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Smart and Interactive Chessboard using AI

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Abstract: —The proposed project offers a web-based chess system with dual functionality: Play Mode for normal play and Learn Mode with AI support for move validation, hints, and optimal move suggestions. There is also a Puzzle Mode for tactical training with pre-set scenarios, and a Post-Game Review Module for analysis of accuracy, errors, and decision time. The complexity of the system is in combining deterministic rule validation, adaptive AI search depth based on difficulty levels, natural language processing interfaces for voice-controlled move execution, and statistical models for performance analysis. The system employs chess.js for rule validation, Stockfish.js for move calculation, Web Speech APIs for voice automation, and gamification through achievement patches. The combination of game logic, AI calculation, and speech functionality provides a seamless platform for both play and learning.

(Keywords— Chess Learning System, Interactive Chess Training, Voice-Controlled Chess, Piece Movement Visualization, User Interface Design, Game Automation, Skill-Based Customization, Human–Computer Interaction, Web-Based Chess Application)

I. INTRODUCTION

Chess is one of the oldest and most popular board games in the world, renowned for developing critical cognitive skills such as logical thinking, problem-solving, strategic planning, concentration, memory, patience, and decision-making skills. For a long time, learning chess was possible only through physical boards, books, and personal instruction, which was a time-consuming and resource-intensive process. This resulted in new learners having difficulty learning the game without proper instruction and feedback. However, with the increasing pace of digital technology, internet connectivity, and smart devices, the game of chess has shifted from physical board games to online versions, making it easier for players all over the world to access and play the game. The latest web-based chess technology enables players to play games in real-time, evaluate positions, and learn anywhere and anytime. However, the current available digital chess technology is mainly geared towards players who want to compete and play at an advanced level. These systems usually have the presumption that the users are already familiar with the basic rules and strategies of playing chess, thus making it difficult for new users to learn. New users usually find it difficult to learn about legal moves, piece coordination, tactical concepts, and long-term strategies because the system does not offer real-time assistance during gameplay. Many systems only have static tutorials and post-game analysis, which is not helpful in correcting mistakes immediately and learning why other moves are better. Moreover, the lack of accessibility features and the absence of interactive and motivational components make it less engaging and less effective for users. In order to overcome these difficulties, this project aims to create a web-based interactive chess system that integrates learning and playing in one system. This system has Play Mode for playing regular chess and Learn Mode for teaching using artificial intelligence components such as legal move checking, contextual hinting, strategic hinting, tactical puzzles, and post-game analysis. The proposed system aims to make learning chess simple, interactive, and effective by utilizing modern web technologies, adaptive AI behavior, and user-centered design.

II. LITERATURE SURVEY

Several studies have highlighted the importance of tactical training in chess improvement.Puzzle learning has been recognized as an effective approach to improve tactical awareness. Various studies have suggested the inclusion of puzzle modules in chess training software to teach users to solve "mate-in-one" or "mate-in-two" puzzles to improve pattern recognition within a time constraint [1] Current implementations are heavily dependent on web technologies such as HTML, CSS, JavaScript, and chess logic libraries such as chess.js for move validation. The inclusion of AI modules such as Stockfish.js makes it easy to analyze decisions in real-time without requiring any installations outside of the browser. Cloud-based data analytics and progress tracking have also been incorporated to offer post-game analysis and performance analysis [2]. In addition, the use of modular design and microservice-based systems makes it easy to scale, maintain, and incorporate new features such as multiplayer functionality or dynamic AI difficulty levels. Such systems improve the efficiency and sustainability of chess learning platforms [3] In general, the current literature shows an increasing fusion of AI, speech interaction, and gamified learning in the design of intelligent chess applications. Nevertheless, a comprehensive web-based platform that integrates real-time AI support, dual learning options, puzzle training, and voice automation is still under-implemented. The proposed system will fill this gap by providing a holistic setting that brings together play, learning, and improvement for chess players of all levels [4][5]

III. METHODOLOGY

The workflow of the system starts from the start point and moves through the following steps as shown in the flowchart:

1. User Authentication:

- The system requests the user to either log in if he or she is a registered user or to register if he or she is a new user.
- If the user is an existing user, he or she logs into the dashboard, but if he or she is a new user, he or she is asked to enter his or her skill level and playing objectives.

