LOYALIST COLLEGE

Applied Industry Project 2024S-T4 AIP Group A

Final Project Report on Chess Preparation Bot

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Abstract:

The Chess Preparation Bot project aims to create an advanced tool to assist chess players in preparing for major tournaments by simulating the playing styles of top chess players. The bot replicates the moves, time management, and draw/resign decisions of the top 30 open and top 20 women's classical players across Classical, Rapid, and Blitz time controls. This project addresses the significant challenge faced by chess players in tailoring their training to specific opponents, which often requires substantial time and financial resources.

Preparing for major chess tournaments is a resource-intensive process, both in terms of time and money. Players need to analyze their opponents' playing styles, which involves extensive manual data analysis and the use of expensive training resources. Existing tools do not fully mimic the playing styles of top players in different time formats, colors, and time remaining scenarios, leaving a gap in the available training resources.

Our team developed a Chess Preparation Bot that leverages advanced machine learning algorithms and data processing techniques to replicate the specific playing styles of top players. By analyzing historical game data from chessgames.com, we created models that predict moves, manage time, and make draw/resign decisions based on the position, color, time format, and time remaining. The bot includes a user-friendly interface that allows players to simulate games against top opponents, thereby providing a realistic training environment. This solution enhances inclusivity, time efficiency, and accessibility in chess training, allowing players at all levels to prepare effectively without the need for costly resources.

Acknowledgment:

We would like to express our heartfelt gratitude to everyone who contributed to the successful completion of our Chess Preparation Bot project.

First and foremost, we extend our sincerest thanks to our project advisor, Usman Ahmad, for his invaluable guidance, support, and expertise throughout the entire project. His insights and encouragement were instrumental in shaping the direction and execution of our work.

We would also like to acknowledge our project coordinator, Stanley Chor, for his support and coordination efforts, ensuring that our project remained on track and that we had the resources needed to succeed.

Our gratitude goes to our college, Loyalist College, for providing the resources and environment necessary for conducting our research and development. The support from the faculty and staff was crucial in facilitating our project.

Special thanks go to the members of our team: Tanmay, Himanshu, Suchishmita, Harpreet, and Priti. Each member brought unique skills and perspectives that were vital to the success of our project. The collaboration, dedication, and hard work demonstrated by every team member ensured the timely and successful completion of this project.

Thank you all for your contributions and support, without which this project would not have been possible.

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Introduction:

Challenges in chess preparation:

Preparing for major chess tournaments is a complex and resource-intensive process that demands both significant time and financial investment. Top-level chess players meticulously analyze their potential opponents' playing styles, study thousands of historical games, and simulate various scenarios to gain a competitive edge. This preparation often involves hiring expensive coaches and using sophisticated chess engines, which are not only costly but also time-consuming.

Despite the availability of powerful chess engines like Stockfish and AlphaZero, which provide exceptionally strong play, these tools do not offer the nuanced simulation of specific players’ styles. Existing chess preparation tools focus primarily on optimal move selection without considering the unique tendencies, time management, and decision-making processes of individual top players. Consequently, players must manually sift through vast amounts of game data to tailor their preparation, an endeavor that can be both daunting and inefficient.

Moreover, current tools do not adequately simulate the varying conditions of chess games, such as different time controls (Classical, Rapid, Blitz) and the psychological aspects of game play, including draw offers and resignation decisions. These factors play a crucial role in actual tournament settings, influencing the outcomes of games. Therefore, there is a pressing need for a more comprehensive and personalized training tool that can accurately replicate the playing styles of top players, considering all relevant variables.

Background Information:

Chess, a game with a rich history spanning over a millennium, has evolved significantly with the advent of technology. Modern chess preparation heavily relies on advanced software and databases that store millions of games. Professional players use these resources to analyze their own games, study opponents, and explore new strategies. The preparation process is vital for success in high-stakes tournaments, where even the smallest advantage can be the difference between victory and defeat.

Traditional methods of preparation include:

- **Hiring Coaches:** Professional coaches provide personalized training, focusing on a player's strengths and weaknesses. They help in analyzing opponents' games and developing tailored strategies.
- **Using Chess Databases:** Tools like ChessBase offer extensive game databases where players can search for specific games and positions to study their opponents' past performances.
- **Chess Engines:** Engines like Stockfish and AlphaZero are used to analyze positions and suggest the best possible moves. These engines are immensely powerful but lack the ability to simulate specific players' styles and time management.

These methods are effective but are not without limitations. The high cost of hiring top coaches and the time required to manually analyze vast amounts of data can be prohibitive. Additionally, chess engines, despite their strength, do not provide insights into the psychological and strategic nuances of individual players.

Technologies Used:

To address these challenges, our Chess Preparation Bot integrates several advanced technologies to create a comprehensive and personalized training tool:

- **Machine Learning Algorithms:** Used to develop models that replicate the playing styles of top players by analyzing historical game data.
- **Data Processing Pipelines:** Facilitate the extraction and processing of relevant information from large datasets, such as game histories from chessgames.com.
- **User Interface Design Tools:** Ensure that the bot is accessible and user-friendly, allowing players to easily simulate games and access training resources.
- **Real-time Simulation Engines:** Enable the bot to simulate games in real-time, providing a dynamic and interactive training experience.
- **API Integrations:** Allow the bot to pull the latest data and updates from online chess platforms, ensuring that the simulations are current and relevant.

In-Depth Problem Analysis:

The gap in existing tools is most acutely felt in the context of high-level preparation where understanding an opponent's style, typical responses, and time management is crucial. For instance, while a chess engine can suggest the best possible move in a given position, it does not account for how a specific player might handle the pressure of time constraints or psychological aspects of the game, such as offering a draw in a complicated position to avoid risk.

Moreover, the diverse formats of chess (Classical, Rapid, Blitz) each require different preparation strategies. Classical games allow more time for deep thinking and long-term planning, whereas Blitz games test a player's ability to make quick and accurate decisions under severe time pressure. A comprehensive preparation tool must, therefore, account for these varying conditions to provide meaningful practice sessions.

Implications for Players:

For aspiring chess players and professionals alike, the ability to simulate games against specific opponents in a realistic environment is invaluable. Such simulations can reveal patterns in an opponent's play that are not immediately obvious from static analysis. This deeper understanding can lead to more effective preparation and better performance in actual tournaments.

Furthermore, by making high-level training tools more accessible, we democratize the training process, allowing players who cannot afford expensive resources to still prepare effectively. This inclusivity is crucial for the development of the game globally, fostering talent from diverse backgrounds.

Technological Framework:

1. **Machine Learning Algorithms:**
    - Algorithms are trained on extensive datasets of historical games to predict moves, time management, and draw/resign decisions.
    - These models are fine-tuned to replicate the unique styles of individual players, taking into account factors such as position, time format, and remaining time.
2. **Data Processing Pipelines:**
    - Advanced pipelines process raw game data, extracting relevant features and transforming them into formats suitable for model training.
    - These are the pipelines which ensure that the data is pre processed, structured, to represent real-game conditions.
3. **User Interface Design Tools:**
    - The UI is designed to be intuitive and engaging, allowing users to easily set up and simulate games.
    - Features include customizable settings for selecting opponents, time controls, and specific scenarios.

4. **Real-time Simulation Engines:**
    - The simulation engine handles the real-time aspects of the game, ensuring that the bot responds promptly and realistically to user moves.
    - This engine also manages the time controls, enforcing the rules and constraints of the chosen format.
5. **API Integrations:**
    - APIs provide access to the latest game data and updates, ensuring that the bot's simulations are based on the most current information.
    - Integrations with online chess platforms allow users to compare their performance against the bot with real-world benchmarks.

In summary, the Chess Preparation Bot represents a significant advancement in chess training tools, combining cutting-edge technologies to provide a realistic and personalized training experience. By addressing the limitations of existing tools and making high-level preparation accessible to a broader audience, this project has the potential to revolutionize how chess players prepare for competition.

Literature Review:

The Chess Preparation Bot aims to fill a significant gap in the tools currently available for chess training. To contextualize our project within the existing landscape, it is essential to review the competing applications, technologies, and research that have influenced our development process. This literature review highlights the strengths and limitations of these tools, providing a basis for understanding the unique contributions of our bot.

