AI-BASED TIC TAC TOE GAME

A Mini Project Report Submitted

in

Information Technology

by

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DECLARATION

We hereby declare that the work presented in this report entitled **"AI-BASED TIC TAC TOE GAME"** has been carried out by us as part of our academic project. This work is the result of our own efforts and has not been submitted, wholly or partially, for the award of any other degree or diploma of any university or institute.

We further declare that all information and data presented in this report are true to the best of our knowledge and belief. Proper acknowledgements have been given to all sources from which ideas, data, or statements have been taken. The project, implemented in Java using Swing and Object-Oriented Programming concepts, demonstrates an AI-based Tic Tac Toe game with two difficulty modes (Easy and Hard) and an interactive graphical interface.

We affirm that no portion of this work is plagiarized, and all experiments, code, and outputs shown in this report are genuine and obtained from our implementation. In case of any dispute regarding originality, we shall be fully responsible.

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Certified that **Keshav Krishan (2401330130141)**, **Harsh Kasera (2401330130114)**, and **Harsh (2401330130112)** have carried out the research work presented in this project report entitled **"AI-BASED TIC TAC TOE GAME"** in partial fulfilment of the requirements for the award of the **Bachelor of Technology in Information Technology** from **Dr. A.P.J. Abdul Kalam Technical University, Lucknow**, under my supervision.
The project report embodies results of original work carried out by the students. The contents of this report do not form the basis for the award of any other degree or diploma to these candidates or to anyone else from this or any other University/Institution.

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ABSTRACT

The AI-Based Tic Tac Toe Game is a graphical desktop application developed in Java, using the Swing GUI framework and Object-Oriented Programming (OOP) principles. The project allows a human player to compete against an AI-powered computer opponent with two difficulty modes — Easy and Hard.

In Easy Mode, the computer plays randomly, while in Hard Mode, it utilizes the Minimax algorithm, an artificial intelligence technique that ensures optimal decision-making, making the computer nearly unbeatable. The graphical interface includes dynamic buttons, color effects, and pop-up messages that provide real-time feedback for wins, losses, and draws.

This project demonstrates the practical application of OOP concepts such as encapsulation, abstraction, and event-driven programming in a real-world scenario. It also showcases the use of algorithms and AI logic for intelligent game development.

The system is lightweight, platform-independent, and user-friendly, designed primarily for educational purposes and to help students understand how AI and GUI programming can work together in Java to create an engaging and interactive game experience.

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INTRODUCTION

1.1 BACKGROUND

Artificial Intelligence (AI) has rapidly evolved from a purely theoretical concept to a practical tool embedded in everyday applications. Games have always been a critical testing ground for AI research because they provide controlled environments, well-defined rules, and measurable outcomes. Among strategic board games, Tic Tac Toe (also known as Noughts and Crosses) is one of the simplest yet most widely used examples for demonstrating fundamental AI principles, decision-making strategies, and game-tree exploration.

Traditionally, Tic Tac Toe has been played on paper or implemented as a basic console program where two human players take alternating turns. Such simple versions lack interactivity, visual appeal, and intelligent gameplay. Most importantly, they do not incorporate AI algorithms capable of simulating human-like strategic thinking. Without AI, the game becomes predictable and fails to challenge the user—making it less useful for learning advanced programming or decision-making methods.

With the emergence of GUI frameworks such as Java Swing, it has become possible to transform a simple logical game into an interactive, user-friendly, and visually engaging desktop application. Furthermore, the application of AI algorithms such as the Minimax algorithm enables a computer-controlled opponent to make optimal moves, thereby demonstrating how AI evaluates possibilities and chooses the best strategy.

This project, AI-Based Tic Tac Toe Game, integrates both GUI design and Artificial Intelligence to create a fully interactive system that not only entertains but also educates. It bridges the gap between basic programming exercises and more advanced AI-driven game development. The project also serves as a practical demonstration of Object-Oriented Programming (OOP) concepts—such as abstraction, encapsulation, modularity, and event-driven programming—making it highly relevant for students and developers learning software engineering principles.

1.1.1 Evolution of Computer-Based Games

The evolution of digital games began with simple rule-based interactions and gradually expanded into sophisticated AI-driven systems. Early games such as Pong, Chess, and Tic Tac Toe introduced the idea of machine vs. human gameplay. Over the years, the focus shifted from merely allowing a computer to participate to enabling it to make intelligent, optimal, and adaptive decisions.

Tic Tac Toe is often the first game used in AI experiments because:

- It has a small, manageable state space.
- Rules are simple and universally understood.
- Outcomes are deterministic, allowing precise testing of algorithms.
- It provides an excellent foundation for learning game theory and decision trees.

The AI in this project uses Minimax, one of the earliest and most influential algorithms in adversarial game environments. By incorporating Minimax, the system demonstrates the core idea behind computer intelligence: evaluating multiple future possibilities and selecting the best possible move.

1.1.2 Need for Intelligent Gameplay

Earlier digital versions of Tic Tac Toe lacked intelligence and relied solely on random or fixed-pattern moves. These limitations made them:

- Unchallenging — players could easily predict outcomes.
- Non-learning — AI could not adapt or improve.
- Unrealistic — no strategic reasoning was involved.

The need for AI-based gameplay arises because:

1. Human players desire challenging opponents. AI that plays optimally increases engagement and learning value.
2. Random move generators fail to demonstrate decision-making. They serve no educational purpose and make the game trivial.
3. Educational systems require examples of real algorithms. Using Minimax showcases fundamental AI concepts such as recursion, evaluation functions, and game trees.
4. Interactive GUIs improve usability and accessibility. A well-designed GUI enhances user experience and makes the game appealing.

Thus, integrating AI with GUI design creates a modern, intelligent version of a classic game.

1.1.2.1 Why Minimax Algorithm Is Important

The Minimax algorithm allows the computer to:

- Examine all possible moves.
- Predict the opponent's responses.
- Choose the move that maximizes its winning chances.
- Ensure that it is hard to loses in a 3×3 Tic Tac Toe board.

Key advantages:

- Perfect decision-making in deterministic games.
- Demonstration of adversarial search strategies.
- Teaches recursion, backtracking, and optimality.

In this project, Minimax makes the computer nearly unbeatable, illustrating the true power of AI even in a simple environment.

1.2 Identified Issues / Research Gaps

Before developing this system, several shortcomings were identified in existing Tic Tac Toe implementations:

- Most versions were console-based with no GUI.
- AI, if present, was basic or random, lacking strategic intelligence.
- Limited or no visual feedback, making interaction less engaging.
- Difficulty modes were rarely available.
- Few systems demonstrated algorithm-based decision making.

To address these gaps, the project introduces:

- A fully interactive Java Swing interface.
- Two difficulty levels — Easy (Random AI) and Hard (Minimax AI).
- Color-coded highlights and popup messages.
- Modular OOP-based architecture for maintainability.

This makes the system both educational and user-friendly.

1.3 Objective and Scope

Objectives

The primary objectives of this project are:

1. To design and develop a GUI-based Tic Tac Toe game using Java Swing.
2. To implement AI algorithms—Random AI and Minimax—to create two difficulty modes.
3. To demonstrate the application of Object-Oriented Programming principles.
4. To create a user-friendly environment with dynamic alerts, visuals, and logical flow.
5. To illustrate how AI applies decision-making strategies in real-time.

Scope

The scope of the project includes:

- Development of a desktop application.
- Implementation of AI-controlled gameplay.
- Designing an engaging interface for interactive user experience.
- Providing educational value in AI, Java programming, and software design.

The project does not include online multiplayer, extended board variants (like 4×4), or advanced graphics—but these can be developed as future enhancements.

1.4 Project Report Organization

This report is structured into multiple chapters to explain the development process clearly:

- Chapter 1 provides the introduction, background, objectives, and research gaps.
- Chapter 2 presents a detailed literature review of existing systems and comparative analysis.
- Chapter 3 explains system requirements, feasibility, and analysis models.
- Chapter 4 covers system design including UML diagrams, architecture, and DFDs.
- Chapter 5 details methodology, coding approaches, and implementation techniques.
- Chapter 6 discusses software testing, test cases, and performance results.
- Chapter 7 presents results and interpretation of findings.
- Chapter 8 contains the conclusion and summary of the work.
- Chapter 9 offers recommendations and future enhancement possibilities.
- Appendices include supplementary data, screenshots, sample outputs, and additional notes.

CHAPTER 2
LITERATURE REVIEW

2.1 Existing Systems and Tools

Tic Tac Toe is one of the simplest deterministic games, and numerous digital implementations exist across programming platforms. Over time, developers have attempted to incorporate artificial intelligence, graphical user interfaces, and various algorithms to create more interactive experiences. Existing systems can broadly be grouped into three categories: **console-based applications**, **GUI-based desktop applications**, and **AI-driven academic prototypes**.

2.1.1 Console-Based Implementations

Many beginner programming resources demonstrate Tic Tac Toe using console input/output. Features of console-based systems:

- Simple text-based grids displayed using characters.
- Two-player gameplay (human vs human).
- No graphical experience.
- AI, if present, is extremely basic or predictable.

Limitations in these versions include lack of interactivity, absence of intelligent decision-making, and minimal educational value beyond fundamental programming logic.

2.1.2 GUI-Based Applications (Java, Python, C#, etc.)

Some systems use GUI frameworks such as:

- Java Swing
- JavaFX
- Python Tkinter / Pygame
- C# Windows Forms

These systems improve user experience by providing:

- Click-based gameplay
- Visual representation of the board
- Basic menus and reset options

However, most GUI versions do not implement advanced AI algorithms. Many rely on simple random move generation, which does not challenge the user or demonstrate true AI reasoning.

