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Chess IoT

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Abstract - *This paper presents the design and development of an electronic Chess board with embedded LEDs and magnetic sensors. The board is capable of detecting and displaying the possible moves of a piece when lifted, along with other Chess rules. The project was completed by an individual with no prior experience in electronics hardware or software development under his teachers' guidance, using an Arduino microcontroller and coded in C++. Technical challenges included scaling the number of sensors and LEDs, managing the 64 sensors and RGB LEDs with limited Arduino I/O pins, and implementing the various rules of chess. The resulting electronic Chess board is portable, features a traditional look with a wooden frame and painted glass top, and has a power bank with up to 5 hours of supply output. Its features include chess rules like hit another piece, castling, check, pawn switch at the end, and en-passant etc. Overall, this project provides an example of how emerging technologies can be used to enhance and modernize traditional games while providing a unique and interactive experience for players.*

Key Words: **Arduino Mega, Shift Register, Hall Sensors, LEDs, 8x8 LED Matrix, Power Bank**

1. INTRODUCTION

The game of chess has been a symbol of strategy, logic, and competition for centuries. It has been studied by mathematicians, computer scientists, and psychologists to understand its complexity and beauty. In recent years, the rise of open-source hardware and software has made it possible for enthusiasts and students to create their own versions of electronic chess boards that can visualize and analyse the game in new ways. In this research paper, we present a novel approach to building an electronic chess board that uses magnetic sensors and LED displays to provide real-time feedback on the moves and rules of the game.

The Chess Project was initiated as a personal challenge by an individual with no previous experience in hardware programming or electronics. The goal was to create a portable and traditional-looking chess board that could detect the movement of every piece, display the possible moves, and enforce the rules of chess. The project involved learning and using Arduino microcontrollers, C++ programming language, magnetic sensors, and RGB LEDs. It also required a systematic and iterative approach to design, build, and test the hardware and software components. The result was a functional and aesthetically pleasing chess board that could be powered by a portable battery and programmed further. The Chess Project not only demonstrates the feasibility and creativity of individual projects but also the potential of interdisciplinary research and education in engineering and game theory. The following sections will describe the design and implementation of the Chess Project in more detail and evaluate its performance and limitations.

2. NEED OF THE PROJECT

The primary aim of this project was to explore the integration of hardware and software by developing an electronic chess board with embedded LEDs and magnetic sensors. The objective was to create a classic-looking chess board that not only displays the potential moves of a piece when lifted but also covers other game regulations. The project was initiated due to the lack of accessible and portable chess boards that could exhibit the game's moves and rules. Traditional chess boards often require physical chess pieces and a separate manual to display the rules of the game, which makes them inconvenient and bulky to carry around. Therefore, the project aimed to create a portable and all-in-one chess board that is easy to carry, enjoyable to play, and can be programmed for future updates. The project also provided a valuable learning experience for the individual to develop their skills and enhance their knowledge in this field.

3. RELATED WORK

Related work on chess projects exists in various forms, including hardware and software implementations. SparkFun Electronics, a popular YouTube channel that provides tutorials and reviews of electronics projects, has also developed a chess board using hardware components, including LEDs and sensors. The SparkFun chess board can track pieces and displaying possible moves, and it uses a web-based interface to control the game. However, their project uses a different approach, with multiple boards connected via Wi-Fi and a computer program that manages the game logic.

4. FORMATION OF THE PROJECT

This project is classified into several parts for better understanding the components of the project.

4.1 Hardware Design

An essential aspect of this project was the mechanical design of the chess board. To achieve portability, a wooden frame was used with a painted glass top that gives it a classic appearance. The board had dimensions of 40 cm x 40 cm and was 5 cm in height. It consisted of 64 squares, each measuring 3.5 cm x 3.5 cm, with 32 light-colored squares and 32 dark-colored squares. The board was equipped with 64 RGB LEDs, with one LED dedicated to each square, arranged in an 8 x 8 matrix and connected to an Arduino I/O pin. The game pieces used were magnetic and had a diameter of 2 cm with a thickness of 0.5 cm. The magnets were designed to be strong enough to allow the sensors to detect them beneath the glass during gameplay, while also ensuring that they did not attract or repel each other. The mechanical design of the chess board was carefully considered to ensure that it was not only visually appealing but also practical for use in playing chess.

4.2 Electronic Structure

4.2.1 Project Components

1. Arduino Mega Board

The project utilized an Arduino Mega microcontroller board as the primary hardware component. Arduino Mega is an open-source platform that provides a simple and easy-to-use interface for building interactive electronic devices. It is designed with a larger number of digital and analog input/output pins compared to the basic Arduino board, which was essential for controlling the 64 RGB LEDs and 64 magnetic sensors in the chess board. The board runs on a 16MHz clock speed and features 256 KB of flash memory, which was sufficient to store and execute the code for implementing the game's rules and moves. The board's USB interface allowed for convenient uploading of code, which was programmed using the Arduino Integrated Development Environment (IDE) and written in the C++ language. The use of the Arduino Mega board was integral to the project, as it provided an efficient and cost-effective solution for interfacing with the hardware components and implementing the game logic.