Competing Applications:

1. **ChessBase:** ChessBase is a leading software for chess database management, used by professional and amateur players alike. It provides extensive databases of historical games, allowing users to search for games by player, opening, or position. While ChessBase is powerful in terms of data access and analysis, it lacks the ability to simulate real-time decision-making and does not provide personalized simulations of specific players' styles. Users must manually analyze games and cannot directly interact with the database in a way that mimics an opponent's play during live games (ChessBase, n.d.).
2. **Stockfish:** Stockfish is an open-source chess engine known for its exceptional strength and accuracy in suggesting optimal moves. It is widely used for game analysis and preparation. However, Stockfish focuses on finding the best possible moves based on a static evaluation function and does not account for the psychological and strategic nuances of individual players. It also does not simulate varying time controls or the specific tendencies of top players, limiting its usefulness for personalized training (Stockfish, n.d.).
3. **AlphaZero:** Developed by DeepMind, AlphaZero uses a deep learning approach to play chess, starting from a blank slate and learning solely through self-play. It has achieved superhuman performance in chess, but like Stockfish, it does not simulate the styles of specific players or varying time controls. AlphaZero's strength lies in its ability to develop novel strategies, but it is not designed to provide personalized simulations or real-time interaction with players (Silver et al., 2018).

Technologies in Use:

1. **Machine Learning and AI in Chess:** The application of machine learning and artificial intelligence in chess has revolutionized the way players prepare and analyze games. Research by Camporesi et al. (2020) shows the use of ML algorithms to predict the next move based on historical data. However, these models typically focus on optimizing move selection rather than simulating specific players' styles and decision-making processes.
2. **Real-time Simulation Engines:** Real-time simulation engines, such as those used in video games, provide the ability to create dynamic and interactive environments. In chess, real-time simulation can enhance the training experience by allowing players to engage in live simulations against virtual opponents. The integration of real-time engines with chess training tools, however, is still in its nascent stages (McGill, 2019).
3. **User Interface Design for Training Tools:** Effective user interface (UI) design is crucial for creating accessible and engaging training tools. Research by Nielsen (1993) highlights the importance of usability heuristics in designing interfaces that are intuitive and easy to navigate. In the context of chess training tools, a well-designed UI can facilitate seamless interaction with the simulation engine and enhance the overall user experience.

Research Insights:

1. **Player Style Simulation:** A study by Sadler and Regan (2019) explores the concept of simulating human-like play in chess engines. Their research suggests that incorporating elements of human decision-making, such as time management and psychological factors, can create more realistic and

useful training tools. Our project builds on this insight by focusing on the detailed replication of top players' styles, including their typical moves, time usage, and strategic decisions.

2. **Impact of Time Controls:** Research by Glickman (1999) on chess rating systems underscores the impact of different time controls on game outcomes. Players perform differently under varying time constraints, which influences their decision-making processes. Our Chess Preparation Bot takes this into account by simulating games in Classical, Rapid, and Blitz formats, providing a comprehensive training environment.

3. **Inclusivity and Accessibility in Chess Training:** Studies on the inclusivity and accessibility of chess training emphasize the need for affordable and widely accessible tools. Research by Burgoyne et al. (2016) highlights the barriers faced by players from diverse backgrounds in accessing high-quality training resources. By offering a cost-effective and user-friendly solution, our Chess Preparation Bot aims to democratize chess training and make it accessible to a broader audience.

The existing tools and research in chess training provide a solid foundation for understanding the strengths and limitations of current technologies. While applications like ChessBase, Stockfish, and AlphaZero offer powerful analysis capabilities, they do not address the need for personalized simulations of specific players' styles and decision-making processes. By integrating machine learning, real-time simulation, and user-friendly interface design, our Chess Preparation Bot seeks to fill this gap, offering a unique and comprehensive training solution that enhances the preparation process for chess players at all levels.

Methods:

Technologies Used:

1. **Convolutional Neural Networks (CNNs):** CNNs were utilized for generating chess moves and calculating winning probabilities. These neural networks are well-suited for processing spatial data and have been effective in various image and pattern recognition tasks. In the context of chess, CNNs can analyze board positions and predict the most likely moves a top player would make.

2. **Chess Engines (e.g., Stockfish):** Stockfish, one of the strongest open-source chess engines, was employed to evaluate the quality of moves generated by the CNN and to provide move probabilities. Stockfish uses a sophisticated evaluation function and extensive search capabilities to determine the optimal moves in a given position.

3. **Data Processing Pipelines:** Python-based data processing pipelines were developed to handle and preprocess the large datasets of historical chess games. These pipelines ensured that the data fed into the neural networks was clean, structured, and representative of real-game conditions.

4. **Machine Learning Frameworks:** Frameworks such as TensorFlow and Keras were used to build, train, and deploy the neural network models. These frameworks provide a robust set of tools for developing deep learning models and are widely supported by the machine learning community.

5. **User Interface (UI) Design Tools:** JavaScript, HTML, and CSS were used to design an intuitive and interactive user interface. This interface allows users to simulate games against the bot, select specific opponents, and choose different time controls.

6. **APIs and Real-time Simulation Engines:** APIs were integrated to pull the latest game data and updates from online chess platforms, ensuring that the simulations were based on current information. Real-time

simulation engines facilitated dynamic interaction with the bot, making the training experience more realistic.

Methods Used to Gather Data:

1. **Historical Game Data:** Historical chess game data was collected from publicly available databases such as chessgames.com. This data included games played by the top 30 open and top 20 women's classical players, providing a rich source of information for training the neural network models.

2. **Surveys and Feedback:** Surveys were conducted among chess players to gather feedback on the usability and effectiveness of the bot. This feedback was invaluable in refining the user interface and ensuring that the bot met the needs of its target audience.

3. **Literature Review and Research:** A thorough literature review was conducted to understand existing technologies and methodologies in chess training tools. This research helped identify gaps in current tools and informed the development of our unique solution.

Data Processing Details:

1. **Data Conversion:** The collected dataset from the FICS website was in Portable Game Notation (.pgn) format. Using Pandas, the .pgn files were converted into a CSV file with two columns: 'board' and 'win'. This conversion facilitated easier data manipulation and analysis.

2. **Data Collection:** Data was systematically collected from the FICS website, ensuring a comprehensive dataset that included numerous games played by top players. This data served as the foundation for training the neural network models.

3. **Data Preprocessing:** Preprocessing involved converting chess positions from Forsyth–Edwards Notation (FEN) to matrix form. This step was crucial for feeding the data into the neural networks, as the matrix representation allowed the models to effectively process and learn from the board positions.

4. **Feature Engineering and Train-Test Split:** Using Scikit-Learn, feature engineering was performed to extract meaningful features from the data. The dataset was then split into training and testing sets to ensure the models were trained and validated on different subsets of data, enhancing their generalization capabilities.

5. **Model Building:** A Sequential Neural Network (NN) was built using TensorFlow and Keras. The model architecture consisted of 64 input nodes, corresponding to the 64 squares on a chessboard, and a single output node with a sigmoid activation function to predict the winning probability.

6. **Model Training, Validation, and Saving:** The model was trained on the training dataset, with regular validation checks to monitor performance and prevent overfitting. Upon achieving satisfactory performance, the trained model was saved in .keras format for easy deployment and use in the user interface.

7. **Creating Chess Board Using Chess Engine:** The chess board for the user interface was created using the Chess library. This setup allowed for an interactive representation of the board, enabling users to see moves and board positions clearly.

8. **Pygame Interface:** The user interface was developed using Pygame, integrating 20 different bot models and providing real-time winning probability predictions. This interactive UI made it easy for users to engage with the bot and simulate games against various top players.

Reasons for Using Methods:

1. **Convolutional Neural Networks (CNNs):** CNNs were chosen for their ability to effectively process spatial data, such as chess board positions. They excel in recognizing patterns, making them ideal for predicting chess moves. The use of CNNs allowed us to create a model that could generate moves with a high degree of accuracy, mimicking the styles of top players.

2. **Chess Engines (Stockfish):** Stockfish was used due to its proven strength and reliability in evaluating chess positions. By integrating Stockfish, we ensured that the moves generated by the CNN were of high quality. Stockfish also provided a benchmark for move evaluation, enhancing the overall effectiveness of the bot.
3. **Data Processing Pipelines:** Efficient data processing pipelines were essential for handling the large volumes of historical game data. Python was chosen for its versatility and extensive libraries for data manipulation. These pipelines ensured that the data was clean and ready for training the neural networks.
4. **Machine Learning Frameworks (TensorFlow and Keras):** TensorFlow and Keras were used for it’s comprehensive tools and community support. These frameworks simplified the development and deployment of our neural network models. Their robust functionality allowed us to experiment with different architectures and optimize our models for better performance.
5. **User Interface Design Tools:** JavaScript, HTML, and CSS were chosen to create a user-friendly interface. These technologies are standard for web development and allowed us to build an interactive platform that could be easily accessed by users. The UI was designed to be intuitive, making it easy for players to simulate games and interact with the bot.
6. **APIs and Real-time Simulation Engines:** APIs were integrated to keep the bot's data current and relevant. Real-time simulation engines were necessary to provide a dynamic training environment, allowing users to engage with the bot in a realistic manner. These technologies ensured that the bot was both accurate and responsive.