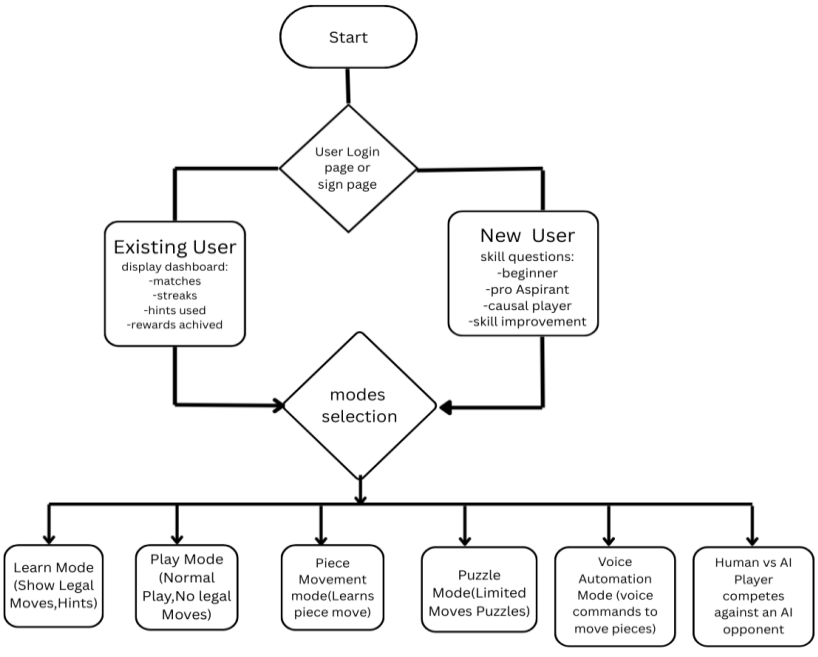

Fig 1: Flowchart

2. Mode Selection:

- After the user has logged in or registered, he or she selects one of the several available operating modes depending on his or her requirements

3.Operational Modes:

- Learn Mode: Shows legal moves and hints for players to learn game concepts and enhance strategies

- Play Mode: Provides normal play with minimal hints and no move support for a realistic playing experience

- Piece Movement Mode: Teaches players how different chess pieces move, ideal for beginners

- Puzzle Mode: Offers move-limited puzzles for tactical training and problem-solving skills

- Voice Automation Mode: Allows players to control the game using voice commands, adding innovation to the playing experience

- Human vs AI Mode: allows users to play chess against an intelligent computer opponent with adjustable difficulty levels, enabling them to practice at their own pace while improving strategic thinking and decision-making skills.

System Features :

The proposed system will have the following key features:

User Management

- Secure login and registration system.

- Personalized dashboard for registered users displaying matches, streaks, and rewards.

Skill-Based Customization

- Option for new users to choose their level of experience (beginner, intermediate, advanced).

- Adaptive interface that adjusts difficulty and functionality based on the chosen level of experience.

Multiple Interactive Modes

- Learning, playing, and puzzle-solving functionalities to suit different user intentions.

- Voice-assisted mode for enhanced interactivity.

AI Assistance & Guidance

- Offers hints, legal move suggestions, and feedback to assist learning.

Performance Tracking

- User statistics such as win percentage, streaks, and puzzle performance tracked.

User-Friendly Interface

- Simple and elegant design to ensure an intuitive interface for all types of users.

Gamification & Rewards System

- Users earn coins, badges, and trophies based on their performance.

- Daily challenges and achievements to encourage continuous learning.

- Unlockable board themes or pieces to increase engagement.

Accessibility & Cross-Platform Support

- Support for mobile, tablet, and desktop platforms with synchronized user progress.

IV. Accessibility features such as high contrast themes and adjustable visuals.

V. IMPLEMENTATION DETAILS AND EXPERIMENTAL RESULTS.

A. Implementation Detail

The system is developed as an interactive web-based chess learning platform that incorporates secure user login functionality, skill-level training, automated gameplay, real-time move detection, and multiple user interaction methods. A Login and Sign-Up feature allows users to register and log in to access their own personalized profile pages where progress, performance metrics, unlocked levels of difficulty, and completed puzzle history are recorded. A single rules engine controls all gameplay features, such as move validation, turn management, piece movement, and special rules like castling, promotion, and In passant, to maintain consistency across all gameplay modes. The system features guided learning through an adaptive training module developed for novice and intermediate users. Legal moves are graphically indicated, illegal moves are prevented, and activities are sequenced based on the user's skill level. The user interface is designed based on human-computer interaction guidelines, incorporating a dynamic 8x8 chessboard with graphical indicators such as highlights, animations, and overlays to indicate legal moves, move history, puzzle solutions, and system feedback. Users can engage in Human vs Human or Human vs AI gameplay modes, in which the AI uses heuristic-based or depth-limited decision-making algorithms. In the Human vs AI game mode, various levels of difficulty are offered, from beginner to expert, with each level unlocked only after successfully completing or winning at the previous level. This ensures a structured approach to skill building and prevents users from progressing too quickly. The system also has a puzzle component that involves tactical puzzles like "mate in 1" and "mate in 2," and a voice-assisted interaction component that enables users to command the movement of pieces using voice commands. As a completely web-based system, it can be accessed on any device without the need for installation, providing seamless access while providing a holistic and engaging learning experience for chess. Apart from these, Firebase Authentication has been used for secure user login and management, and Firebase Firestore has been employed for storing user profiles, progress, game statistics, and puzzle solutions. Firebase Hosting has been used to provide reliable hosting for the web application, ensuring rapid access and real-time synchronization of data across devices.

