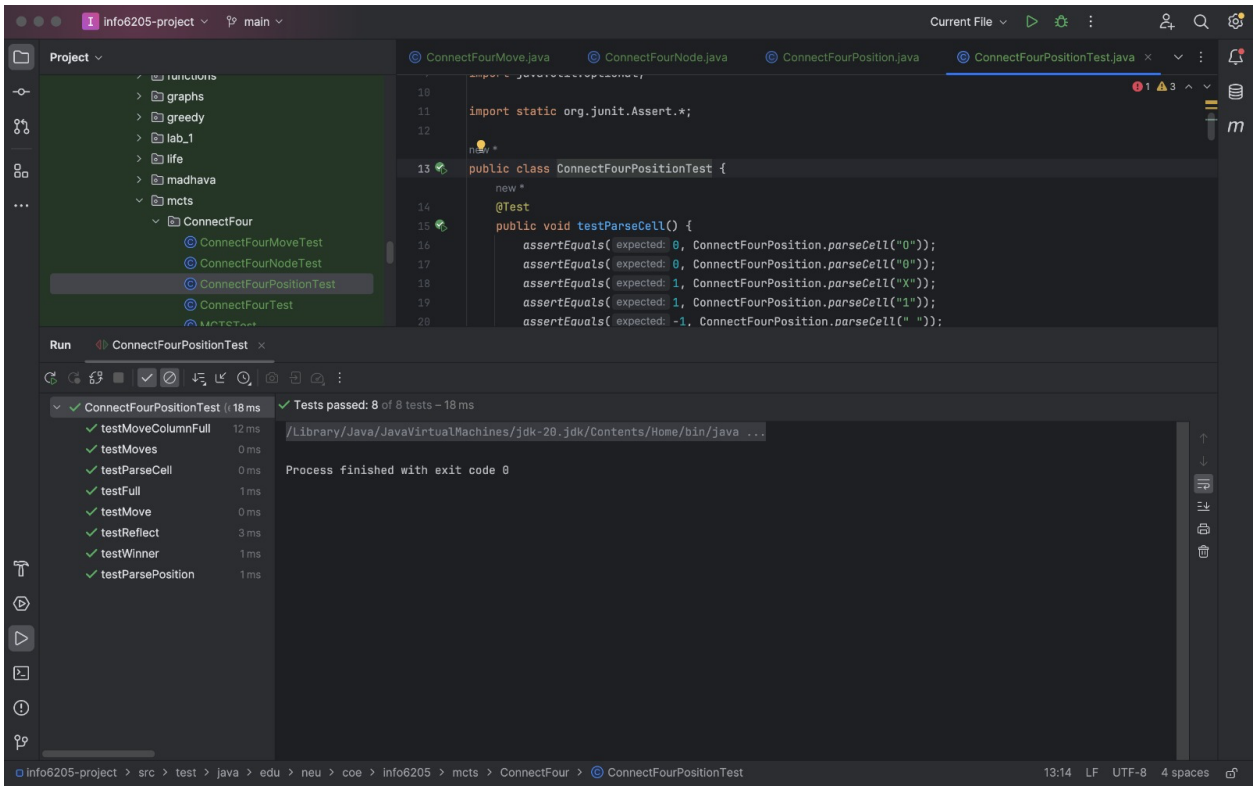
testPlayer: Verifies if the current player is correctly identified.

testWinner: Checks if there is no winner at the start of the game.