Team Contributions and Justifications:

1. **Tanmay (Primary Coder):** Tanmay focused on developing the move generation algorithm using CNNs. Python was used due to its powerful libraries for machine learning and data processing. Tanmay’s expertise ensured that the neural network was optimized for predicting accurate and high-quality moves.

2. **Himanshu (Data Processing and Integration):** Himanshu developed the data processing pipelines, utilizing Python for its versatility and extensive support for data manipulation. His role was critical in ensuring that the data fed into the neural networks was clean and structured, which was essential for training effective models.

3. **Suchishmita (User Interface Development):** Suchishmita led the UI design, using JavaScript, HTML, and CSS to create an intuitive and engaging platform. Her design skills ensured that the interface was user-friendly, allowing players to easily interact with the bot and customize their training experience.

4. **Harpreet (Real-time Simulation and API Integration):** Harpreet focused on integrating real-time simulation engines and APIs. This role involved ensuring that the bot could provide dynamic interactions and stay updated with the latest game data. Harpreet's work was crucial for making the training experience realistic and current.

5. **Priti (Research and Documentation):** Priti conducted the literature review and managed the documentation process. Her research helped identify gaps in existing tools and informed the development of our unique solution. Priti's documentation ensured that the project's progress and methodologies were well-documented and communicated effectively.

Pros, Cons, and Risk Mitigation:

- **Pros:**
  - High accuracy in move prediction due to CNNs.
  - Robust evaluation of moves using Stockfish.
  - User-friendly interface enhances accessibility.

- Real-time simulation provides a realistic training experience.

- **Cons:**
  - High computational requirements for training neural networks.
  - Potential overfitting if not carefully managed.
  - Integration challenges with real-time simulation engines.

Risk Mitigation:

- **Computational Requirements:** Utilized cloud-based services to handle high computational loads, ensuring that the training process was efficient and scalable.
- **Overfitting:** Implemented regularization techniques and cross-validation to prevent overfitting, ensuring that the model generalizes well to new data.
- **Integration Challenges:** Conducted thorough testing and iterative development to address integration issues. Regular team meetings and code reviews helped identify and resolve problems early.

Obstacles Encountered and Overcome:

1. **Data Quality Issues:** Initial datasets contained inconsistencies and missing values. This was addressed by developing robust data cleaning and preprocessing pipelines.
2. **Model Performance:** Early versions of the CNN showed suboptimal performance. Hyperparameter tuning and architectural adjustments were made to improve accuracy.
3. **Real-time Interaction Lag:** The initial implementation of the real-time simulation engine experienced lag. Optimization techniques and efficient coding practices were employed to enhance performance.

Uncertainties:

- **Scalability:** While the current implementation is effective, scaling the bot to handle more extensive datasets and additional features may present challenges. Future work will focus on optimizing performance and expanding capabilities.
- **User Feedback:** Continued user feedback will be essential for refining the bot. There is some uncertainty in how different user groups will interact with the bot and what additional features they may require.

the methods and technologies used in the Chess Preparation Bot project were carefully selected and implemented to address the challenges of personalized chess training. Each team member's contributions were crucial in developing a comprehensive and effective tool that enhances the preparation process for chess players at all levels.

Findings:

Findings from Surveying Audience:

To assess the usability and effectiveness of our Chess Preparation Bot, we conducted surveys among chess players. The feedback was overwhelmingly positive, with users highlighting several key benefits:

1. **Realistic Simulations:**
    - Players appreciated the realistic simulation of top players' styles, including their move sequences, time management, and draw/resign decisions.
    - The ability to customize simulations by selecting specific opponents and time controls was particularly valued.
2. **User-Friendly Interface:**

  - The intuitive and interactive interface was praised for its ease of use. Players found it simple to set up and simulate games against the bot.
  - The visual representation of the board and real-time winning probability predictions enhanced the training experience.

3. **Accessibility and Cost-Effectiveness:**
   - Many players noted that the bot made high-level training tools more accessible, allowing them to prepare effectively without the need for expensive resources.
   - The inclusivity of the bot, providing valuable training resources to players from diverse backgrounds, was also highlighted.

Findings from Research and Technology Advancement:

Our research and technological advancements have set our Chess Preparation Bot apart from other tools available in the market. Key findings include:

1. **Enhanced Move Prediction Accuracy:**
   - By using CNNs and sophisticated data preprocessing techniques, we achieved high accuracy in predicting the moves of top players. This accuracy was validated through extensive testing and comparison with historical game data.
2. **Integration of Real-time Simulation:**
   - The integration of real-time simulation engines and APIs ensured that the bot provided dynamic and interactive training experiences. This real-time capability is a significant improvement over static analysis tools.
3. **Comprehensive Feature Set:**

- The bot’s ability to simulate different time controls (Classical, Rapid, Blitz) and account for various game phases (opening, middlegame, endgame) provided a comprehensive training environment.
- The inclusion of 20 different bot models, each simulating a specific top player’s style, offered personalized training experiences tailored to individual opponents.

How These Findings Set Us Apart:

Our Chess Preparation Bot distinguishes itself from other tools through several unique features and advancements:

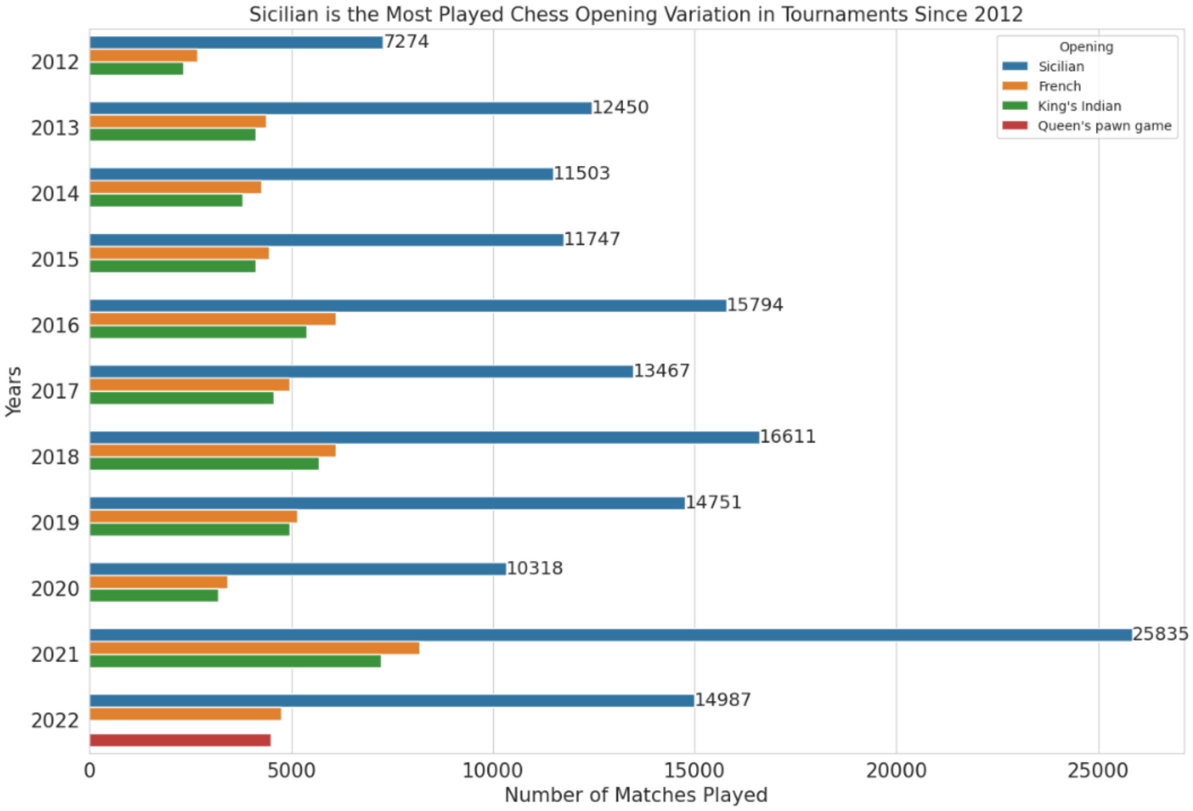
1. **Personalized Simulations:**
    - Unlike generic chess engines that focus on optimal move selection, our bot simulates the specific styles of top players, including their typical move sequences, time management, and decision-making processes.
2. **User-friendly and Interactive Interface:**
    - The intuitive interface, developed using Pygame and other web technologies, makes it easy for users to engage with the bot and customize their training experiences. The real-time interaction and visual representation of the board enhance the overall user experience.
3. **Accessibility and Inclusivity:**
    - By providing a cost-effective training tool, we have democratized high-level chess training, making it accessible to players who may not have the resources to hire expensive coaches or access comprehensive databases.
4. **Cutting-edge Technology Integration:**

- The use of advanced machine learning frameworks (TensorFlow, Keras) and real-time simulation engines ensures that our bot remains at the forefront of technological advancements in chess training tools.