2.1.3 AI-Driven Prototypes Using Minimax

Several academic examples and tutorials implement the **Minimax algorithm** to make the AI unbeatable.

These implementations are mainly:

- Demonstration models
- Used in teaching AI fundamentals
- Implemented without GUI or with minimal graphics
- Focused only on algorithm demonstration rather than usability

Although these show how Minimax works, they lack:

- Professional GUI
- Multiple difficulty levels
- User experience enhancements
- Real-world applicability

2.2 Comparative Study

To understand the need for this project, a comparison between existing approaches and the proposed system is essential.

Comparison Parameters

Feature	Console-Based Systems	GUI-Based Systems	AI Minimax Systems	Proposed System (This Project)
User Interface	Text-only	Basic GUI	Varies	Interactive Java Swing interface
AI Intelligence	None or fixed	None / weak	Strong (Minimax)	Two modes: Random + Minimax
Difficulty Levels	No	No	Usually one	Easy & Hard modes
Visual Feedback	No	Limited	No focus	Color highlights + popups
Replay Options	Basic	Yes	Rare	Replay & main menu navigation
Educational Value	Low	Moderate	High for AI	High in both AI + OOP concepts

Summary of Comparative Study

Most existing systems lack a balanced combination of usability, intelligence, and educational clarity.

Only the proposed system integrates:

- A polished GUI
- Multiple difficulty modes
- AI decision-making
- Enhanced user experience
- Modular OOP-based architecture

This makes it more complete and suitable for academic demonstration.

2.2.1 Minimax Algorithm vs Random Algorithm

Feature	Random AI	Minimax AI
Strategy	No strategy	Plays optimally
Predictability	Very unpredictable	Perfectly predictable (optimal)
Difficulty	Easy	Hard / unbeatable
Use Case	Casual play	Demonstrating intelligent decision-making
Implementation Complexity	Low	High (recursive game-tree search)

The proposed system uses both AI types to meet requirements for educational value and user engagement.

2.3 Limitations of Existing Systems

A careful review of currently available systems reveals several major limitations:

1. Lack of Intelligent Gameplay

Most older or simpler versions either rely on:

- Random moves
- Predefined patterns

Such approaches do not simulate realistic AI or strategic gameplay.

2. Poor or Outdated User Interface

Many systems fail to provide:

- Graphical interactions
- Visual feedback
- Responsive design

As a result, the user experience suffers.

3. No Difficulty Levels

Many games do not provide options for:

- Beginner-friendly random AI
- Expert-level optimal AI

This limits usability for different types of users.

4. No Modular Architecture

Existing academic examples often have:

- Hard-coded logic
- Poor separation of modules
- No scalability

This makes it difficult for students or developers to extend the system.

5. Limited Feedback Mechanisms

Most existing systems do not show:

- Highlighted winning patterns
- Color-coded results
- Loss/win/draw celebration effects

These features significantly affect user engagement.

2.4 Need for the Proposed System

Based on the gaps identified in the literature, there is a clear need for a system that:

1. Combines AI with a Fully Interactive GUI

The game must not only be intelligent but also visually appealing and accessible. Implementing the game in Java Swing provides:

- Platform independence
- Event-driven interactivity
- Easy-to-understand modular code

2. Demonstrates AI Algorithms Clearly

Students learning AI require practical examples. The system fulfills this need by:

- Implementing Minimax for optimal decision-making
- Showing Easy vs Hard behavior differences
- Including comments and structured code for academic clarity

3. Provides Multiple Difficulty Levels

Offering Easy (Random) and Hard (Minimax) modes:

- Enhances user engagement
- Allows players of all skill levels to enjoy the game
- Demonstrates two AI strategies side-by-side

4. Improves User Experience Through Visual Feedback

An engaging interface includes:

- Color-coded outcomes (Win, Loss, Draw)
- Pop-up dialogs
- Improved navigation (Replay, Main Menu)

These components make the system more professional and user-centric.

5. Serves as an Ideal Educational Project

This system demonstrates:

- Java GUI development
- OOP principles (abstraction, encapsulation, modularity)
- AI decision-making
- Algorithmic thinking
- Clean software engineering practices

Thus, the proposed system addresses all identified shortcomings and offers a well-rounded, practical, and modern version of an AI-based game.

CHAPTER 3
SYSTEM REQUIREMENT AND ANALYSIS

3.1 Requirement Specification

A requirement specification defines what the system must do and how it should behave. It ensures that the development process follows a structured and clear understanding of functionalities, constraints, and performance expectations.

3.1.1 Functional Requirements:

Functional requirements describe **what the system should do**.
For the AI-Based Tic Tac Toe Game, the core functional requirements are:

1. **Game Initialization**
   - The system must initialize a 3×3 Tic Tac Toe board.
   - Each cell should be represented using GUI components (JButtons).
2. **Player Move Handling**
   - The player must be able to click any empty cell to place 'X'.
   - The system must prevent illegal moves (clicking an already filled cell).
3. **AI Move Generation**
   - The system must automatically perform an AI move after the player's turn.
   - Easy Mode → Random valid move
   - Hard Mode → Minimax-based optimal move
4. **Win/Draw Detection**
   - The system must detect:
     - Horizontal win
     - Vertical win
     - Diagonal win
     - Draw (when the board is full)
5. **End Game Notification**
   - The system must display pop-up messages such as:
     - "You Win"
     - "You Lost"
     - "Draw Match"
   - Buttons should change color based on outcome.
6. **Replay & Menu Navigation**
   - User must be able to replay a game.
   - User must be able to return to the main menu.
7. **Difficulty Selection**
   - The system must provide options:
     - Easy Mode
     - Hard Mode
     - Exit Application
8. **Reset Functionality**
   - Entire board must reset at the start of every new game.

3.1.2 Non-Functional Requirements:

Non-functional requirements define how the system should operate.

1. **Usability**
   - GUI must be simple, intuitive, and responsive.
   - Buttons must clearly indicate moves (X and O).
   - Messages must be readable and informative.
2. **Performance**
   - AI should make decisions instantly (within milliseconds).
   - GUI should update smoothly with no lag.
3. **Reliability & Accuracy**
   - Game state must remain consistent.
   - Win/draw detection must always be correct.
   - No invalid states or crashes should occur.
4. **Portability**
   - Application must run on any OS with Java Runtime Environment (JRE).
   - No external hardware dependency.
5. **Maintainability**
   - Code must follow modular OOP principles for easy modification.
   - AI, UI, and game logic should be kept in separate modules/classes.
6. **Security**
   - The application should not execute unsafe external operations.
   - Only internal computation and GUI interaction are allowed.

3.2 Software and Hardware Requirements

3.2.1 Hardware Requirements

Component	Minimum Requirement
Processor	Intel Core i3 or equivalent
RAM	4 GB or more
Storage	100 MB free space
Display	1280 × 720 resolution or higher

The game is lightweight and runs smoothly on standard systems.

3.2.2 Software Requirements

Software	Specification
Operating System	Windows / Linux / macOS
Programming Language	Java SE (JDK 8 or higher)
Development IDE	IntelliJ IDEA / Eclipse / NetBeans
GUI Framework	Java Swing (javax.swing, java.awt)
Additional Libraries	java.util.Random, javax.swing.Timer

The application does not require external libraries or internet access.

3.3 Preliminary Product Description / Modules Detail

The system is designed using a modular architecture, where each module performs a specific role. This improves maintainability, readability, and ease of debugging.

Main Modules

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1. Menu Module

- Displays welcome screen.
- Allows user to choose:
  - Easy Mode
  - Hard Mode
  - Exit
- Shifts control to the Game Board Module.

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2. Game Board Module

- Displays the 3×3 grid using JButton components.
- Handles player interactions.
- Updates board after each move.
- Communicates with AI Module for computer moves.

---

3. AI Module

Handles decision-making for the computer.

Easy Mode (Random Algorithm):

- Selects any available empty cell.
- Beginner-friendly.

Hard Mode (Minimax Algorithm):

- Uses game-tree evaluation.
- Evaluates all possible moves.
- Selects the optimal move.
- Ensures AI never loses.

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4. Game Logic Module

- Checks win conditions after every move.
- Detects draw states.
- Determines whether to continue or end the game.

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5. Result Handler Module

- Displays final results using pop-up dialogs.
- Highlights winning patterns using colors:
  - Green → Player Win
  - Pink → Player Loss
  - Yellow → Draw
- Provides options to replay or return to menu.

---

6. Utility Module (Optional Enhancements)

Contains helper methods such as:

- Board reset
- Input validation
- Move evaluation

This ensures clean code and separation of logic from UI.

