**Programming Project Report**

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**Academic Integrity Statement:** I pledge that I have neither given nor received unauthorized help on this programming assignment.

**Problem Statement:**

The primary goal of this programming project was to provide students with experience extending an existing class by adding new methods. The Tic4 class from the previous assignment was used for this project, and the task was to modify the previous class to add in new methods and implement a game AI that would automatically select moves for O’s while the user plays as X’s. The inputs for this project were the user inputs being ‘row’ to select the row on the board, ‘col’ to select the column on the board, and ‘X’ for their move as X’s. The output for this project was the board after the user’s move and the board after the AI’s move. Error handling in this program was primarily focused on user input; if the user put in any other input than ‘X’, they were looped and prompted for ‘X’ until they input it. The program also checks to make sure that ‘row’ and ‘column’ are within the array bounds for the board.

**Design:**

The design for this program is very similar to the design for Project 6, but instead O’s are now played by an AI while X’s are played by the user. The Tic4 class from the previous project was expanded upon with 4 new methods implemented; these methods are the SimpleAI, RandomAI, CleverAI, and FancyAI. The data structures used in this project were a new class with various methods implemented within the class, user input, and the object Tic4 used in the main program. The Tic4 class can still be easily altered and expanded upon if more methods need to be added to the class. This allows for the class to continue to be built upon, and if necessary, used as a base for future projects.

The methods for the Tic4 class are located in a secondary .cpp file named ‘tic4.cpp’, which allows the programmer to modify the Tic4 class in the future without having to do any work in the ‘PF-Project7.cpp’ file. This also allows the methods to be hidden from the user, as they will not find them in the main .cpp file. There is also a ‘tic4.h’ header file that contains the constructors, de-constructors, class definition, and public methods.

**Implementation**

Implementation for this project took a total of around 5-7 hours. Much of the code came from project 6 and was built upon for this project. To begin, the new methods were declared in ‘tic4.h’, and then skeleton code was implemented in ‘tic4.cpp’. The SimpleAI was programmed first and tested on its own until it functioned as required. Next, RandomAI was programmed and tested until it functioned as desired; the RandomAI provided a bit more of a challenge to make it truly random instead of running through a sequence of “random numbers” on every test run of the program. To do this, ‘rand’ was seeded by doing ‘srand(time(NULL));’ in order to generate a truly random sequence of numbers. By doing this, no two test runs of the program resulted in the same output.

CleverAI was programmed next; CleverAI searches all of the diagonals for a spot to play and if no spot is found, the CleverAI method then calls SimpleAI to make a move in the very first spot found by the SimpleAI method. Lastly, FancyAI was coded; FancyAI calls one of the three previously programmed AI methods. To do this, rand is seeded again by doing srand(time(NULL));. rand is then modulo’d by three and using the remainder (0, 1, or 2), calls either SimpleAI, RandomAI, or CleverAI to make its move.

**Testing**

Testing the program was relatively easy. The three cases necessary for testing were making sure that the program worked when X’s won, O’s won, and that nobody won if the board was full and the game resulted in a tie. Another case to test was that the user input was valid and within the bounds of the board.

Test 1:

Hello, and welcome to Tic-tac-toe! You will be playing against an AI in this game.

You will be X's and the AI will be O's. You will be going first.

0 1 2 3

+---+---+---+---+

0 | | | | |

+---+---+---+---+

1 | | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

You may input your first move when you are ready. Please make your move as 'row, column, X'

Your move: 0 0 X

0 1 2 3

+---+---+---+---+

0 | X | | | |

+---+---+---+---+

1 | | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | | | |

+---+---+---+---+

1 | | O | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

0 3 X

0 1 2 3

+---+---+---+---+

0 | X | | | X |

+---+---+---+---+

1 | | O | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | | | X |

+---+---+---+---+

1 | | O | | |

+---+---+---+---+

2 | | | O | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

1 2 X

0 1 2 3

+---+---+---+---+

0 | X | | | X |

+---+---+---+---+

1 | | O | X | |

+---+---+---+---+

2 | | | O | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | | | X |

+---+---+---+---+

1 | | O | X | |

+---+---+---+---+

2 | | | O | |

+---+---+---+---+

3 | O | | | |

+---+---+---+---+

2 1 X

0 1 2 3

+---+---+---+---+

0 | X | | | X |

+---+---+---+---+

1 | | O | X | |

+---+---+---+---+

2 | | X | O | |

+---+---+---+---+

3 | O | | | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | | | X |

+---+---+---+---+

1 | | O | X | |

+---+---+---+---+

2 | | X | O | |

+---+---+---+---+

3 | O | | | O |

+---+---+---+---+

2 3 X

0 1 2 3

+---+---+---+---+

0 | X | | | X |

+---+---+---+---+

1 | | O | X | |

+---+---+---+---+

2 | | X | O | X |

+---+---+---+---+

3 | O | | | O |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | O | | X |

+---+---+---+---+

1 | | O | X | |

+---+---+---+---+

2 | | X | O | X |

+---+---+---+---+

3 | O | | | O |

+---+---+---+---+

0 2 X

0 1 2 3

+---+---+---+---+

0 | X | O | X | X |

+---+---+---+---+

1 | | O | X | |

+---+---+---+---+

2 | | X | O | X |

+---+---+---+---+

3 | O | | | O |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | O | X | X |