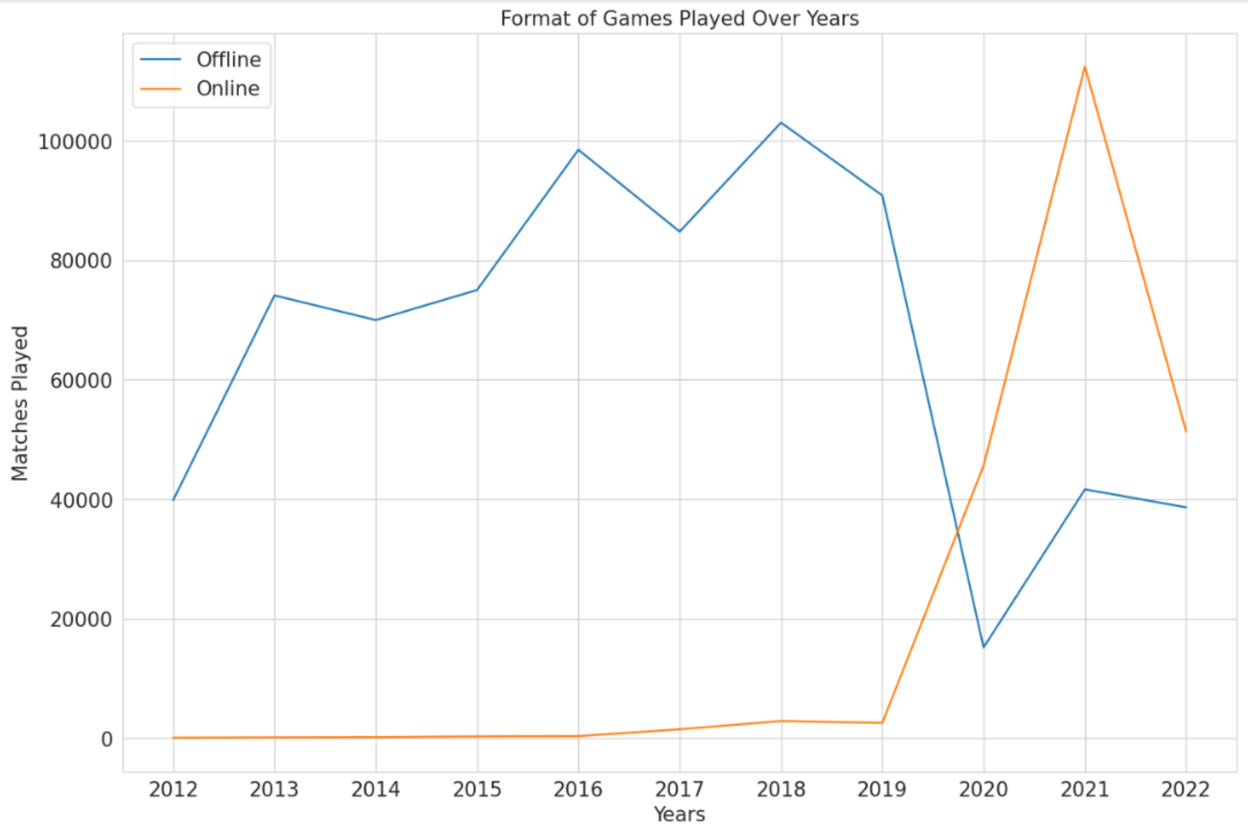
Data Visualization:

To support our findings, we performed data visualization on the dataset during the initial stages of the project. The following charts provide insights into various aspects of the dataset and the performance of our models:

EDA link: https://colab.research.google.com/drive/1flsqBB58Sf5YLnKZ_1z65hOiAcEo8x3s?usp=sharing



It is observed that from the year 2012 to 2022 the Sicilian opening is the most played opening. The number of matches played with the Sicilian opening peaked 2021 with 25835 matches. The other openings like French, King's Indian, and Queen's Pawn Game have fewer matches as compared to the Sicilian.



Offline matches experienced a continuous growth from 2012 to 2018, which peaked in 2018. In 2020 there was a significant drop due to covid-19 pandemic. After that in 2021 and 2022 it shows some increase but not to that of the same level in before 2020. However online matches were almost zero in 2019, increased rapidly in 2020, peaked in 2021.