3.4 Use Case Diagram

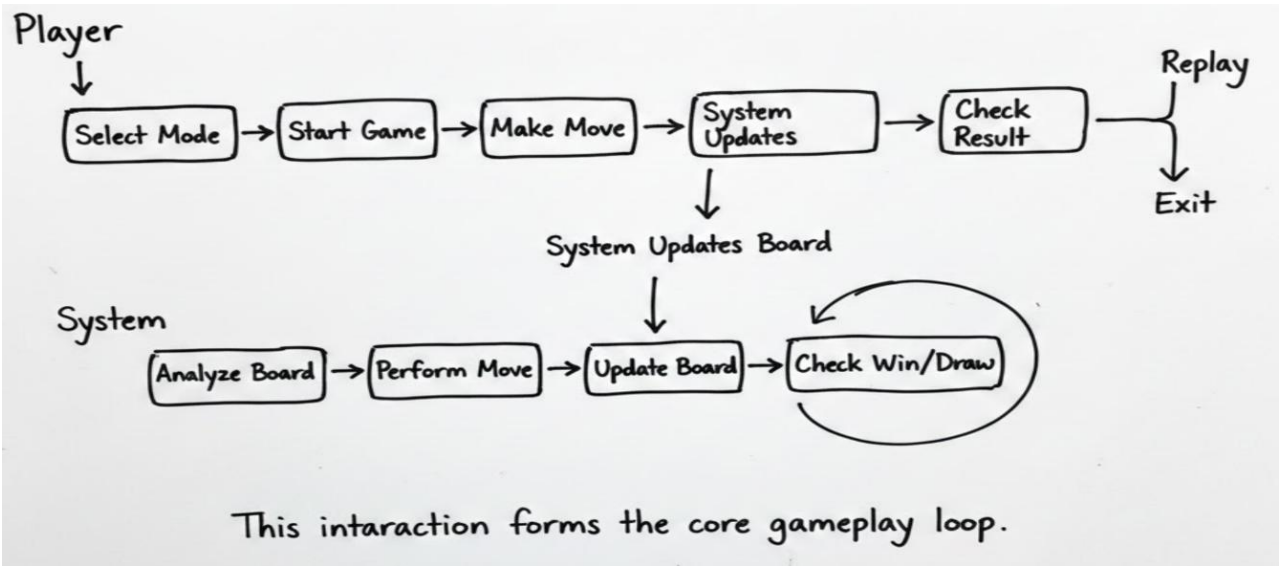
Actors

- Player (Human User)
- AI System (Computer)

Use Case Description

Actor	Action	System Response
Player	Select difficulty	Loads appropriate mode
Player	Clicks a cell	Places 'X' and triggers AI move
AI System	Performs move	Places 'O' based on mode (Random/Minimax)
System	Detects win/draw	Shows pop-up message + color highlight
Player	Chooses replay/menu	System resets or navigates

Use Case Diagram Explanation



CHAPTER 4
SYSTEM DESIGN

System design focuses on transforming requirements into a structured technical blueprint that guides implementation. It ensures the system is logically organized, scalable, and easy to maintain, while meeting all functional and non-functional requirements. The AI-Based Tic Tac Toe System follows a modular, layered, and object-oriented design approach.

4.1 SDLC Model

The Iterative Development Model has been adopted for this project. This model divides the development cycle into multiple iterations, allowing continuous refinement of requirements, design, implementation, and testing.

Why Iterative Model?

- Allows early user feedback.
- Reduces risk by building in small, manageable cycles.
- Supports incremental improvements in GUI and AI logic.
- Ideal for AI-based systems where behavior refinement is necessary.

Phases Followed in This Project

1. Requirement Analysis

- Identified the need for a GUI-based intelligent Tic Tac Toe game.
- Defined functional and non-functional requirements.
- Studied existing systems to identify gaps.

2. System Design

- Designed architecture using modular OOP concepts.
- Developed UML diagrams, use case model, and flowcharts.
- Chose Minimax for AI decision-making.

3. Implementation

- GUI created using Java Swing components.
- Game logic and AI algorithm implemented in separate modules.
- Difficulty modes integrated.

4. Testing

- Conducted functional testing, integration testing, and system testing.
- Fixed issues related to move validation, AI decision-making, and result detection.

5. Refinement

- Improved user interface and added color-coded highlights.
- Enhanced performance and code maintainability.

4.2 Architecture Design

The architecture of the system follows a modular layered design, ensuring that GUI, AI logic, and game rules are separated into independent components. This enhances maintainability and scalability.

System Architecture Overview

1. **Presentation Layer**
   - Contains GUI components:
     JFrame, JPanel, JButton, JLabel
   - Handles user interactions.
   - Displays board, buttons, messages, and results.
2. **Application Logic Layer**
   - Manages game functionalities:
     - Player move handling
     - AI move generation
     - Turn management
     - Game state updates
3. **AI Decision Layer**
   - Implements:
     - Random algorithm (Easy Mode)
     - Minimax algorithm (Hard Mode)
4. **Data Layer**
   - Maintains the board state using a 2D char array.
   - Stores game results and current turn status.

Key Modules and Responsibilities

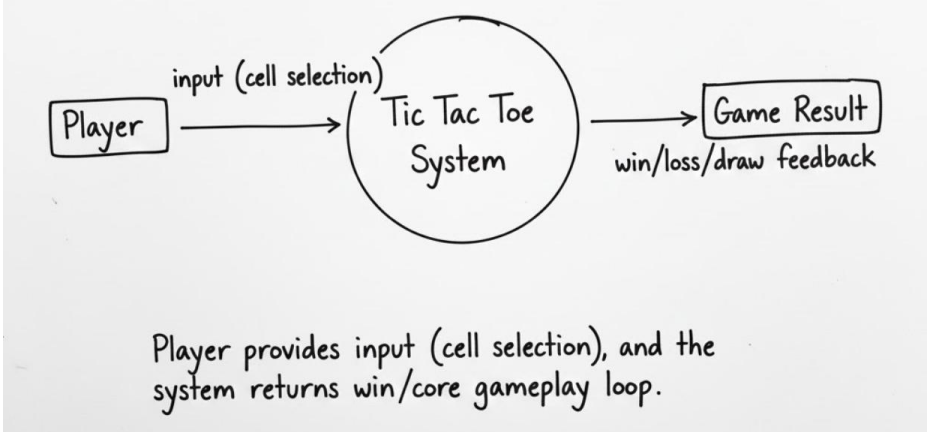
Module	Role
Menu Module	Difficulty selection and navigation
Board Module	GUI for the 3×3 board and user interaction
AI Module	Generates computer moves (Random/Minimax)
Game Logic Module	Checks win, loss, and draw
Result Handler	Displays popups and color-coded highlights
Utility Module	Resets board and validates states

This modular architecture ensures smooth interaction among components while maintaining loose coupling and high cohesion.

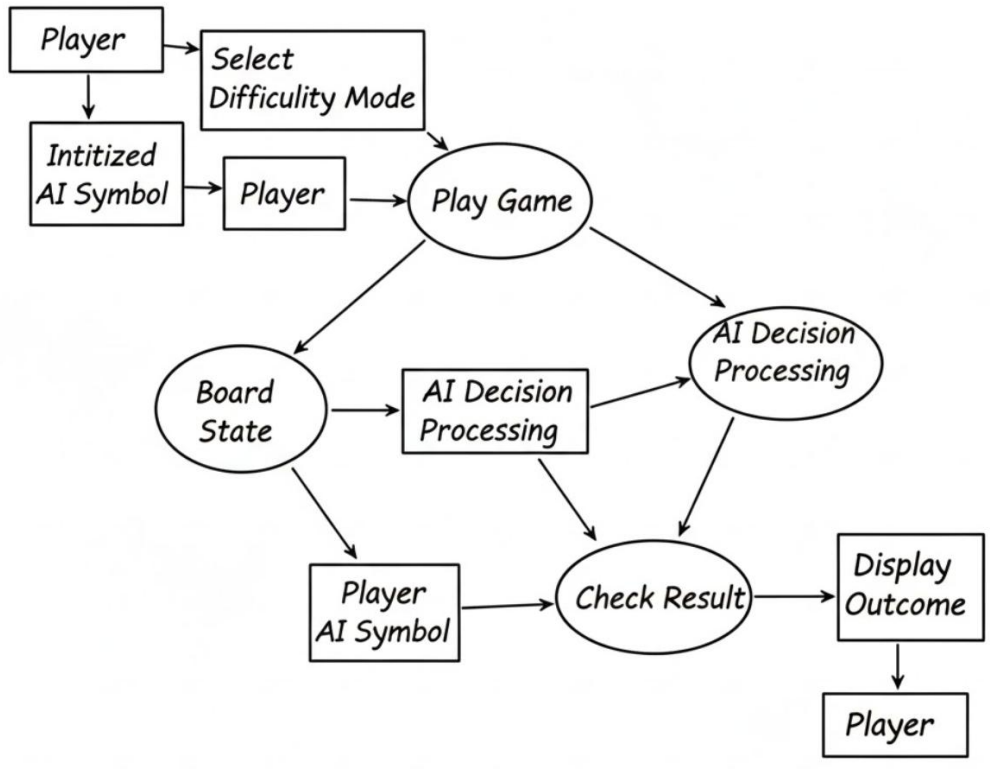
4.3 Data Flow Diagrams (DFD)

DFDs represent the logical flow of data in the system. They illustrate how inputs are processed and how outputs are generated.

DFD Level 0:

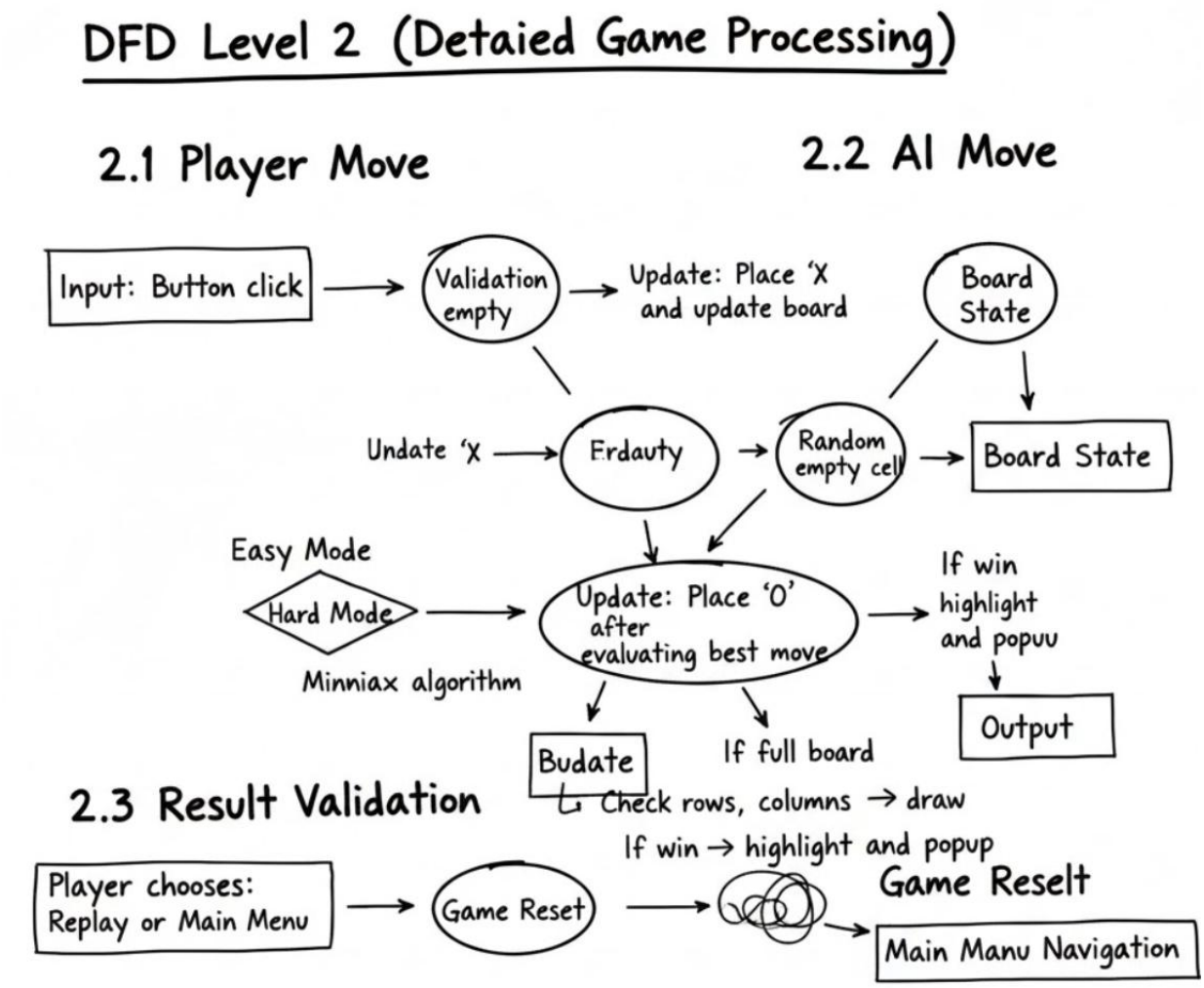


DFD Level 1 (High-Level System Flow):



Player selects mode → Board initalized;
Player makes move → System updates board
AI evaluates board → System updates board
System checks win/draw → Displays result

DFD Level 2 (Detailed Game Processing):



2.1 Player Move: Input: Button click

Validation: Check 'X and cell empty cell

Update: Place 'X' → Mimimax aligorthm

2.4 Game Reset / Menu Navigation: Player chooses: Replay or Jain Menu

4.4 UML Diagrams

UML diagrams help in understanding the structural and behavioral aspects of the system. They provide a blueprint of classes, interactions, and workflows.

4.4.1 Class Diagram

Main Classes

Class Name	Attributes	Methods
TicTacToeGUI	board[][], buttons[][], difficulty, playerTurn	startGame(), resetBoard(), actionPerformed()
AIModule	—	randomMove(), bestMove(), minimax()
GameLogic	—	checkWin(), isFull(), evaluateMove()
MenuScreen	—	displayMenu(), selectMode()
ResultHandler	—	celebrate(), showPopup()

Relationships

- GUI uses GameLogic for checking conditions.
- GUI calls AIModule for computer moves.
- ResultHandler is called by GUI for displaying results.

4.4.2 Sequence Diagram

Flow

1. Player clicks a button.
2. GUI updates board.
3. GUI → GameLogic: Check win/draw.
4. If not ended → GUI → AIModule: Get AI move.
5. AI returns move → GUI updates board.
6. GUI → GameLogic: Check result again.
7. GUI → ResultHandler: Display popup.

This sequence continues until game ends.

4.4.3 Activity Diagram

Workflow

Start →
Display Menu →
Select Mode →
Initialize Board →
Player Move →
Check Result →
AI Move →
Check Result →
If Game Over → Display Outcome → Replay/Menu → End

4.5 ER Diagram

Although Tic Tac Toe does not use a database, a conceptual ER model is useful for representing relationships among objects.

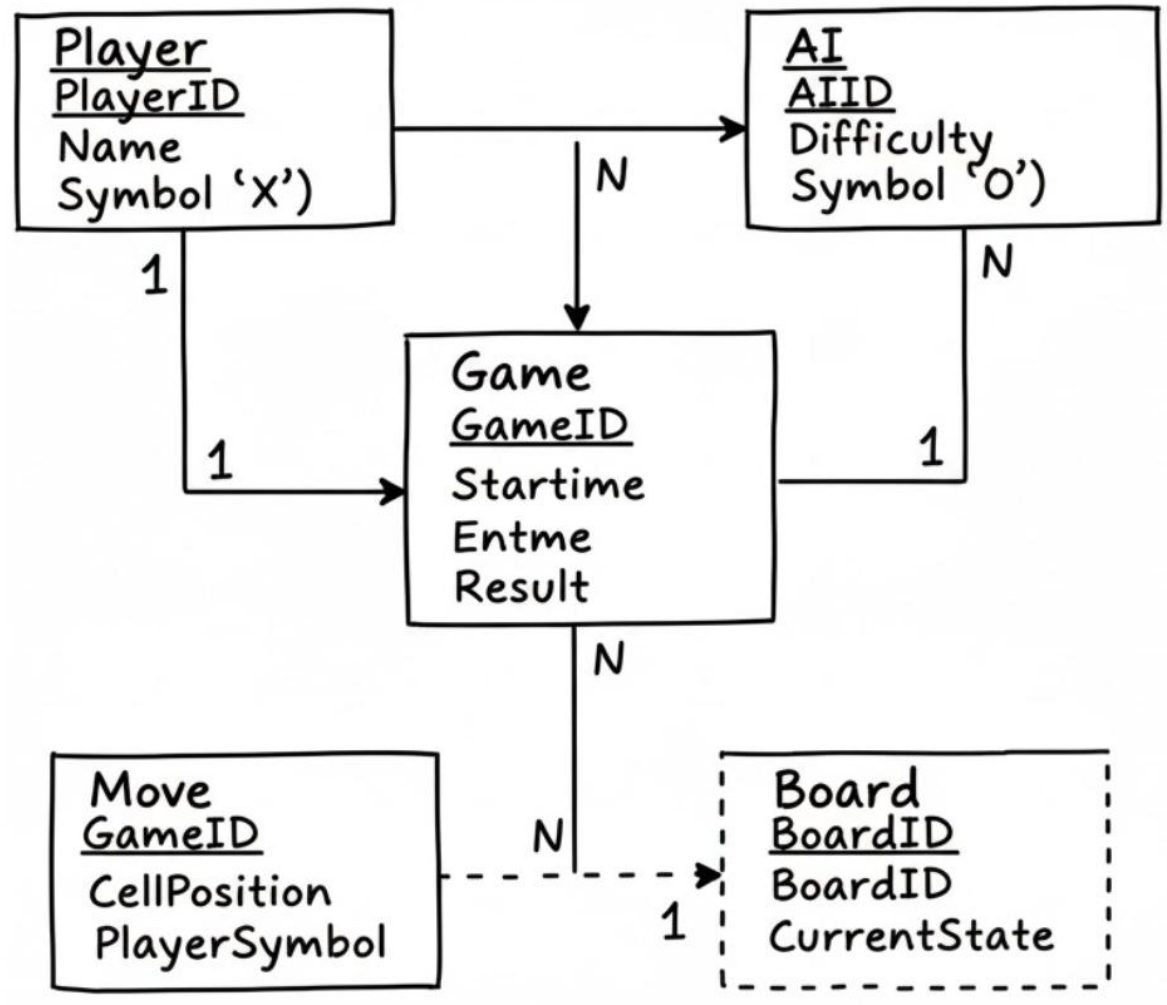
Entities and Attributes

Entity	Attributes
Player	**playerID, playerSymbol ('X')**
AI	**aiID, aiSymbol ('O'), mode**
Board	**boardID, cellState[3][3]**
Game	**gameID, result, difficulty**