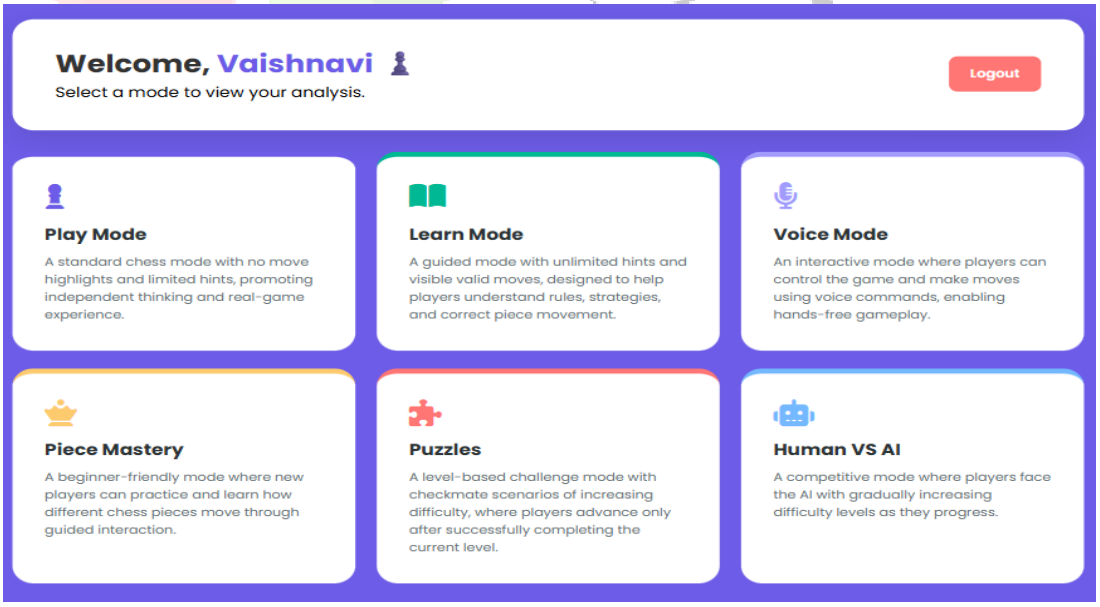

Fig 2: Interface showing mode selection for the chess learning system

This figure 2 allows users to choose different chess modes for learning, practice, and gameplay from a single dashboard

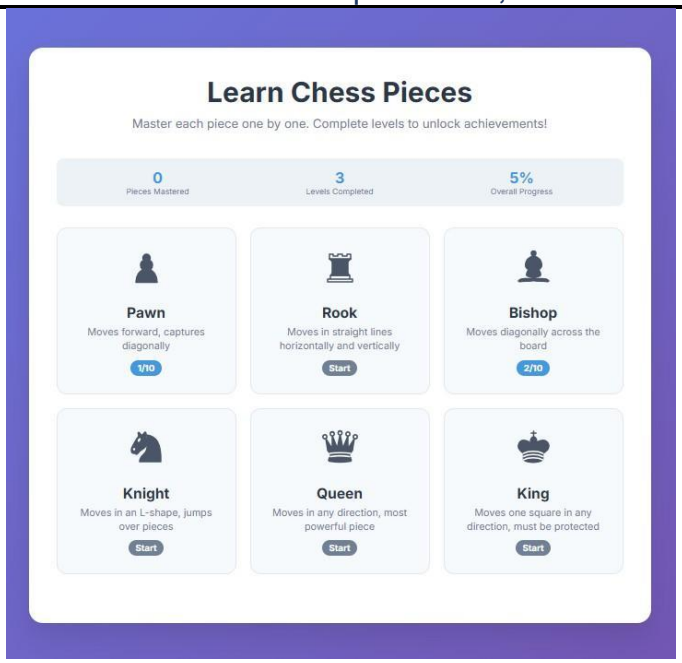

Fig 3: Piece Movement (Interface showing chess-piece movement tutorial.)