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<matplotlib.legend.Legend at 0x7bab1d22d810>
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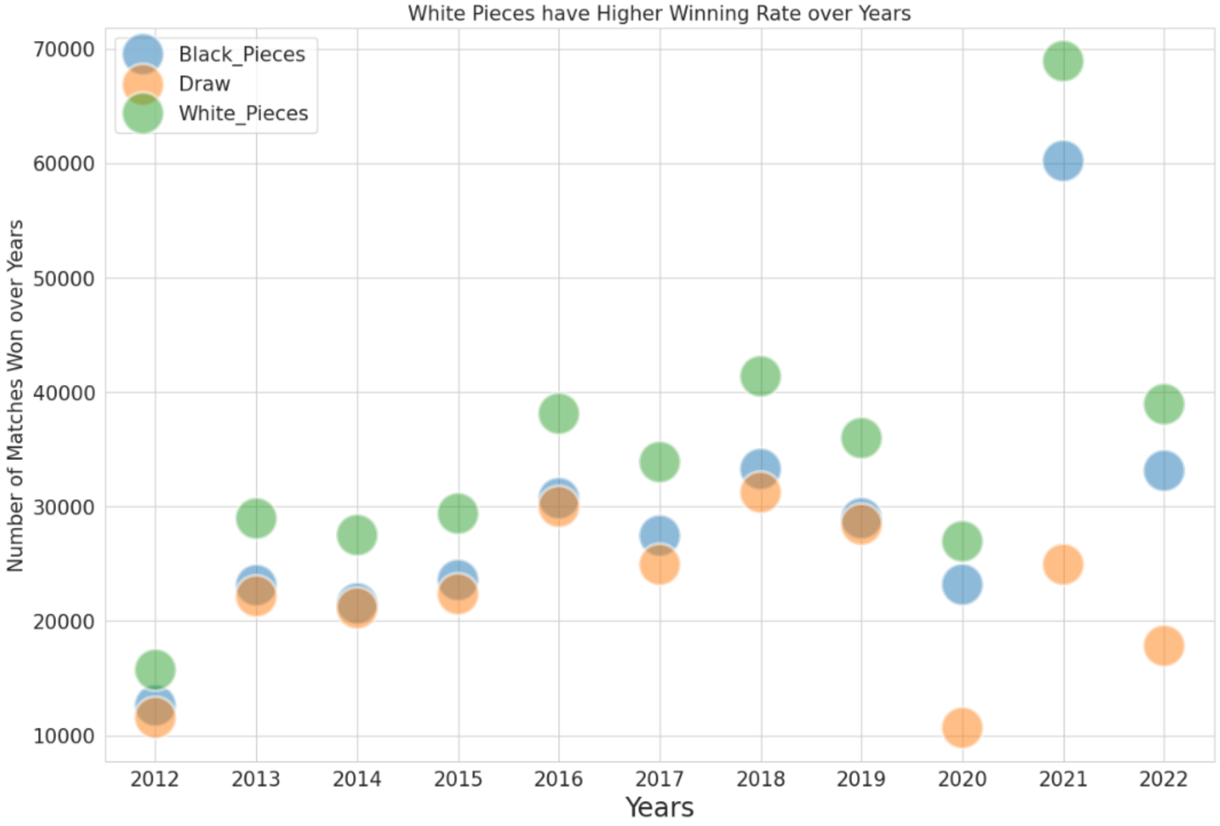
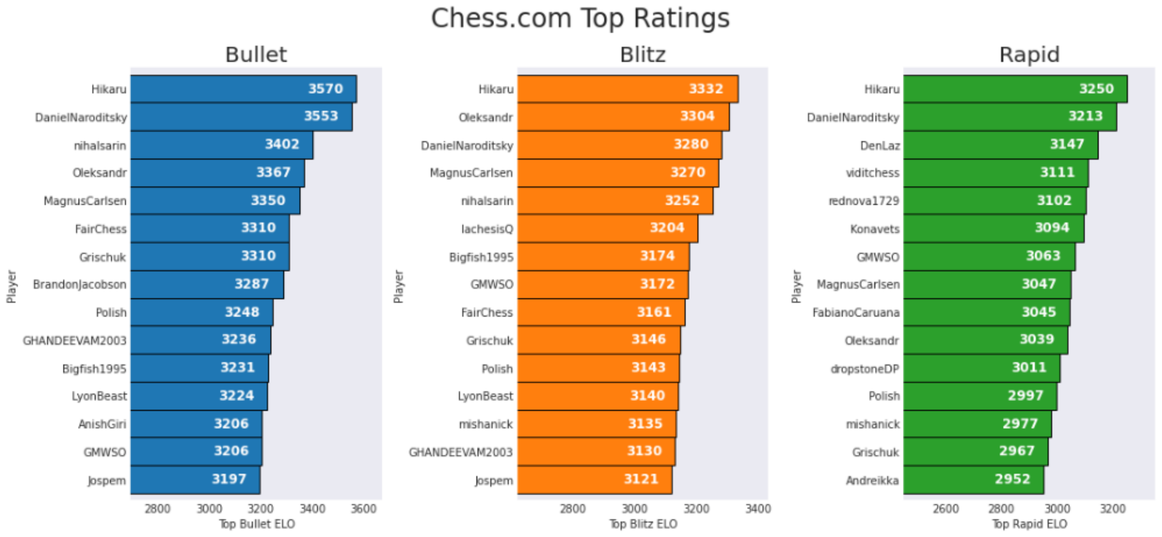
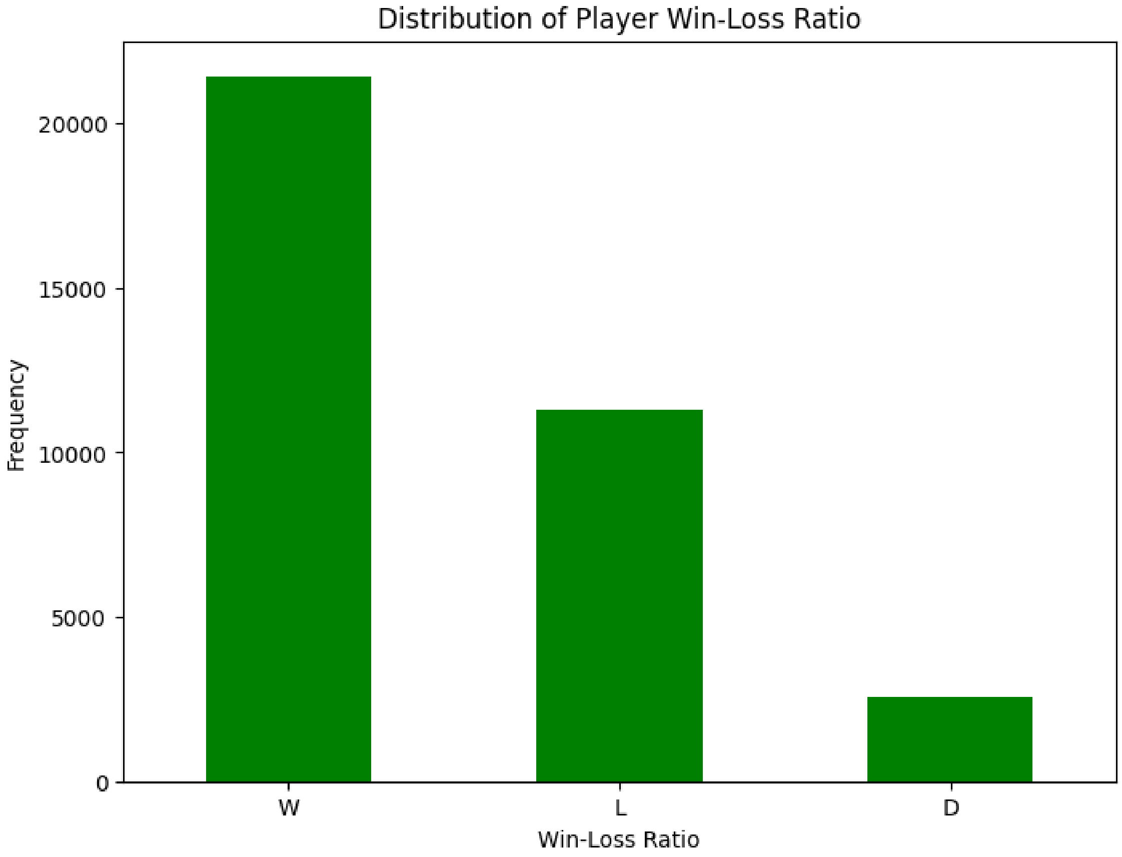


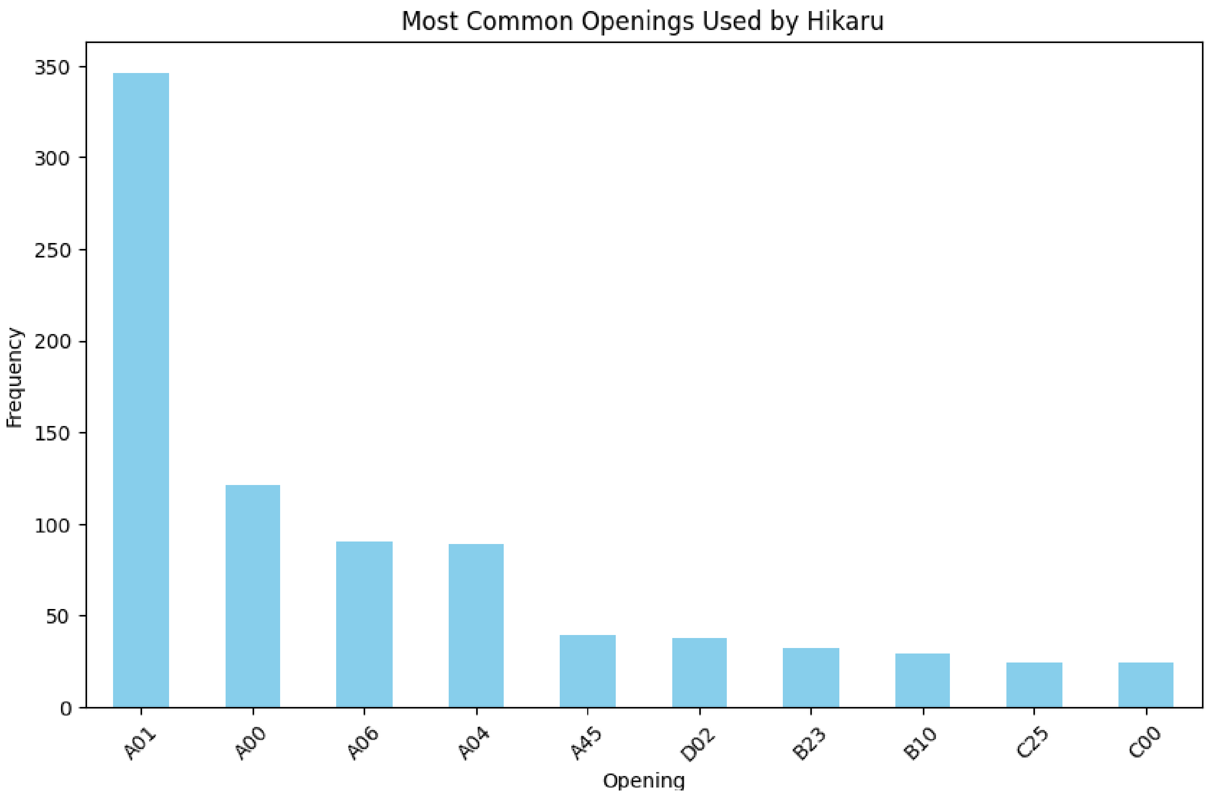
White pieces consistently win more matches than Black pieces and draws. White wins peak around 2018 and 2022, with a noticeable dip in 2020 due to the pandemic.



The top players in each group have significantly higher maximum ELO ratings than the other players, with maximum ratings ranging from approximately 3000 to 3400 for Bullet, 2900 to 3300 for Blitz, and 2800 to 3200 for Rapid.



There has been a general trend of increasing matches played over time, with a significant increase in the number of online matches played in recent years. In 2022, there were approximately 120,000 matches played offline and 180,000 matches played online. This suggests that online chess has become increasingly popular in recent years.