+---+---+---+---+

1 | O | O | X | |

+---+---+---+---+

2 | | X | O | X |

+---+---+---+---+

3 | O | | | O |

+---+---+---+---+

3 1 X

0 1 2 3

+---+---+---+---+

0 | X | O | X | X |

+---+---+---+---+

1 | O | O | X | |

+---+---+---+---+

2 | | X | O | X |

+---+---+---+---+

3 | O | X | | O |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | O | X | X |

+---+---+---+---+

1 | O | O | X | |

+---+---+---+---+

2 | O | X | O | X |

+---+---+---+---+

3 | O | X | | O |

+---+---+---+---+

3 2 X

0 1 2 3

+---+---+---+---+

0 | X | O | X | X |

+---+---+---+---+

1 | O | O | X | |

+---+---+---+---+

2 | O | X | O | X |

+---+---+---+---+

3 | O | X | X | O |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | O | X | X |

+---+---+---+---+

1 | O | O | X | O |

+---+---+---+---+

2 | O | X | O | X |

+---+---+---+---+

3 | O | X | X | O |

+---+---+---+---+

Sorry, nobody wins!

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Test 2:

Hello, and welcome to Tic-tac-toe! You will be playing against an AI in this game.

You will be X's and the AI will be O's. You will be going first.

0 1 2 3

+---+---+---+---+

0 | | | | |

+---+---+---+---+

1 | | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

You may input your first move when you are ready. Please make your move as 'row, column, X'

Your move: 4 0 X

0 4 X

4 4 X

0 0 X

0 1 2 3

+---+---+---+---+

0 | X | | | |

+---+---+---+---+

1 | | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | | | |

+---+---+---+---+

1 | | | O | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

1 1 X

0 1 2 3

+---+---+---+---+

0 | X | | | |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | | | |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | | O | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

0 1 X

0 1 2 3

+---+---+---+---+

0 | X | X | | |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | | O | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | X | O | |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | | O | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

3 2 X

0 1 2 3

+---+---+---+---+

0 | X | X | O | |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | | O | |

+---+---+---+---+

3 | | | X | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | X | O | O |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | | O | |

+---+---+---+---+

3 | | | X | |

+---+---+---+---+

2 1 X

0 1 2 3

+---+---+---+---+

0 | X | X | O | O |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | X | O | |

+---+---+---+---+

3 | | | X | |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | X | X | O | O |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | X | O | |

+---+---+---+---+

3 | | | X | O |

+---+---+---+---+

3 1 X

0 1 2 3

+---+---+---+---+

0 | X | X | O | O |

+---+---+---+---+

1 | | X | O | |

+---+---+---+---+

2 | | X | O | |

+---+---+---+---+

3 | | X | X | O |

+---+---+---+---+

X wins!!

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Test 3:

Hello, and welcome to Tic-tac-toe! You will be playing against an AI in this game.

You will be X's and the AI will be O's. You will be going first.

0 1 2 3

+---+---+---+---+

0 | | | | |

+---+---+---+---+

1 | | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | |

+---+---+---+---+

You may input your first move when you are ready. Please make your move as 'row, column, X'

Your move: 3 3 X

0 1 2 3

+---+---+---+---+

0 | | | | |

+---+---+---+---+

1 | | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | O | | | |

+---+---+---+---+

1 | | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

1 0 X

0 1 2 3

+---+---+---+---+

0 | O | | | |

+---+---+---+---+

1 | X | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | O | O | | |

+---+---+---+---+

1 | X | | | |

+---+---+---+---+

2 | | | | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

2 0 X

0 1 2 3

+---+---+---+---+

0 | O | O | | |

+---+---+---+---+

1 | X | | | |

+---+---+---+---+

2 | X | | | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | O | O | | |

+---+---+---+---+

1 | X | | | |

+---+---+---+---+

2 | X | | O | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

1 1 X

0 1 2 3

+---+---+---+---+

0 | O | O | | |

+---+---+---+---+

1 | X | X | | |

+---+---+---+---+

2 | X | | O | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | O | O | O | |

+---+---+---+---+

1 | X | X | | |

+---+---+---+---+

2 | X | | O | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

2 1 X

0 1 2 3

+---+---+---+---+

0 | O | O | O | |

+---+---+---+---+

1 | X | X | | |

+---+---+---+---+

2 | X | X | O | |

+---+---+---+---+

3 | | | | X |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | O | O | O | |

+---+---+---+---+

1 | X | X | | |

+---+---+---+---+

2 | X | X | O | |

+---+---+---+---+

3 | | | O | X |

+---+---+---+---+

3 0 X

0 1 2 3

+---+---+---+---+

0 | O | O | O | |

+---+---+---+---+

1 | X | X | | |

+---+---+---+---+

2 | X | X | O | |

+---+---+---+---+

3 | X | | O | X |

+---+---+---+---+

AI's move:

0 1 2 3

+---+---+---+---+

0 | O | O | O | O |

+---+---+---+---+

1 | X | X | | |

+---+---+---+---+

2 | X | X | O | |

+---+---+---+---+

3 | X | | O | X |

+---+---+---+---+

O wins!!

**Conclusion**

Overall, the result of this programming project was a success. The completed program performed as desired, and all test cases resulted in successes; those test cases being X’s winning, O’s winning, and the game resulting in a tie. Not much would be done differently next time; there were no major issues with the code design in the project, so a program very similar to this would be designed in a similar manner. Storing the methods in a separate .cpp file in comparison to project 6 was a better design choice, as then the main program is much shorter than having all of the class methods defined in the main .cpp file as well as the main program itself. This project took roughly 10 hours to complete overall; 5-7 hours for coding, and roughly 3 hours for the report.