This figure 3 shows the learning module where each chess piece is shown along with the rules of its movement, making it easy for learners to grasp the rules of movement of each piece in a simple and clear manner

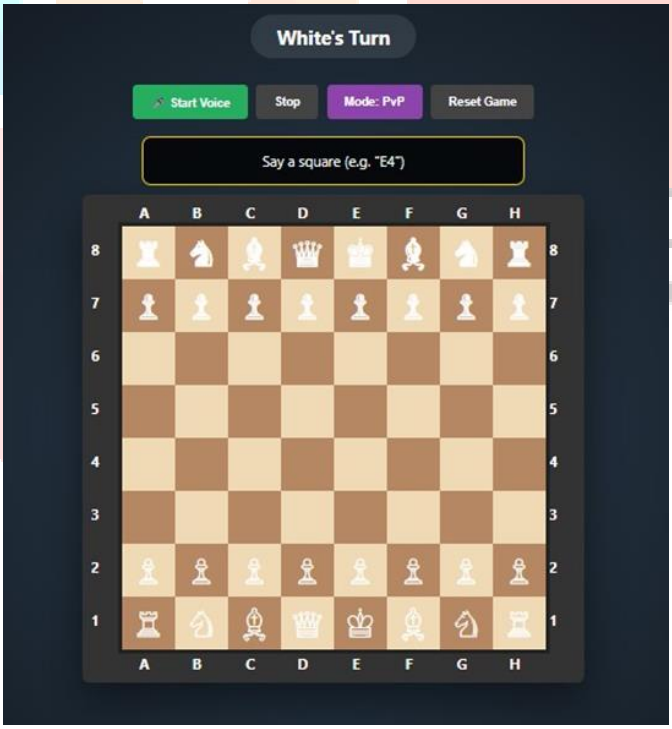

Fig 4: Interface displaying chess game with voice-command Input

The figure 4 shows the chess game interface with voice command functionality, which includes buttons for starting and stopping voice commands, speaking commands, and a digital chessboard for carrying out commands using speech

B. Experimental Results

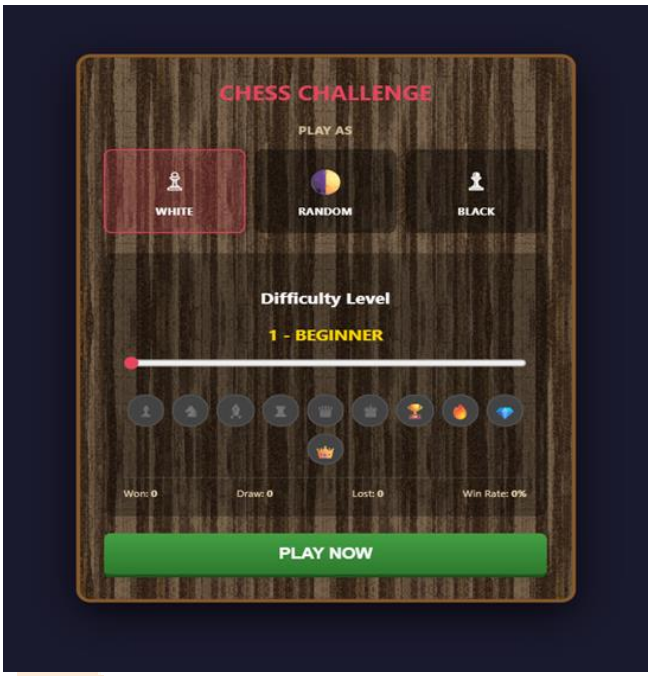

Fig 5: Human Vs AI Interface

Figure 5 illustrates the screen where players select the difficulty level of the AI, with new levels opening up as they progress, and where players can easily start a Human vs AI game.