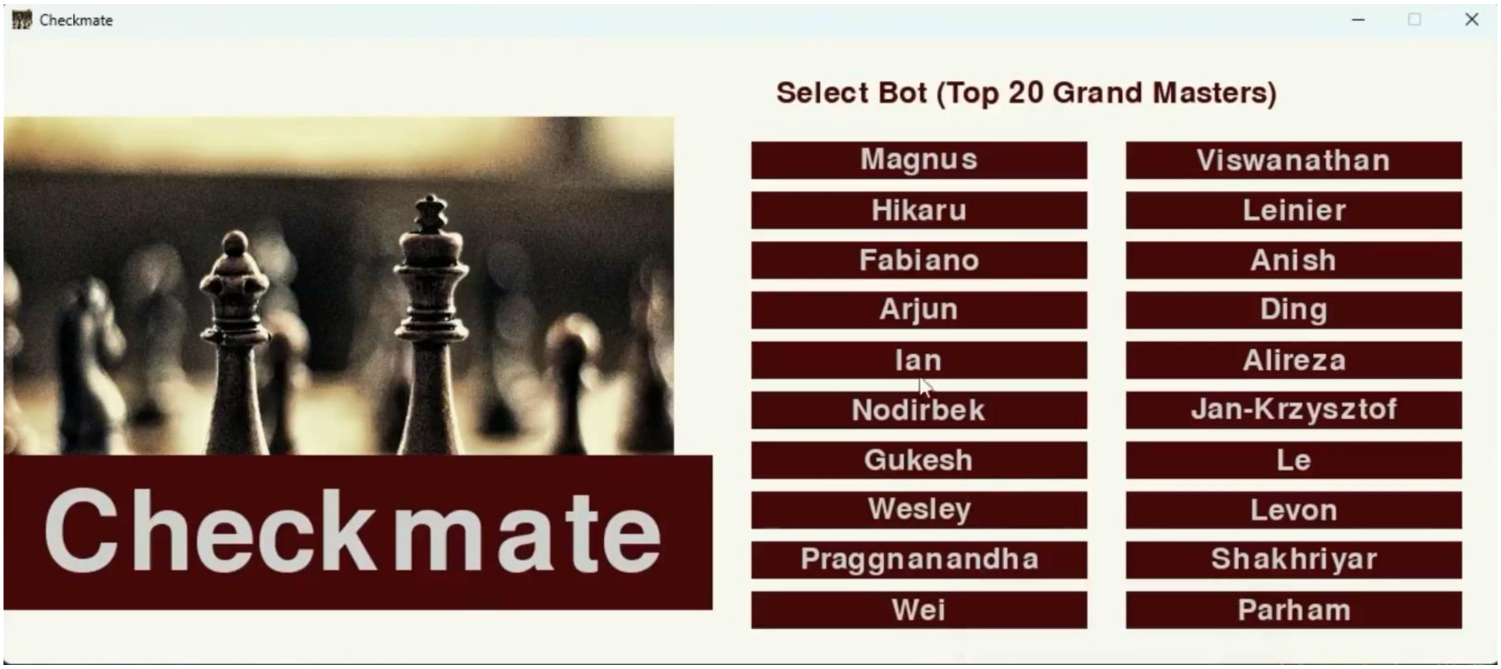


There has been a general trend of increasing chess streams on Twitch over time, with a significant increase in the number of streams in 2020. In October 2022, there were approximately 1500 chess streams on Twitch.

Discussions:

In-depth Discussion About Our Product:

Our Checkmate! is designed to provide a realistic training experience for aspiring chess players to play tournaments. It simulates the playing styles of the top 20 players, enabling users to practice and prepare for tournaments against virtual versions of their potential opponents. The bot integrates advanced machine learning algorithms, data processing techniques, and user-friendly interfaces to offer a comprehensive training tool. Below, we will discuss the features of our product in detail, using screenshots from the gameplay to illustrate key aspects.

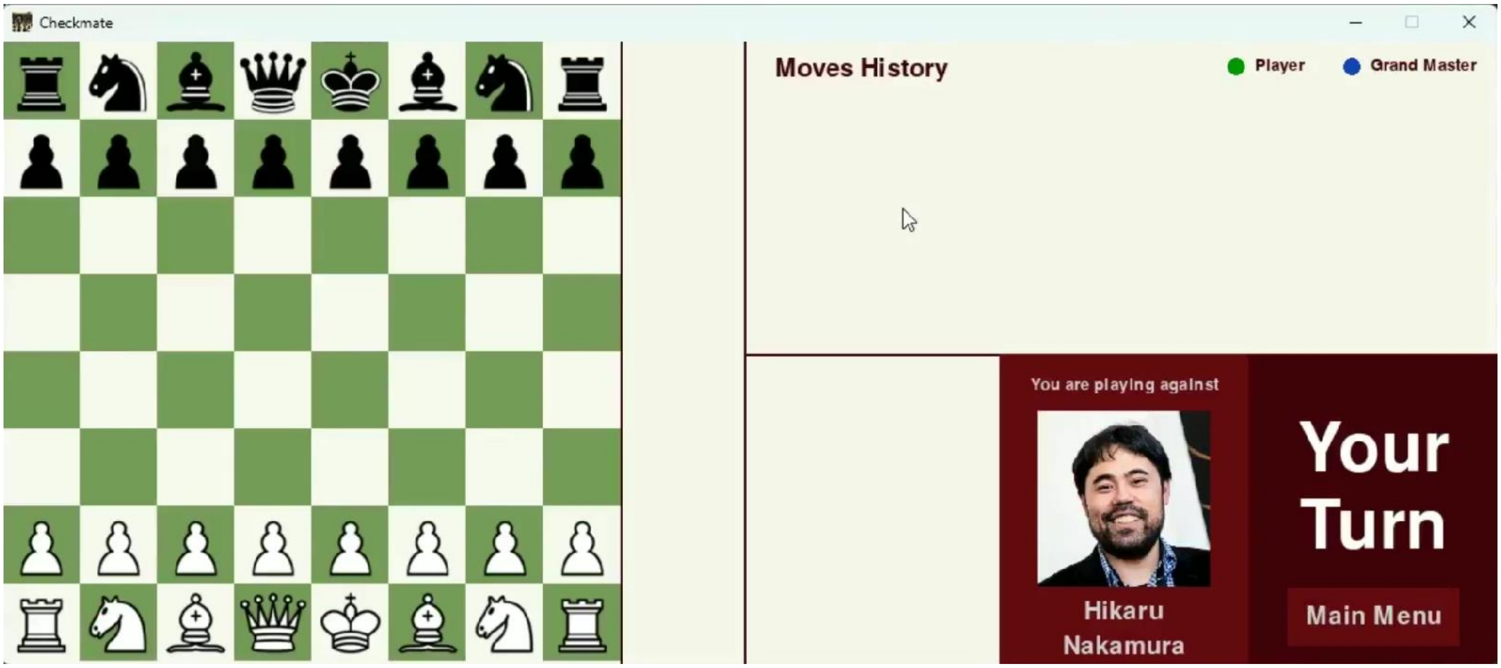


The above image shows the initial interface where users can select a bot representing one of the top 20 grandmasters. The user interface is clean and intuitive, making it easy for players to choose their opponent. Each button on the right side of the screen corresponds to a top grandmaster, including notable names such as Magnus Carlsen, Viswanathan Anand, Hikaru Nakamura, and others.

- **User Interface Design:** The interface is designed to be visually appealing and user-friendly. The names of the grandmasters are displayed in a clear and organized manner, allowing users to quickly identify and select their preferred opponent. The background image of chess pieces enhances the visual appeal and creates an immersive environment for the user.

- **Bot Selection:** The ability to select from a range of top players is a key feature of our bot. Each selected grandmaster bot is programmed to replicate the unique playing style, strategies, and tendencies of the respective player. This provides a realistic and personalized training experience, as users can prepare against the specific styles they are likely to encounter in real tournaments.

- **Customization:** This interface allows for customization of the training session. Users can choose the opponent they wish to practice against, which is particularly useful for preparing against specific players in upcoming matches. This feature enhances the relevance and effectiveness of the training provided by our bot.