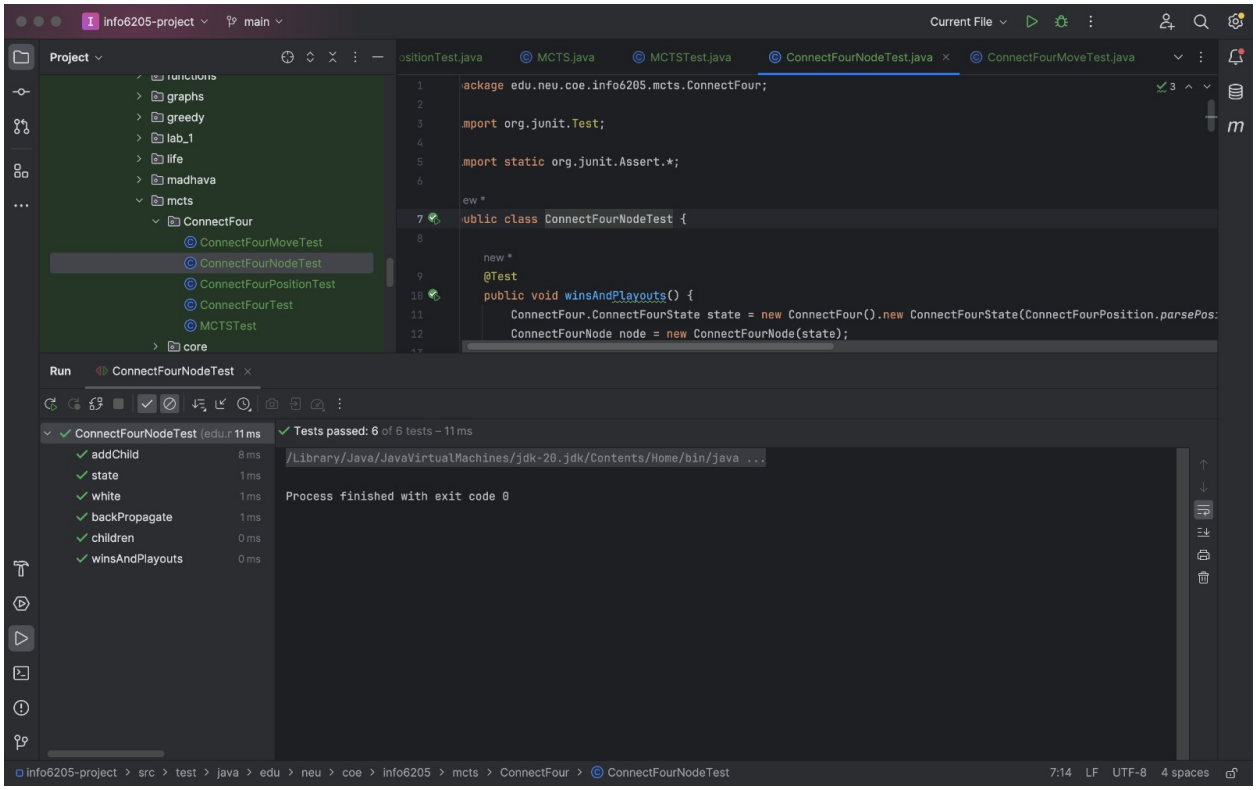
testRandom: Ensures proper initialization of a random number generator.

testMoves: Checks if there are available moves for the current player.