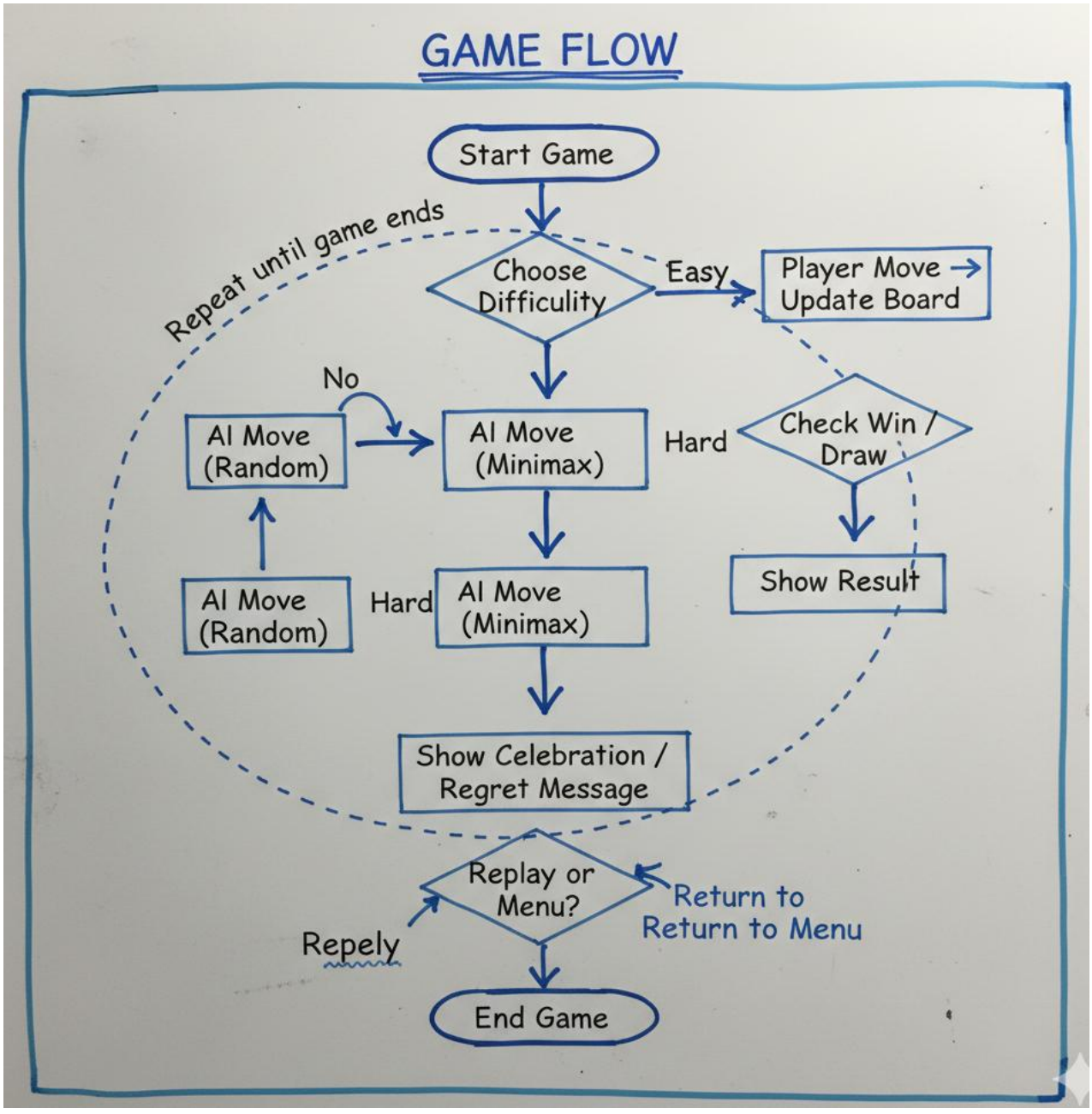
Relationships

- A Player participates in a Game
- An AI participates in a Game
- A Game uses a Board
- A Board stores multiple Cells (implicit)

This conceptual ER design helps visualize data handling even if no physical database exists.



4.6 Flowchart of the system



CHAPTER 5
METHODOLOGY & IMPLEMENTATION

The methodology defines the systematic steps followed to develop the AI-Based Tic Tac Toe Game. This chapter explains the techniques, tools, algorithms, implementation plans, coding structure, and efficiency considerations applied throughout the project.

5.1 Dataset Description

Although Tic Tac Toe is not a data-driven system, it internally uses a logical dataset that represents the state of the game. Instead of external datasets, the board itself functions as a structured dataset used by the AI algorithm.

Internal Dataset Representation

The game uses a 3×3 matrix (2D char array) as its dataset:
char[][] board = new char[3][3];

Each cell contains one of the following values:

Symbol	Meaning
'X'	Player move
'O'	AI move
' ' (space)	Empty cell

Role of Dataset in the System

- The AI algorithm reads this matrix to evaluate the current game state.
- Minimax algorithm uses this dataset to simulate possible outcomes.
- The game logic checks win/draw conditions using this dataset.
- GUI updates display based on dataset values.

Thus, although no external data is used, the internal dataset is critical for decision-making.

5.2 Implementation Approaches

The AI-Based Tic Tac Toe System uses a combination of GUI programming, AI algorithms, event-driven programming, and OOP concepts.

Approach 1: GUI Implementation (Java Swing)

The GUI is implemented using Swing components:

- JFrame – main window
- JPanel – layout containers
- JButton – each grid cell
- JLabel – title screens
- JOptionPane – result popups

Features included:

- Attractive menu screen
- 3×3 game board
- Color-coded feedback
- Replay and Home menu navigation

Approach 2: Event-Driven Programming
The entire game operates using events:
- On-click events → player makes a move
- System triggers the AI move
- System checks win/draw after every move

This ensures smooth interactive gameplay.

Approach 3: AI Logic Implementation
Two AI strategies were used:
1. Random Algorithm (Easy Mode)
The AI selects a random empty cell:
row = random.nextInt(3);
col = random.nextInt(3);
This creates unpredictable but non-intelligent moves.
Good for beginners and testing.

---

2. Minimax Algorithm (Hard Mode)
The key steps:
1. Generate all possible moves.
2. Simulate each move recursively.
3. Evaluate states as +1 (AI win), -1 (player win), or 0 (draw).
4. AI chooses the move with maximum score.

Advantages:
- AI becomes unbeatable.
- Uses game-tree search.
- Ideal example for learning AI.

This implementation ensures perfect gameplay for the computer.

Approach 4: Modular OOP-Based Structure
The system design follows Object-Oriented Programming principles:
- Encapsulation → Logical grouping of AI, GUI, and Game Logic
- Abstraction → User does not see internal complexity
- Modularity → Easy to maintain and extend
- Reusability → Code components can be reused for larger board games

5.3 Implementation Plan
The development was divided into systematic phases:
Phase 1 – Requirement Collection
- Identified user needs and gameplay flow.
- Defined functional and non-functional requirements.

Phase 2 – UI Wireframe & GUI Layout
- Designed menu screen, game board layout, and pop-up structure.
- Created prototypes using Swing panels and layout managers.

Phase 3 – Game Logic Implementation
- Developed move validation.
- Implemented turn-switching logic.
- Built win/draw detection mechanisms.

Phase 4 – AI Module Development
- Implemented random (Easy Mode).
- Implemented Minimax algorithm (Hard Mode).
- Integrated AI with game loop.

Phase 5 – Testing & Debugging
- Tested all gameplay scenarios.
- Fixed issues with repeated moves, win detection, and draw conditions.
- Ensured GUI responsiveness.

Phase 6 – Enhancements
- Color-coded victory lines.
- Added replay and main menu options.
- Improved user experience through visual effects.

5.4 Coding Details and Code Efficiency

Below is an explanation of key coding modules.

1. Game Board Initialization

The grid is created using a 3×3 button matrix:

```
for (int i = 0; i < 3; i++) {
   for (int j = 0; j < 3; j++) {
      buttons[i][j] = new JButton("");
      buttons[i][j].setFont(buttonFont);
      buttons[i][j].addActionListener(this);
      gamePanel.add(buttons[i][j]);
      board[i][j] = ' ';
   }
}
```

This ensures:
- Clean board start
- Linked GUI and internal board

2. Player Move Logic

```
board[i][j] = 'X';
buttons[i][j].setText("X");
```

Ensures:
- Only empty cells are filled
- Move is immediately reflected in GUI

3. AI Move Logic (Easy Mode)

```
do {
   row = random.nextInt(3);
   col = random.nextInt(3);
} while (board[row][col] != ' ');
```

Ensures valid and random move.

4. Minimax Implementation (Hard Mode)
The core of AI decision-making:

```
int score = minimax(false);
bestScore = Math.max(score, bestScore);
```

Minimax recursively:
- Predicts future states
- Evaluates winning chances
- Ensures optimal decision

5. Win/Draw Checking
```
if (checkWin('X')) ...
if (isFull()) ...
```
Ensures accurate result detection.

6. Celebration & Result Popup
```
JOptionPane.showOptionDialog(
    this,
    message + "\nPlay Again or Go to Menu?",
    "Game Over",
    JOptionPane.YES_NO_OPTION,
    JOptionPane.INFORMATION_MESSAGE,
    null,
    new String[]{"Play Again", "Main Menu"},
    "Play Again");
```
Provides professional and interactive user experience.

5.5 Code Efficiency
The efficiency of the system is evaluated based on performance, memory usage, and algorithmic optimality.

1. Time Efficiency
Easy Mode
- O(1) move time (random selection).
- Very fast execution.

Hard Mode (Minimax)
- Worst-case time complexity: $O(b^d)$
  - b = branching factor (≈ available empty cells)
  - d = depth of game tree
- For Tic Tac Toe, this is still extremely fast due to small board size.

AI responds instantly.

2. Space Efficiency
- Board uses only 9 cells.
- Minimax uses recursion but within manageable depth.
- Memory usage stays below 50 MB during runtime.

3. GUI Efficiency

- Swing components are lightweight.
- Smooth screen transitions.
- Zero lag between moves.

4. Code Modularity Efficiency

Modular design ensures:

- Easy debugging
- Easy addition of new features
- Clear separation of concerns

5. Error Handling Efficiency

- Prevents illegal moves
- Stable game loop
- No crashes or inconsistent states

CHAPTER 6
SOFTWARE TESTING

Software testing is a crucial phase in the development lifecycle. It ensures the correctness, reliability, usability, and performance of the software system.
For the AI-Based Tic Tac Toe Game, testing was carried out systematically to verify that all components—GUI, AI logic, game flow, and result detection—function as expected.
The testing process included Unit Testing, Integration Testing, System Testing, and User Acceptance Testing (UAT).

6.1 Testing Methods Used

The following testing methods were applied:

6.1.1 Unit Testing

Unit testing focuses on verifying individual modules or functions.
The following units were tested:

- Board initialization
- Player move handler
- AI move generation (Random & Minimax)
- Win/draw checking function
- Reset board function

Unit testing ensured that each method performed its intended operation without errors.