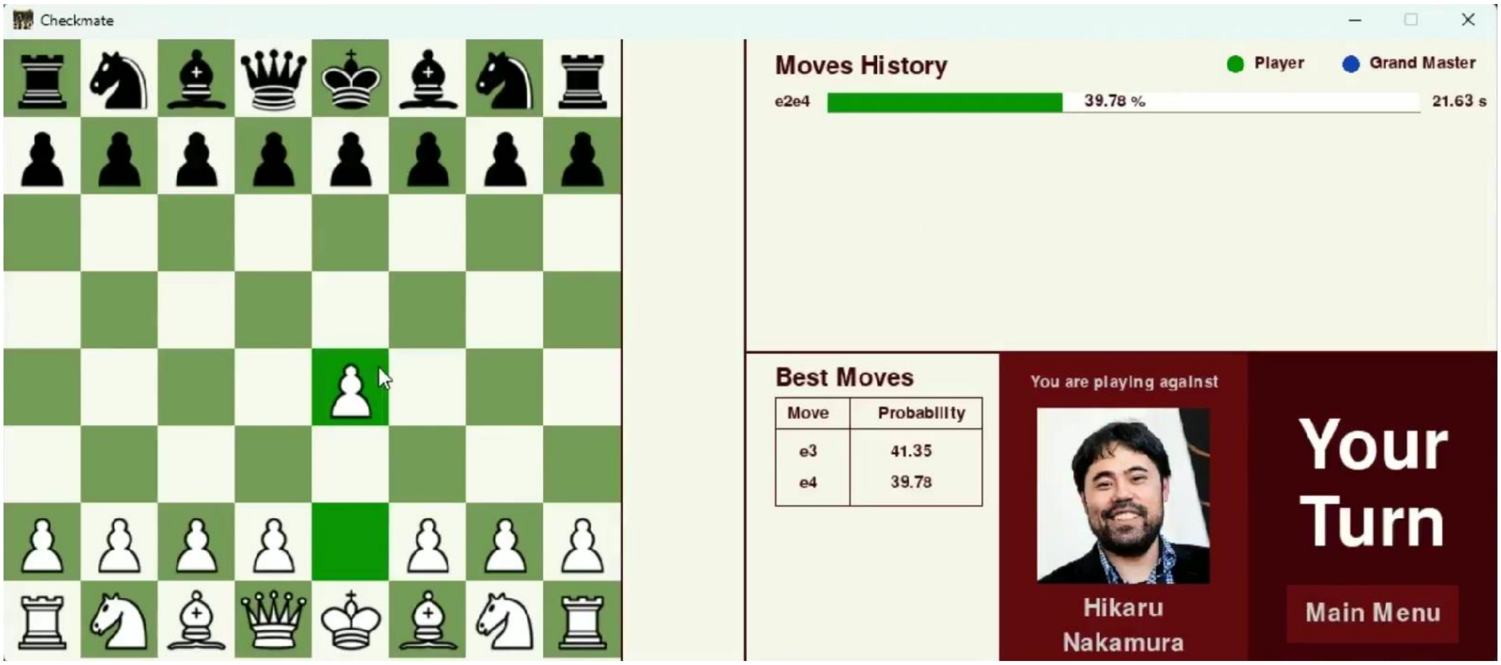


In this screenshot, the user has selected Hikaru Nakamura as their opponent. The game interface is displayed, which shows the initial setup of a chess game playing. Here, we can see several key features of our product in action.

- **Chess Board Display:** The chess board is clearly laid out with standard notation, making it easy for players to follow the game. The pieces are represented with traditional chess icons, and the board is set in a familiar green-and-white color scheme.

- **Move History Panel:** On the right side of the screen, there is a panel labeled "Moves History," which will display the sequence of moves made by both the player and the bot. The moves will be color-coded, with green for the player and blue for the grandmaster, providing a clear and easy-to-follow record of the game.

- **Opponent Information:** Below the move history panel, the opponent's information is displayed, including a picture and the name "Hikaru Nakamura." This personalizes the training experience, reminding the user of the specific style and strategies they are practicing against.
- **Player's Turn Indicator:** The interface clearly indicates whose turn it is with the "Your Turn" message. This helps keep the player engaged and aware of the game state.
- **Navigation Options:** A "Main Menu" button is provided for easy navigation, allowing users to return to the main selection screen if they wish to change their opponent or adjust settings.



e2e4 39.78 % 21.63 s

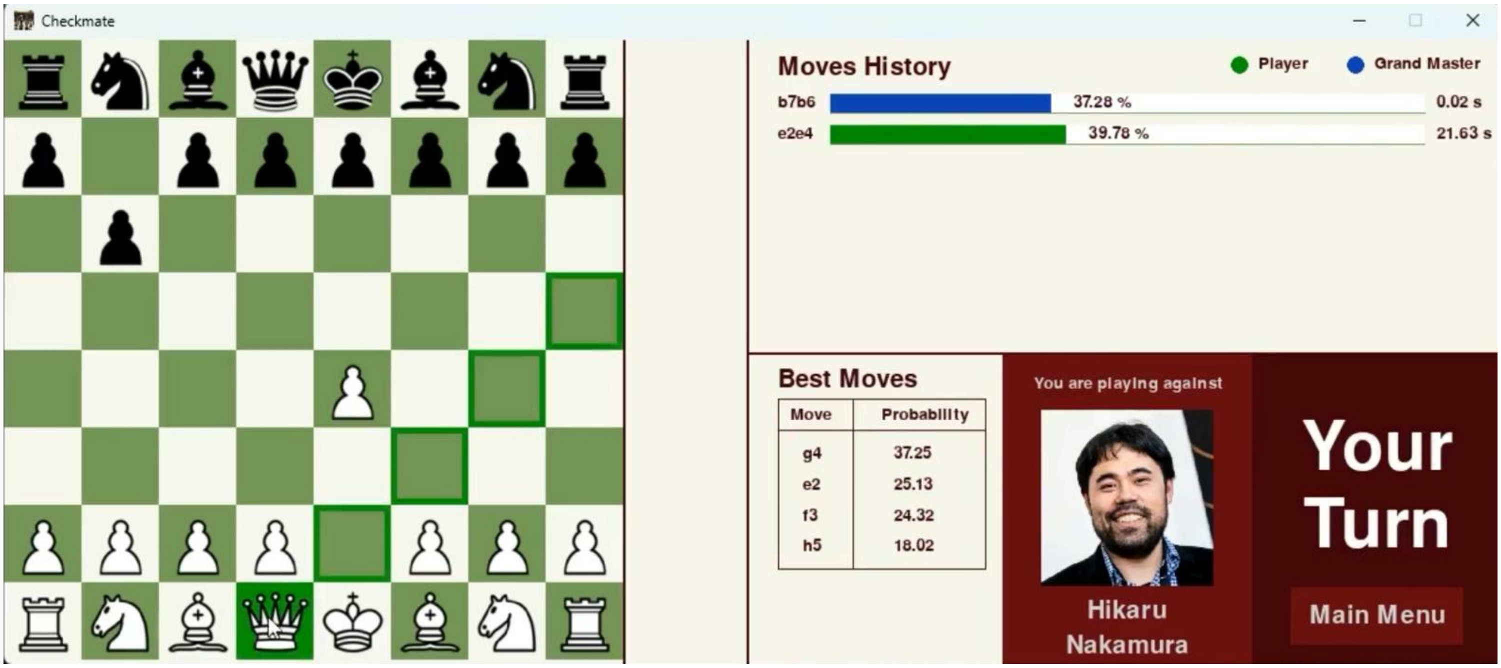
Best Moves

Move	Probability
e3	41.35
e4	39.78

In this screenshot, the user has made the first move in the game against Hikaru Nakamura. The move history panel and best moves section are now populated with relevant information, providing valuable insights into the game.

- **Move Execution:**
  - The player has moved the pawn from e2 to e4, a common opening move in chess. This move is highlighted on the board, making it clear which piece was moved and to where.

- **Move History Panel:**
    - The move history panel now shows the move e2 to e4, indicated by "e2e4". The panel includes a progress bar showing the time taken by the player to make the move (21.63 seconds) and the probability of the move (39.78%). This helps the player understand the time management aspect and the likelihood of success of the chosen move.
- **Best Moves Section:**
    - The best moves section lists the two most probable moves (e3 and e4) along with their respective probabilities (41.35% for e3 and 39.78% for e4). This feature provides strategic guidance by suggesting the most effective moves based on the current board position.