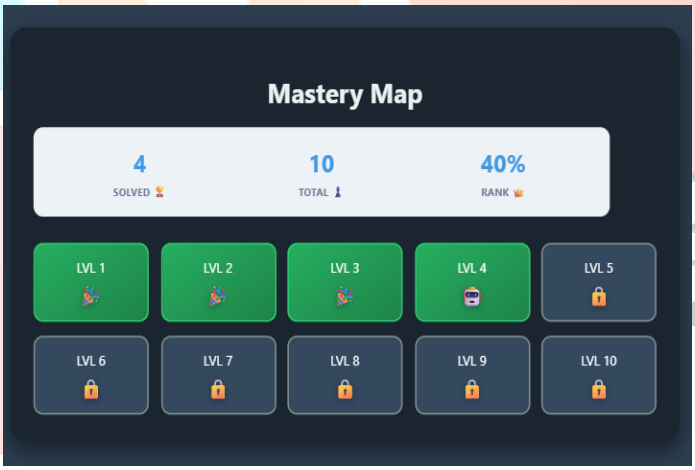

Fig 6: Mastery Map

The figure 6 shows Mastery Map/Puzzle Mode provides move-limited chess puzzles focused on tactical situations such as checkmate, forks, pins, and sacrifices. Players must find the best move within a limited number of attempts. This mode improves problem-solving skills, pattern recognition, and tactical awareness. It encourages logical thinking and strategic planning.

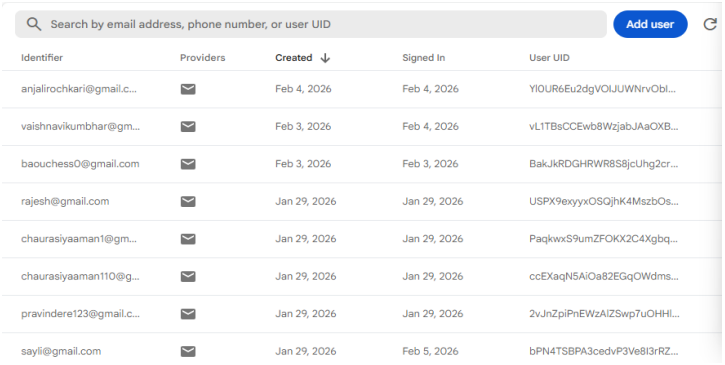

Fig 7:User Authentication & Management

In this figure 7 the system successfully supports secure multi-user registration and login using Firebase Authentication. Each user is assigned a unique UID, enabling safe and personalized data storage and access.

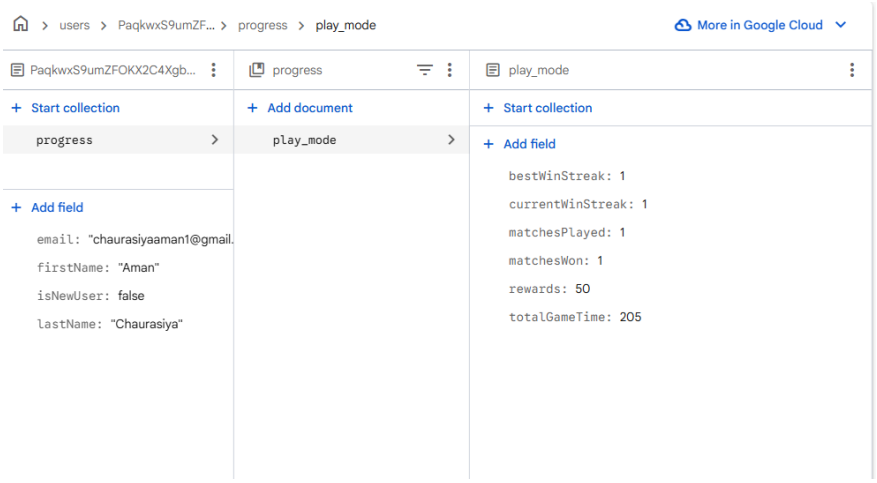

Fig 8: Gameplay Data & Progress Tracking

The figure 8 shows the Smart Chessboard effectively stores and updates individual gameplay statistics in Firestore, allowing accurate tracking of performance, rewards, and player progress over time.

VI. CONCLUSION

The proposed chess learning and playing platform provides a novel and useful approach to enhancing chess learning by integrating artificial intelligence, voice interaction, and web technology. Unlike other chess applications that only work as simple chess games, the proposed system is designed to work in both Learn Mode and Play Mode. In Learn Mode, users are assisted by useful AI suggestions, move guidance, and voice assistance, making it easier for users to learn the rules and strategies of playing chess. On the other hand, Play Mode simulates a real game environment where users have to think on their own without any assistance, thus helping them improve their decision-making and playing skills over time. Neuroplasticity is the brain's capacity to rewire and adapt itself by creating new connections throughout life. This is especially important during childhood, when the brain is undergoing synaptic pruning and myelination. Studies have shown that environmental stimulation and learning have a direct effect on cortical thickness and dendritic branching. Moreover, studies using functional magnetic resonance imaging have shown that the adult brain also has a high degree of neuroplasticity, which helps the brain compensate for injuries and learn new skills. The implications of neuroplasticity are far-reaching and have many applications in the field of educational psychology and rehabilitation medicine.

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