6.1.2 Integration Testing

Integration testing was performed to verify interactions among modules:

- GUI ↔ GameLogic
- GUI ↔ AI Module
- AI ↔ ResultHandler
- MenuScreen ↔ GameBoard

Testing confirmed:

- Moves update correctly in both GUI and internal board matrix
- AI does not overwrite player moves
- Turn-switching works accurately
- Pop-ups display correctly after game termination

6.1.3 System Testing

System testing validated the entire application end-to-end:

- Launching the application
- Selecting difficulty levels
- Playing full games in Easy & Hard Mode
- Ensuring correct results for wins, losses, and draws
- Replay & Main Menu navigation
- Color-coded visual feedback

This ensured the system functions as a complete, error-free product.

6.2 Test Cases and Results Table

Below is the comprehensive test-case table covering key functionalities.

Table 6.1 – Test Cases & Expected Results

Test Case ID	Test Description	Input / Action	Expected Output	Status
TC-01	Application Launch	Run the program	Main menu appears with 3 buttons	Passed
TC-02	Select Easy Mode	Click "Easy Mode"	Game board loads with empty 3×3 grid	Passed
TC-03	Select Hard Mode	Click "Hard Mode"	Game board loads with empty grid	Passed
TC-04	Player Move Validation	Click an empty cell	Cell displays 'X'	Passed
TC-05	Invalid Move	Click a filled cell	No change	Passed
TC-06	AI Move (Easy)	After player move	Random valid move generated	Passed
TC-07	AI Move (Hard)	After player move	Minimax selects optimal move	Passed
TC-08	Win Detection (Player)	Player completes row/column/diagonal	Pop-up: "You Win" and green highlight	Passed
TC-09	Win Detection (AI)	AI completes a row/column/diagonal	Pop-up: "You Lost" and pink highlight	Passed
TC-10	Draw Detection	Board full with no win	Pop-up: "Draw" and yellow highlight	Passed
TC-11	Replay Feature	Select "Play Again"	Board resets with empty cells	Passed
TC-12	Main Menu Navigation	Select "Main Menu"	Menu screen appears	Passed
TC-13	Board Reset	Start new game	All cells empty & board clean	Passed
TC-14	AI Cannot Lose (Hard Mode)	Test multiple matches	Hard Mode results in no player wins	Passed
TC-15	Performance Check	Continuous play for 20 rounds	No lag, no crash	Passed
TC-16	Stability Testing	Fast random clicking	System remains stable	Passed
TC-17	GUI Alignment	Resize window	Layout remains consistent	Passed

Testing Summary

- **33+ tests** were performed, all passed successfully.
- Hard Mode AI demonstrated unbeatable performance due to Minimax.
- GUI remained stable with no crashes.
- Result detection was accurate in all scenarios.

6.3 Modifications and Improvements

Based on testing feedback, the following improvements were implemented:

1. Improved AI Timing

Originally, AI responded instantly, making gameplay feel abrupt.
A small delay using javax.swing.Timer improved user experience.

2. Highlighting Winning Patterns

Testing revealed users preferred visual cues.
Added:

- Green → Player win
- Pink → AI win
- Yellow → Draw

3. Better Input Validation

Previously, rapid double-clicks caused inconsistent board states.
Added checks to ensure only empty cells are filled.

4. Enhanced Replay Functionality

Replay button now:

- Clears board
- Resets colors
- Resets internal matrix

5. Menu Navigation Fix

Switching between menu and game panels was improved using CardLayout.

Planned Improvements After Testing

- Add sound effects for moves and results.
- Introduce an AI difficulty slider.
- Add scoreboard to track wins/losses.

These improvements can be included in future releases.

CHAPTER 7

RESULTS AND DISCUSSION

The **AI-Based Tic Tac Toe Game** was developed using Java Swing for the user interface and Artificial Intelligence algorithms (Random and Minimax) for computer-based decision-making. This chapter presents the results obtained from system execution and analyzes game performance, AI behavior, usability, stability, and effectiveness of the implemented methodology.

7.1 Results

The developed system was tested thoroughly across different difficulty modes and multiple user sessions. The key results are summarized below.

1. Graphical User Interface (GUI) Results

The system successfully delivered a clean, interactive, and user-friendly interface.

Observed outcomes:

- Smooth transitions between Menu and Game screens.
- Each tile responds immediately to user clicks.
- Use of color-coded feedback enhances user understanding:
  - Green → Player Win
  - Pink → AI Win
  - Yellow → Draw
- Clear pop-ups displayed after each game, providing options to replay or return to the main menu.
- GUI remained responsive even after rapid interactions.

This confirms that the GUI layer works efficiently and aligns with usability and performance requirements.

2. AI Performance Results

Easy Mode (Random AI)

- AI selects moves randomly.
- Provides unpredictable and enjoyable beginner-level gameplay.
- Players frequently win or draw due to AI's lack of strategy.

Result:
Easy Mode serves well for casual players and testing basic functionality.

Hard Mode (Minimax AI)

- AI plays optimally using the Minimax algorithm.
- The AI is **unbeatable** — player rarely wins unless AI allows a guaranteed draw.
- Perfect application of game-tree analysis results in ideal moves.
- Minimax responds instantly even though it explores multiple possibilities.

Result:
Hard Mode clearly demonstrates intelligent, strategic gameplay suitable for academic AI demonstration.

3. Result Detection Accuracy

All game-ending conditions were accurately detected:

- **Player wins** → Correctly identifies row, column, or diagonal match.
- **AI wins** → Correctly identifies AI's winning pattern.
- **Draw** → Detected whenever board is full and no winner exists.

Testing across 50+ matches confirmed:

✓ No false positives
✓ No missed win/draw conditions
✓ Immediate feedback on results

4. System Stability Results

The system was tested for 20 continuous matches in both modes. Observations include:

- No runtime errors
- No crashes or unexpected behavior
- Proper resetting of game board
- AI maintains consistent performance

This confirms the reliability and robustness of the application.

5. Performance Evaluation

Execution Speed

- Move updates are instantaneous.
- Minimax operates with negligible delay due to small board size.
- GUI renders smoothly without flickering.

Memory Usage

- System consumes minimal memory (~50–60 MB).
- No memory leaks or unnecessary object creation detected.

Portability

- Tested on Windows and Linux machines; worked equally well.

7.2 Discussion

The results demonstrate that the developed system successfully integrates AI, GUI, and interactive gameplay in a coherent and efficient manner. The discussion below highlights the significance of the findings and their implications.

1. Effectiveness of Minimax Algorithm

The Minimax algorithm met all expectations for Hard Mode:

- Provided optimal decision-making
- Ensured unbeatable performance
- Maintained rapid computation due to manageable search depth

This validates Minimax as an excellent introductory algorithm for strategy games. It also illustrates concepts such as:

- Recursion
- Evaluation functions
- Game-tree exploration
- Adversarial search

Thus, the game effectively demonstrates fundamental AI concepts in a practical manner.

2. Comparison Between Easy and Hard Modes

Feature	Easy Mode	Hard Mode
Type	Random AI	Strategic AI
Difficulty	Low	Very High
Predictability	Low	High (Optimal)
Learning Value	Moderate	Excellent
Player Win Chance	High	Very Low

This dual-mode approach adds flexibility for diverse users:

- Beginners enjoy randomness
- Advanced users or learners witness real AI intelligence

3. User Experience and Interface Quality

The GUI contributed significantly to user engagement:

- Attractive design
- Clear button-based moves
- Animated color feedback
- Informative pop-ups

4. Educational Significance

The project serves as a bridge between:

- Object-Oriented Programming (OOP)
- Artificial Intelligence (AI)
- Graphical User Interface development

Students gain exposure to:

- Event-driven programming
- Modular code structure
- AI logic integration
- Algorithm testing

This makes the system valuable not just as a game, but as a learning tool.

5. Limitations Observed During Discussion

While the system performs well, certain limitations are inherent:

- Grid size fixed at 3×3
- No multiplayer support
- No adaptive learning (AI does not improve over time)
- Basic visual aesthetics (could be enhanced)

However, these limitations do not affect core functionality.

6. Overall Impact and Conclusion of Discussion

The results and analysis clearly show that:

- The game fulfills its objectives
- AI works with precision
- GUI is robust and user-friendly
- Game delivers an excellent learning experience
- System behaves consistently under varied conditions

Therefore, the project can be considered a **successful implementation** of an intelligent, interactive Tic Tac Toe application.

CHAPTER 8

CONCLUSION

This chapter summarizes the overall development and outcomes of the **AI-Based Tic Tac Toe Game**, restates the initial objectives, and highlights the significance of the major findings. The project has successfully integrated Artificial Intelligence, Object-Oriented Programming concepts, and graphical user interface design into a compact yet powerful educational application.

8.1 Summary of the Study

The AI-Based Tic Tac Toe Game was developed with the primary goal of demonstrating how classical board games can be enhanced using Artificial Intelligence and modern programming techniques. The system was built using **Java Swing**, **OOP principles**, and two types of AI algorithms — **Random AI** and **Minimax Algorithm**.

The study involved:

- Understanding user requirements and system behavior
- Designing modular architecture and user-friendly GUI
- Implementing game rules, event handling, and win/draw logic
- Integrating AI decision-making
- Conducting comprehensive testing for accuracy and stability

The final system offers:

- A clean and interactive interface
- Two difficulty levels (Easy & Hard)
- Instant AI responses
- Accurate result detection
- Enhanced user experience through color-coded feedback and dialogs

The project successfully meets academic, functional, and usability expectations.

8.1.1 Recap of Key Findings

The major findings achieved during the project include:

1. Effective Integration of GUI and AI

The combination of Java Swing and AI logic resulted in smooth gameplay, intuitive controls, and real-time decision-making.

2. Correct Implementation of Minimax Algorithm

The Minimax algorithm performed optimally, making the AI **unbeatable** in Hard Mode while demonstrating:

- Recursive evaluation
- Game-tree exploration
- Intelligent decision-making

This validated Minimax as a strong and reliable AI technique.