Moves History

```
b7b6   37.28 %   0.02 s
e2e4   39.78 %   21.63 s
```

Best Moves

Move	Probability
g4	37.25
e2	25.13
f3	24.32
h5	18.02

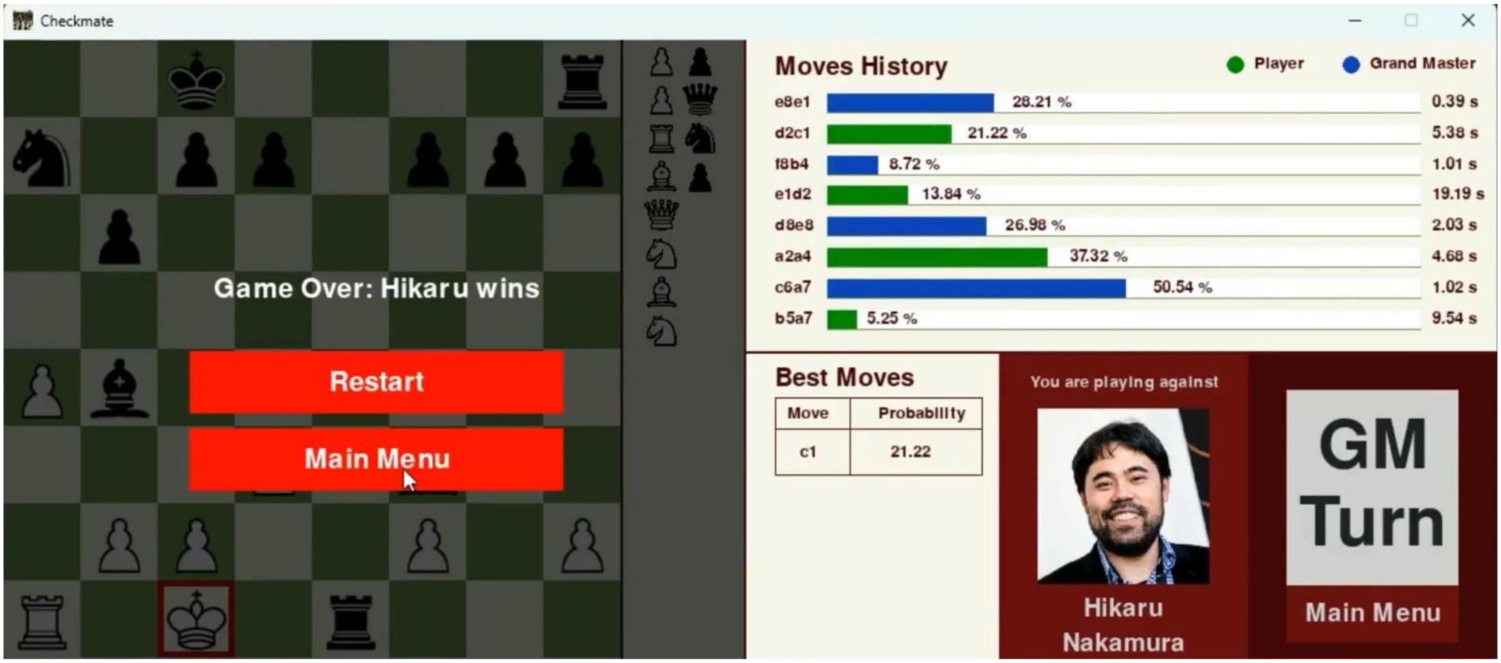
In this screenshot, the game has progressed with both the player and the grandmaster bot having made their first moves. The move history panel now includes entries for both the player's and the bot's moves, providing a comparative analysis of their decisions.

- **Move Execution and Comparison:**

- The player moved the pawn from e2 to e4, which is shown on the chess board. The grandmaster bot responded with a pawn move from b7 to b6. Both moves are displayed in the move history panel, with the player's move in green and the bot's move in blue.

- **Move History Panel:**
  - The move history panel shows the moves "e2e4" and "b7b6," along with the probabilities and times taken for each move. The player took 21.63 seconds for the e4 move with a 39.78% probability, while the bot made the b6 move in 0.02 seconds with a 37.28% probability. This comparison helps the player understand the efficiency and strategic implications of their moves versus those of the grandmaster.

- **Best Moves Section:**
  - The best moves section now lists the most probable next moves based on the current board position. It suggests moves like g4, e2, f3, and h5, with their respective probabilities. This feature provides ongoing strategic guidance as the game progresses.



Game Over: Hikaru wins

Moves History

● Player ● Grand Master

e8e1	28.21 %	0.39 s
d2c1	21.22 %	5.38 s
f8b4	8.72 %	1.01 s
e1d2	13.84 %	19.19 s
d8e8	26.98 %	2.03 s
a2a4	37.32 %	4.68 s
c6a7	50.54 %	1.02 s
b5a7	5.25 %	9.54 s

Best Moves

Move	Probability
c1	21.22

In this screenshot, the game has concluded with the grandmaster bot, Hikaru Nakamura, emerging as the winner. The final move history is displayed, along with options for the player to restart the game or return to the main menu.

- **Game Over Notification:**
  - A clear message "Game Over: Hikaru wins" is displayed at the center of the screen, indicating the conclusion of the game. This notification provides immediate feedback to the player about the game's outcome.
- **Move History Panel:**
  - The move history panel now shows a comprehensive list of moves made during the game by both the player and the grandmaster bot. Each move is color-coded (green for the player and blue for the grandmaster) and includes the move probability and time taken.
  - The final moves leading to the grandmaster's victory are displayed, providing the player with insights into the sequence of moves that resulted in their defeat.
- **Best Moves Section:**
  - The best moves section continues to suggest optimal moves based on the current board position. For instance, it suggests c1 with a 21.22% probability. Although the game has ended, this feature helps players understand better alternatives they could have considered during the game.
- **Restart and Main Menu Options:**
  - Two prominent buttons, "Restart" and "Main Menu," are provided for the player. The "Restart" button allows the player to start a new game against the same or a different grandmaster bot, facilitating continuous practice and improvement.

- The "Main Menu" button takes the player back to the initial selection screen, where they can choose a different opponent or adjust game settings.

Features of Our Product:

1. **Real-time Move Analysis:**
    - The bot analyzes each move in real-time, providing immediate feedback on the chosen move's effectiveness and time taken. This helps players understand the implications of their decisions and improve their time management skills.
2. **Probability-based Move Suggestions:**
    - The best moves section offers probability-based suggestions, guiding players towards optimal moves. This feature leverages the predictive power of our machine learning models to enhance the player's decision-making process.
3. **Interactive Move History:**
    - The move history panel tracks all moves made during the game, with color-coded indicators for player and grandmaster moves. This feature allows players to review the game's progression and analyze their performance.
4. **Time Management Feedback:**
    - By displaying the time taken for each move, the interface helps players develop better time management skills, crucial for different time controls in chess.

Impact of research on technology:

Our research into the playing styles and decision-making processes of top grandmasters enabled us to develop models that not only predict moves but also provide a comparative analysis. This helps players understand the rationale behind different moves and the implications of time management in high-level chess.

Impact of Findings on Technology:

The data visualization and analysis conducted during the project informed the development of features like the move history panel and best moves section. Understanding the importance of move comparison and probability-based guidance led to the implementation of these features, providing players with comprehensive analytical tools.

Conclusion:

Throughout this project, we have successfully developed a Chess Preparation Bot that provides a realistic simulation of playing against top grandmasters. Our tool is designed to assist chess players in preparing for tournaments by offering an interactive training experience tailored to the unique styles of the world's best players. The bot's features, such as real-time move analysis, probability-based move suggestions, and detailed move history tracking, enhance players' understanding of strategic gameplay and decision-making.

While we have addressed many challenges in replicating the playing styles of top players and providing a comprehensive training tool, there are still areas for improvement. One ongoing challenge is optimizing the bot's performance for different time controls and game phases, ensuring that the simulations are accurate and representative of real-world conditions. Additionally, user feedback has indicated a desire for more personalized training options, which we are committed to exploring in future iterations of the bot.

The Chess Preparation Bot represents a significant advancement in chess training tools. By democratizing access to high-level preparation resources, our project supports inclusivity and accessibility in the chess community. The comprehensive feature set, including move prediction, real-time feedback, and interactive interface, provides a valuable resource for players at all levels, from amateurs to professionals.

Recommendations:

Features to Add or Improve:

1. **Enhanced Personalization:**
   - **Player Profiles:** Allow users to create profiles that track their progress, strengths, and weaknesses. This feature would enable more personalized training sessions tailored to individual needs.
   - **Adaptive Difficulty Levels:** Implement adaptive difficulty levels that adjust based on the player's performance, providing a more challenging and tailored experience.
2. **Expanded Opponent Library:**
   - **Additional Grandmasters:** Expand the list of available grandmaster opponents to include more players, offering users a broader range of playing styles to practice against.
   - **Historical Players:** Introduce historical grandmasters and famous players from different eras to provide diverse strategic insights and learning opportunities.
3. **Improved User Interface:**

- **Enhanced Visuals:** Upgrade the visual design of the chess board and interface to create a more engaging and modern user experience.
- **Tutorials and Guides:** Add in-game tutorials and guides to assist new players in understanding the bot's features and chess strategies.

4. **Advanced Analytics:**
   - **Post-game Analysis:** Offer detailed post-game analysis that highlights key moments, mistakes, and potential improvements in the player's gameplay.
   - **Win Probability Graphs:** Display dynamic graphs showing win probabilities over time, providing insights into how each move impacted the game's outcome.
5. **Multiplayer Functionality:**
   - **Online Multiplayer Mode:** Introduce an online multiplayer mode where users can compete against each other or collaborate in training sessions.
   - **Community Features:** Implement community features such as leaderboards, challenges, and social sharing to foster a sense of competition and camaraderie among users.

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