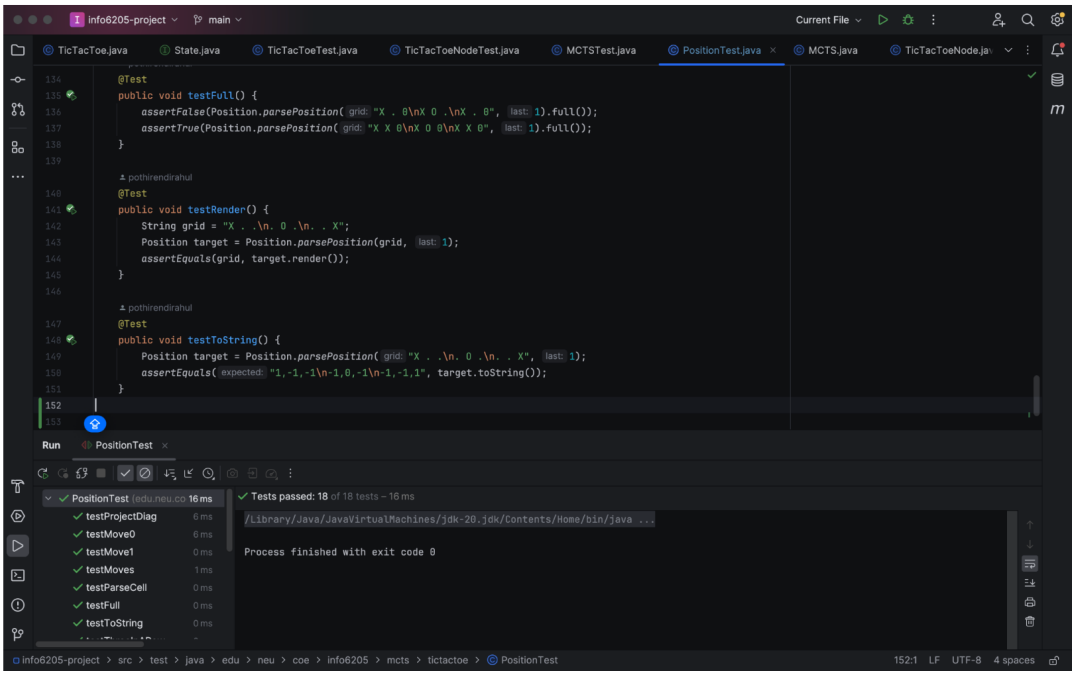
testNext: Tests if the next method correctly generates the next state after making a move.
testMoveIterator: Validates if the move iterator is properly initialized.