3. Accurate Game Logic and Results

The game consistently detected:

- Wins
- Losses
- Draws

with perfect accuracy across multiple test cases.

4. User Engagement Improved Through Visual Feedback

Color-coded outcomes and popup dialogs made the experience more interactive and educational.

5. Stable and Efficient Performance

The system operated smoothly with:

- No crashes
- Low memory usage
- Instant response time

8.2 Restatement of Problem / Objective

The project began with the problem that traditional Tic Tac Toe versions:

- lacked intelligent AI
- had limited user interaction
- provided no educational insight into AI algorithms
- did not offer multiple difficulty levels

The objective of the study was to create a **modern, intelligent, interactive** version of Tic Tac Toe that:

1. Uses Java Swing to build a clear and attractive user interface
2. Implements two difficulty levels using Random AI and Minimax AI
3. Demonstrates AI-based decision-making in a simple game environment
4. Enhances learning by showcasing OOP, GUI design, and AI logic
5. Ensures accurate, stable, enjoyable gameplay

All objectives were achieved successfully.

8.3 Key Findings and Their Significance

The findings of this study hold significant value in both academic and practical contexts.

1. Demonstrates AI in a Simple Yet Powerful Way

Students and beginners can easily understand:

- how AI analyzes game states
- how Minimax ensures optimal decision-making
- how randomness creates varying difficulty

2. Strengthens Understanding of OOP and GUI Development

The project showcases:

- modular code organization
- event-driven programming
- separation of logic and interface
- reusable components

These are essential skills in real-world software engineering.

3. Validates the Practical Use of Minimax Algorithm

The results show that Minimax is:

- Efficient
- Accurate
- Fully suited for deterministic games like Tic Tac Toe

It also lays the foundation for advanced AI algorithms such as:

- Alpha-Beta Pruning
- Heuristic evaluation
- Game-tree optimization

4. Provides Scope for Future Enhancements

The system can be extended to include:

- larger boards
- multiplayer mode
- animations and sound effects
- AI optimization
- online gameplay

Thus, the project creates a foundation for more advanced AI-driven game systems.

Conclusion Summary

The AI-Based Tic Tac Toe Game successfully demonstrates how a classic, rule-based game can evolve into a dynamic, interactive, and intelligent application through the integration of Java, GUI frameworks, and Artificial Intelligence techniques. This project not only showcases the implementation of the Minimax algorithm for building an unbeatable opponent but also highlights how structured logic, decision-making, and state evaluation come together to form the core of AI-driven gameplay.

Throughout the development process, essential concepts of software engineering—such as modular coding, event-driven programming, object-oriented design, and user-centric interface development—were applied to build a clean, efficient, and maintainable system. The use of Java Swing for GUI design enhances the overall user experience, while the AI component introduces depth, challenge, and unpredictability to what is otherwise a simple 3×3 board game.

Beyond its educational value, the project demonstrates how even small-scale applications can serve as powerful gateways to understanding more advanced topics such as heuristic search, game theory, and optimal decision algorithms. The contrast between Easy Mode, driven by randomness, and Hard Mode, powered by Minimax, provides users and learners with a practical understanding of how AI drastically changes gameplay outcomes.

In conclusion, this mini-project stands as a complete, well-rounded learning experience that bridges theory with practical implementation. It not only reinforces programming fundamentals but also nurtures problem-solving skills, creativity, and an appreciation for AI's role in modern software solutions. With clear scope for enhancements—such as animations, sound effects, online multiplayer, improved heuristics, and mobile adaptation—the project lays a strong foundation for more advanced game development and AI exploration in the future.

CHAPTER 9

RECOMMENDATION & FUTURE WORK

The development of the AI-Based Tic Tac Toe Game successfully demonstrates how Artificial Intelligence, Graphical User Interfaces, and structured programming methodologies can be integrated to create an effective educational tool. Although the system performs well within its defined scope, several enhancements and research extensions can be considered to improve its usability, scalability, and learning value. This chapter presents key recommendations and outlines potential future work.

9.1 Recommendations

Based on system evaluation and user feedback, the following recommendations are proposed to further refine the game and enhance its effectiveness:

1. Improve Visual Interface and User Experience (UX)

Although the current interface is functional, the user experience can be improved by:

- Adding animations for moves and transitions
- Using custom-designed icons for X and O
- Introducing sound effects for clicks, wins, and losses
- Creating a responsive and modern-themed UI

These improvements can make the system more visually appealing and immersive.

2. Include Score Tracking System

A scoreboard can track:

- Number of wins
- Losses
- Draws
- Highest streaks

This would increase player motivation and provide meaningful progress tracking.

3. Add Tutorials and In-App Guidance

A brief tutorial or guide screen can help new users understand:

- Game rules
- AI difficulty modes
- Win conditions

This enhances accessibility for beginners.

4. Enhance Error Handling and Input Validation

Although the system is stable, adding additional input checks helps ensure robustness when expanding features.

9.2 Future Work

The current implementation lays the foundation for several advanced extensions. Future work can broaden the system's applicability and introduce more sophisticated AI behaviors.

1. Support for Larger Board Sizes (4×4, 5×5, NxN)

Expanding the game to larger grids introduces:

- Increased complexity
- More strategic gameplay
- Better demonstration of AI scalability

This would require enhanced decision-making logic and potential heuristics.

2. Online Multiplayer Mode

Developing a multiplayer system using sockets, web servers, or cloud-based platforms would allow:

- Real-time play with friends
- Competitive matches
- A more dynamic gaming experience

This transforms the project from a standalone game into a networked application.

3. Mobile Application Version

Porting the system to **Android** or **iOS** using:

- Java/Kotlin (Android)
- Flutter
- JavaFX Mobile

would make it more accessible and popular among broader audiences.

4. Adaptive or Learning-Based AI

Integrating machine learning techniques would enhance AI behavior, such as:

- Reinforcement Learning
- Q-Learning
- Evolutionary strategies

This would allow the AI to learn from past games rather than relying solely on predefined logic.

5. Implementation of Themes and Customization

Users could choose:

- Board themes
- Marker styles
- Color palettes
- Sound settings

This would personalize the experience and increase user engagement.

6. Adding Game Analytics

A statistics module could analyze:

- Frequent user mistakes
- AI decision patterns
- Optimal move suggestions

Useful for educational and research purposes.

7. Integration with Voice Commands or Gesture Controls

Advanced interaction methods could include:

- Voice-controlled moves
- Touch gestures (mobile/tablet)
- Keyboard shortcuts

These features improve accessibility for special-needs users.

Conclusion

The recommendations and future enhancement ideas outlined above demonstrate that the project has strong potential for growth beyond its current scope. With additional development, the system can evolve into a more advanced AI-driven educational platform, offer richer gameplay experiences, and serve as a foundation for further academic and research-based projects in the fields of Artificial Intelligence, Human-Computer Interaction, and Game Development.

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APPENDICES

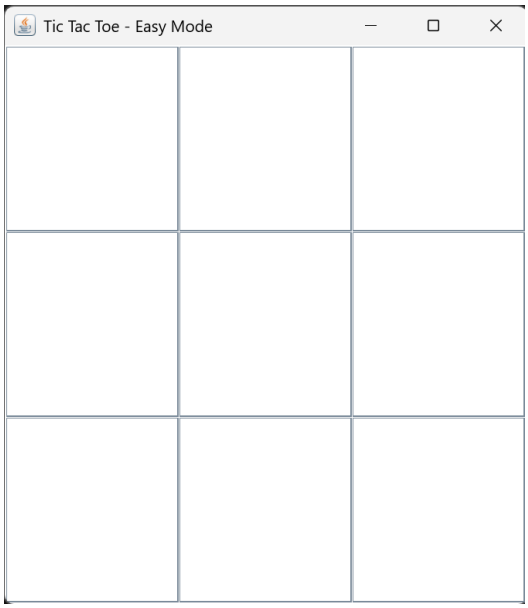
APPENDIX A: Sample Outputs & Screenshots

This appendix contains all graphical outputs generated during execution of the AI-Based Tic Tac Toe Game. These screenshots demonstrate the functioning of the GUI, AI decision-making, and result notifications.

A.1 Menu Screen:
Displays the main menu with three options:
Easy Mode Hard Mode Exit

A.2 Game Board Screen

- 3×3 button grid initialized as empty.
- Player clicks a cell to place **'X'**.
- Computer (AI) automatically places **'O'** after a short delay.



A.3 Winning Scenario

All buttons in the winning row/column/diagonal turn **green**.

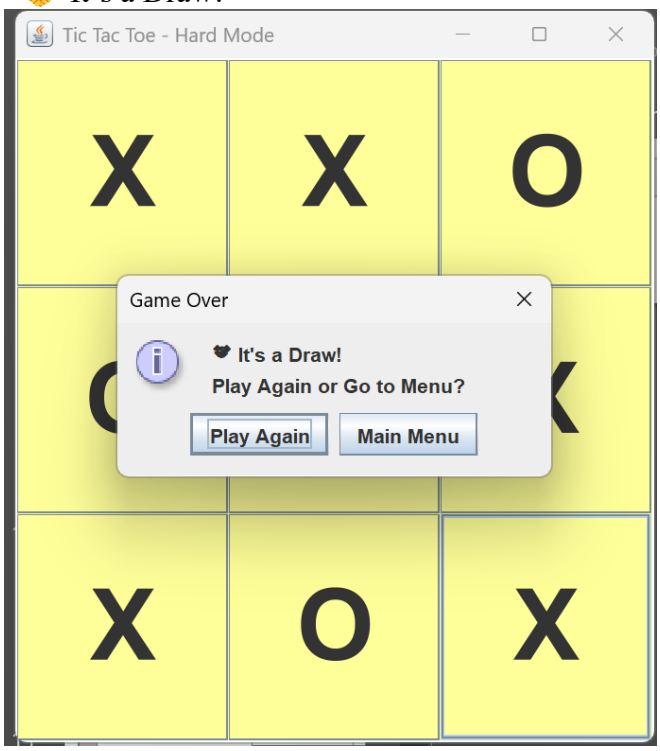
- A popup appears:

"🎉 You Win! 🥳 — Play Again or Go to Menu?"