ConnectFour Position Test

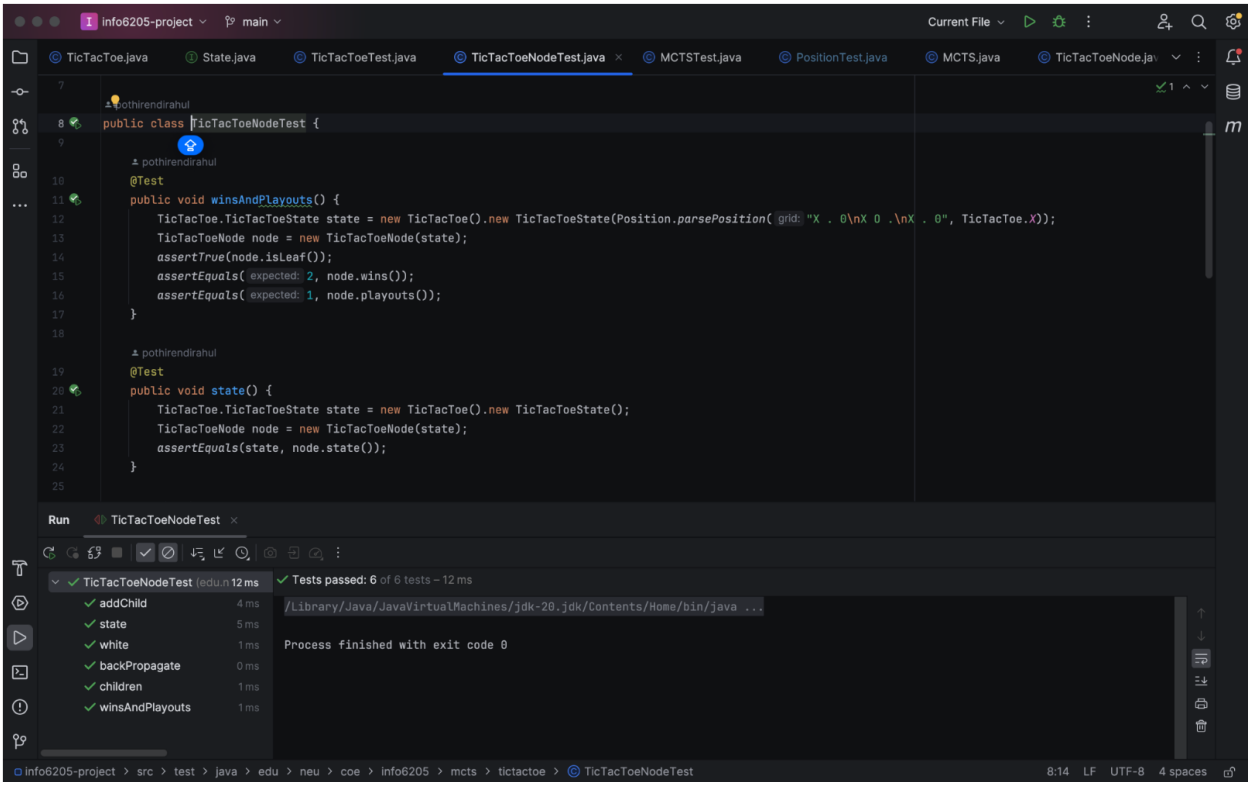


Connect Four Node Test



Unit test for PositionTest

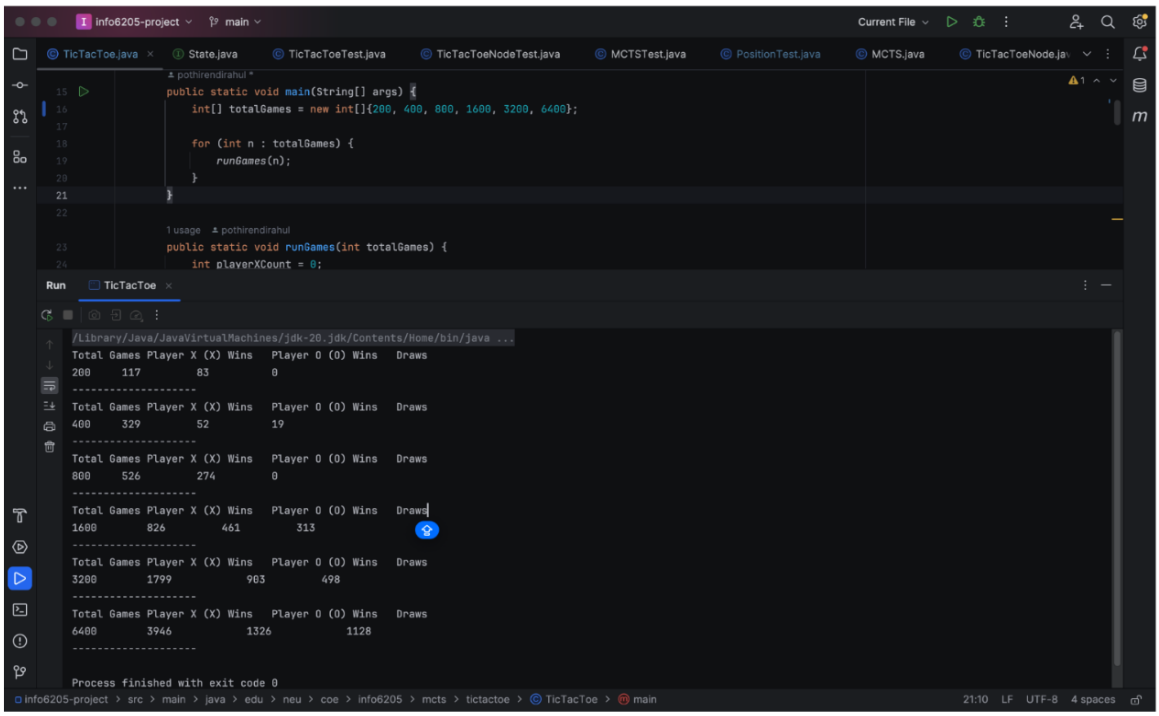
Unit test for TicTacToc Node

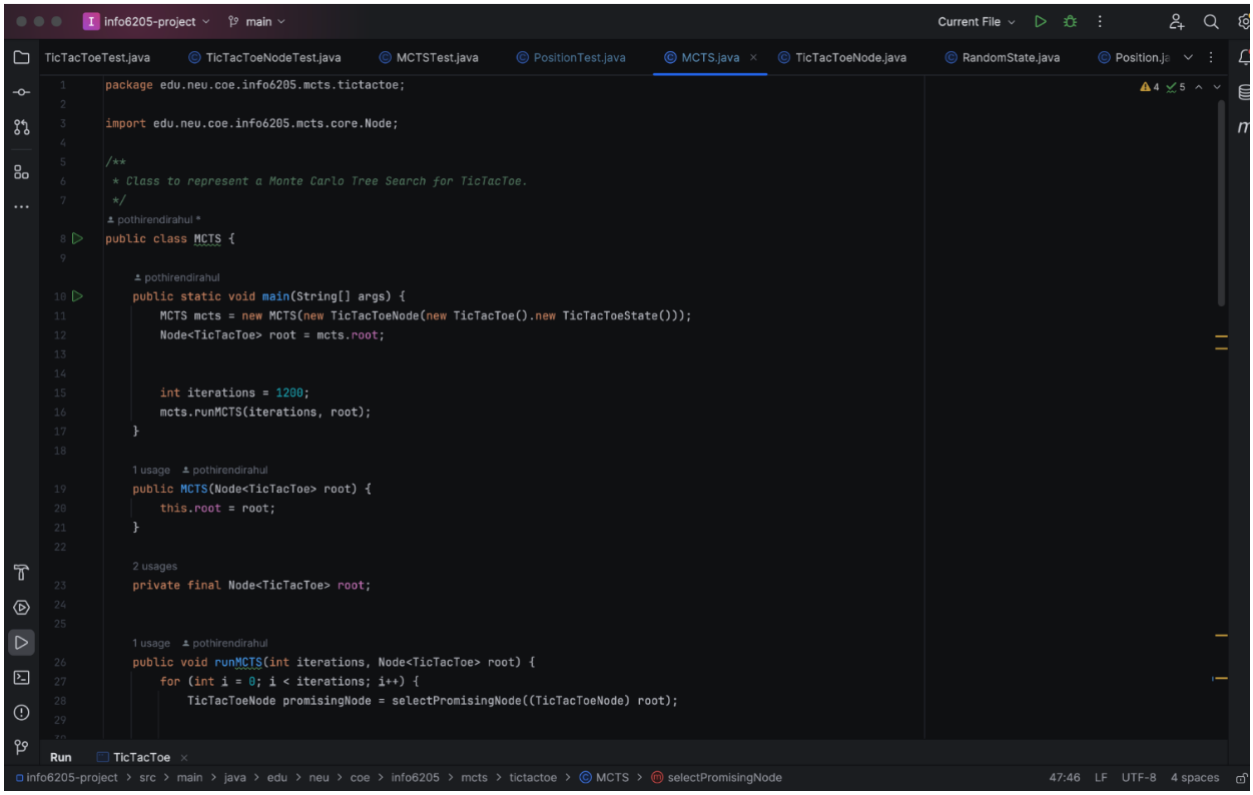


IMPLEMENTATION

As we brainstormed our game concept, we considered developing a Connect Four game. The game would start with a grid where players can drop their tokens. The grid would have multiple columns and rows. Players take turns dropping their tokens into a column, and the tokens stack up vertically. The objective is to connect four of their tokens vertically, horizontally, or diagonally before their opponent does. For example, a player might choose column 3 and drop their token into it, causing the token to stack on top of any existing tokens in the column.

IMPLEMENTATION OF TICTACTOE.JAVA





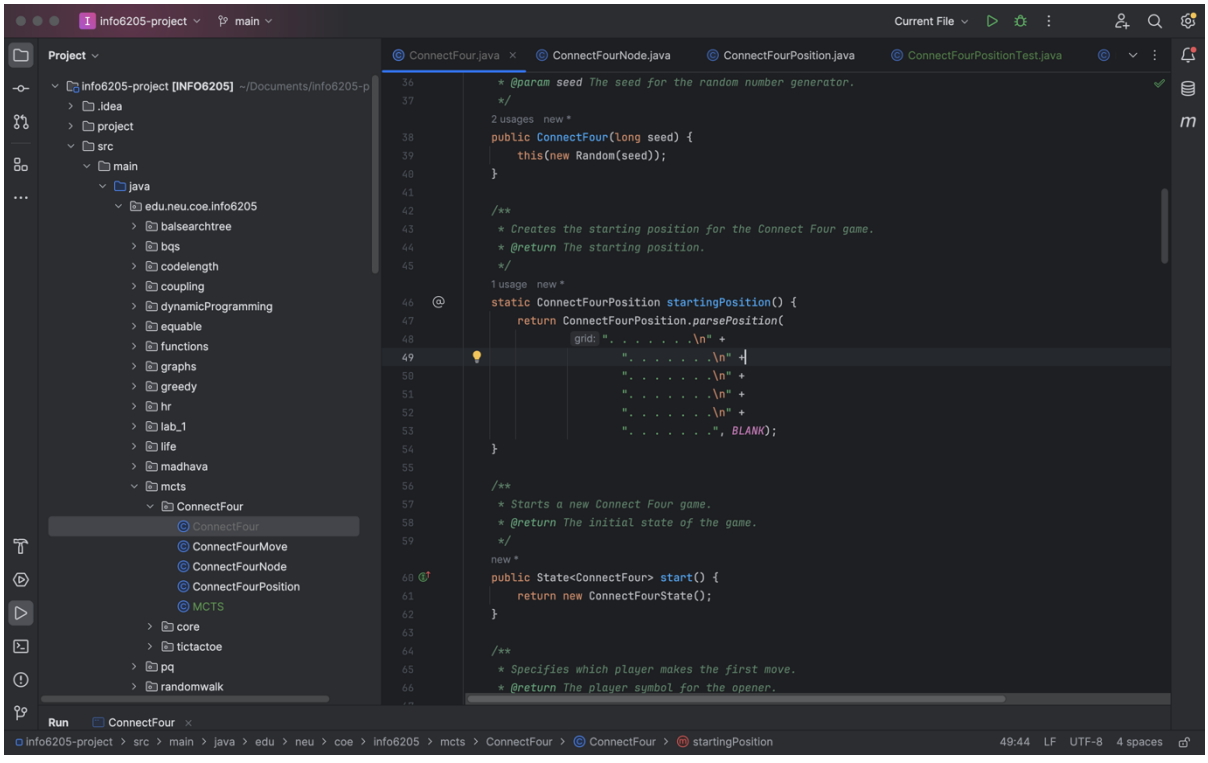
MCTS TicTacToe

```
. X . . X . O
. X . O X . X
. O . X X O O
O O . X O O X
X X O O X X O
O O O X X X O

. X . . X . O
. X . O X . X
. O . X X O O
O O . X O O X
X X O O X X O
O O O X X X O

ConnectFour: Winner is: O (Random)
ConnectFour: The Winner is: O

Process finished with exit code 0
```



EVALUATION

With these implementations in place, we tested our game to ensure its functionality. The screenshot below depicts the appearance of the Connect Four game, with the grid correctly generated and the game logic functioning as intended. Additionally, other sections of the program include unit tests to verify the proper execution of methods.

Total Games	Player X (X) Wins	Player O (O) Wins	Draws
200	104	78	18
400	234	166	0
800	381	387	32
1600	703	660	237
3200	1850	988	362
6400	3152	2122	1126

CONCLUSIONS

In this project, we recognize MCTS as a search algorithm utilized in decision-making games, enabling complex decision-making through Selection, Expansion, Simulation, and Backpropagation. Initially, we grasped the concept of MCTS by engaging with a sample Tic-Tac-Toe game. Subsequently, we delved further into MCTS by crafting our own Connect Four game.

REFERENCES

FOR TICTACTOE

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FOR MCTS CONNECT FOUR
https://ai.stackexchange.com/questions/21019/should-monte-carlo-tree-search-be-able-to-consistently-beat-me-in-the-connect-fo

https://link.springer.com/article/10.1007/s10462-022-10228-y