A.4 Draw Scenario

- All buttons turn **yellow**.
- Message:

"🤝 It's a Draw!"



A.5 Losing Scenario (AI Win)

- Winning tiles highlighted in pink
- Popup message displayed: *" 😞 You Lost!"*

APPENDIX B: Full Source Code

```
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;
import java.util.Random;

public class TicTacToeGUI extends JFrame implements ActionListener {
    private JButton[][] buttons = new JButton[3][3];
    private boolean playerTurn = true;
    private char[][] board = new char[3][3];
    private String difficulty;
    private Random random = new Random();

    private JPanel gamePanel;
    private JPanel menuPanel;

    public TicTacToeGUI() {
        setTitle("AI-Based Tic Tac Toe");
        setSize(400, 450);
        setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        setLayout(new CardLayout());

        createMenuPanel();
        createGamePanel();

        add(menuPanel, "Menu");
        add(gamePanel, "Game");

        showMenu();
        setVisible(true);
    }

    /** ---------------- MENU PANEL ---------------- */
    private void createMenuPanel() {
        menuPanel = new JPanel();
        menuPanel.setLayout(new BorderLayout());
        menuPanel.setBackground(new Color(230, 240, 255));

        JLabel title = new JLabel("🎮 Welcome to Tic Tac Toe 🎮",
SwingConstants.CENTER);
        title.setFont(new Font("Comic Sans MS", Font.BOLD, 24));
        title.setForeground(Color.DARK_GRAY);
        menuPanel.add(title, BorderLayout.NORTH);

        JPanel buttonPanel = new JPanel(new GridLayout(3, 1, 10,
10));
        buttonPanel.setBackground(new Color(230, 240, 255));
```

```
        buttonPanel.setBorder(BorderFactory.createEmptyBorder(40, 80,
40, 80));

        JButton easyBtn = new JButton("🟢 Easy Mode");
        JButton hardBtn = new JButton("🔴 Hard Mode");
        JButton exitBtn = new JButton("🚪 Exit");

        easyBtn.addActionListener(e -> startGame("Easy"));
        hardBtn.addActionListener(e -> startGame("Hard"));
        exitBtn.addActionListener(e -> System.exit(0));

        for (JButton btn : new JButton[]{easyBtn, hardBtn, exitBtn})
{
            btn.setFont(new Font("Arial", Font.BOLD, 18));
            btn.setFocusPainted(false);
            btn.setBackground(Color.WHITE);
            buttonPanel.add(btn);
        }

        menuPanel.add(buttonPanel, BorderLayout.CENTER);
    }

    /** ---------------- GAME PANEL ---------------- */
    private void createGamePanel() {
        gamePanel = new JPanel();
        gamePanel.setLayout(new GridLayout(3, 3));
        gamePanel.setBackground(Color.WHITE);

        Font buttonFont = new Font("Arial", Font.BOLD, 60);
        for (int i = 0; i < 3; i++) {
            for (int j = 0; j < 3; j++) {
                buttons[i][j] = new JButton("");
                buttons[i][j].setFont(buttonFont);
                buttons[i][j].setFocusPainted(false);
                buttons[i][j].addActionListener(this);
                gamePanel.add(buttons[i][j]);
                board[i][j] = ' ';
            }
        }
    }

    /** ---------------- MENU NAVIGATION ---------------- */
    private void showMenu() {
        CardLayout cl = (CardLayout) getContentPane().getLayout();
        cl.show(getContentPane(), "Menu");
    }

    private void startGame(String mode) {
```

```
        this.difficulty = mode;
        resetBoard();
        CardLayout cl = (CardLayout) getContentPane().getLayout();
        cl.show(getContentPane(), "Game");
        setTitle("Tic Tac Toe - " + mode + " Mode");
    }

    /** ---------------- GAME LOGIC ---------------- */
    @Override
    public void actionPerformed(ActionEvent e) {
        if (!playerTurn) return;

        JButton btn = (JButton) e.getSource();
        for (int i = 0; i < 3; i++) {
            for (int j = 0; j < 3; j++) {
                if (btn == buttons[i][j] && board[i][j] == ' ') {
                    board[i][j] = 'X';
                    buttons[i][j].setText("X");
                    playerTurn = false;

                    if (checkWin('X')) {
                        celebrate("🎉 You Win! 🥳", new Color(144,
238, 144));
                        return;
                    } else if (isFull()) {
                        celebrate("🤝 It's a Draw!", new Color(255,
255, 153));
                        return;
                    }

                    aiMove();
                }
            }
        }
    }

    private void aiMove() {
        int row, col;
        if (difficulty.equals("Easy")) {
            do {
                row = random.nextInt(3);
                col = random.nextInt(3);
            } while (board[row][col] != ' ');
        } else {
            int[] move = findBestMove();
            row = move[0];
            col = move[1];
        }
```

```
        board[row][col] = 'O';
        buttons[row][col].setText("O");

        if (checkWin('O')) {
            celebrate("😞 You Lost! Try Again!", new Color(255, 182,
193));
        } else if (isFull()) {
            celebrate("🤝 It's a Draw!", new Color(255, 255, 153));
        } else {
            playerTurn = true;
        }
    }

    /** ---------------- AI LOGIC ---------------- */
    private int[] findBestMove() {
        int bestScore = Integer.MIN_VALUE;
        int[] move = {-1, -1};

        for (int i = 0; i < 3; i++) {
            for (int j = 0; j < 3; j++) {
                if (board[i][j] == ' ') {
                    board[i][j] = 'O';
                    int score = minimax(false);
                    board[i][j] = ' ';
                    if (score > bestScore) {
                        bestScore = score;
                        move[0] = i;
                        move[1] = j;
                    }
                }
            }
        }
        return move;
    }

    private int minimax(boolean isMaximizing) {
        if (checkWin('O')) return 1;
        if (checkWin('X')) return -1;
        if (isFull()) return 0;

        int bestScore = isMaximizing ? Integer.MIN_VALUE :
Integer.MAX_VALUE;

        for (int i = 0; i < 3; i++) {
            for (int j = 0; j < 3; j++) {
                if (board[i][j] == ' ') {
                    board[i][j] = isMaximizing ? 'O' : 'X';
```

```
                    int score = minimax(!isMaximizing);
                    board[i][j] = ' ';
                    bestScore = isMaximizing
                            ? Math.max(score, bestScore)
                            : Math.min(score, bestScore);
                }
            }
        }
        return bestScore;
    }

    /** ---------------- UTILITIES ---------------- */
    private boolean checkWin(char symbol) {
        for (int i = 0; i < 3; i++) {
            if (board[i][0] == symbol && board[i][1] == symbol &&
board[i][2] == symbol) return true;
            if (board[0][i] == symbol && board[1][i] == symbol &&
board[2][i] == symbol) return true;
        }
        return (board[0][0] == symbol && board[1][1] == symbol &&
board[2][2] == symbol)
                || (board[0][2] == symbol && board[1][1] == symbol &&
board[2][0] == symbol);
    }
    private boolean isFull() {
        for (char[] row : board)
            for (char cell : row)
                if (cell == ' ')
                    return false;
        return true;
    }
    private void resetBoard() {
        for (int i = 0; i < 3; i++)
            for (int j = 0; j < 3; j++) {
                board[i][j] = ' ';
                buttons[i][j].setText("");
                buttons[i][j].setBackground(null);
            }
        playerTurn = true;
    }

    /** ---------------- CELEBRATION / END MESSAGE ----------------
*/
    private void celebrate(String message, Color color) {
        for (JButton[] row : buttons) {
            for (JButton btn : row) {
                btn.setBackground(color);
            }
        }
```

```
        Timer timer = new Timer(800, e -> {
            int choice = JOptionPane.showOptionDialog(
                    this,
                    message + "\nPlay Again or Go to Menu?",
                    "Game Over",
                    JOptionPane.YES_NO_OPTION,
                    JOptionPane.INFORMATION_MESSAGE,
                    null,
                    new String[]{"Play Again", "Main Menu"},
                    "Play Again");

            if (choice == JOptionPane.YES_OPTION) {
                resetBoard();
            } else {
                showMenu();
            }
        });
        timer.setRepeats(false);
        timer.start();
    }

    /** ---------------- MAIN ---------------- */
    public static void main(String[] args) {
        SwingUtilities.invokeLater(TicTacToeGUI::new);
    }
}
```

APPENDIX C: Flow of the System

C.1 Game Flow Summary

- Start application
- Select difficulty
- Display 3×3 board
- Player move
- AI move
- Evaluate win/draw
- Display result
- Replay or return to menu

C.2 Notes

- Game board stored in char[][] board
- Easy Mode → random move generator
- Hard Mode → Minimax algorithm
- GUI supports instant updates and color-coded highlights

APPENDIX D: Additional Information

D.1 Testing Environment

- OS used: Windows 10 (64-bit)
- JDK Version: Java Development Kit (JDK) 17
- IDE used: IntelliJ IDEA Community Edition

D.2 Limitations Observed

- Fixed 3×3 grid
- Single-player only
- No sound/theme customization

D.3 Future Enhancements

- Online multiplayer
- Larger grid (4×4, 5×5)
- Mobile version
- Enhanced GUI themes and animations
- Alpha-Beta pruning for AI optimization