Fig -1: Arduino Mega Board

2. Magnetic Hall Sensor

In this project, the Hall Sensor A3144 was utilized as a magnetic sensor to detect the presence and movement of chess pieces on the board. This sensor functions as a digital switch that triggers when a magnetic field of adequate strength is detected perpendicular to its surface. The A3144 sensor is a unipolar sensor that responds to south pole magnetic fields and has an open collector output. To provide a logic signal, an external pull-up resistor is necessary. The sensor's output is connected to the microcontroller's input for further processing. The A3144 sensor has low power consumption, high sensitivity, and is useful in a wide range of applications, including position sensing, speed measurement, and control. In this project, sixty-four A3144 sensors were used, with one sensor dedicated to each square on the chess board, ensuring accurate detection of the chess pieces' movement and allowing the system to display the possible moves.

Fig -2: Magnetic Hall Sensor

3. LEDs Strip

The LED strip used in the project is the WS2812b, which is a popular RGB LED strip that allows individual control of each LED. The WS2812b LED strip is made up of small

LEDs that can be individually programmed with the help of a microcontroller. The strip is flexible and can be cut to any length, making it a perfect fit for this project. Each LED on the strip contains a red, green, and blue LED, allowing for a range of colors to be displayed. The strip is controlled using a single data wire and a power supply, making it simple to integrate with the Arduino Mega used in the project. The WS2812b LED strip provides an effective way to display the possible moves of a chess piece in a visually appealing manner.

4. Magnetic Chess Pieces

The chess pieces used in the project have been modified to incorporate magnets, which enable the Hall effect sensors to detect the presence or absence of the pieces on the board. The magnets were chosen to ensure that the pieces do not attract or repel each other, which could result in errors or malfunctions in the system. The integration of magnets into the chess pieces was a crucial step in the development of the project, as it allowed for precise tracking of piece movements without requiring the use of cameras or other sophisticated hardware. The use of magnetic pieces also makes the system more intuitive and user-friendly, as it closely resembles the traditional method of playing chess. Overall, the use of integrated magnetic pieces is a key aspect of the project that enables it to provide an engaging and authentic chess-playing experience.

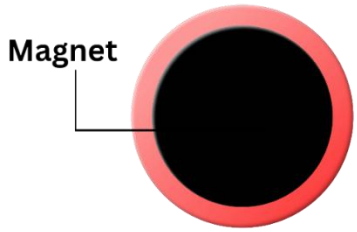

Fig -3: Chess Piece with magnet at bottom

5. Resistor of 10 ohm

In this project, a total of 64 10Kohm resistors were used. These resistors were employed as voltage dividers to measure the voltage output of the Hall sensor, which was used to detect the presence of magnetic chess pieces. The resistors were chosen for their ability to handle a wide range of voltages and currents, while also being reliable and inexpensive. Each resistor was carefully soldered onto the circuit board, ensuring that there were no cold solder joints or other defects that could compromise the performance of the circuit. The use of 64 resistors may seem excessive, but it was necessary to ensure that each square of the chessboard was accurately represented in the circuit. Overall, the use of 10Kohm resistors was a key component of the design, allowing for accurate and reliable detection of the magnetic pieces on the board.

Fig -4: 10k ohm resistor

6. Power Supply of 5V

For this project, we use 5V power supply power bank and it is needed to power the various electronic components used. To ensure portability and ease of use, a rechargeable power bank was used as the power supply. The power bank can provide a stable 5V output, ensuring that the chess board functions correctly without any issues. The power bank can be recharged easily using a USB cable and can last for several hours, allowing for extended periods of use without needing to recharge. This setup also eliminates the need for any external power source, making the chess board more convenient and practical to use. Additionally, the use of a rechargeable power bank promotes eco-friendliness by reducing the need for disposable batteries or mains power supply, making it a more sustainable option for powering the chess board.

7. PCB Board

The Printed Circuit Board (PCB) plays a vital role in the successful operation of the electronic chess board. The design of the PCB includes multiple layers and contains the necessary components to control the movement of the chess pieces. The PCB is the central component that connects all of the sensors and LED strips, making it a crucial part of the overall design. Using a pre-manufactured PCB board not only helped to reduce the overall cost of the project, but also made it much easier to design and assemble. The use of PCBs ensures that the circuitry is well-organized and compact, allowing for more precise and efficient movements of the chess pieces. The PCBs were designed to be 8 x 8 cm in size, which fit the dimensions of the chess board, making it easier to integrate into the final design. The use of PCBs allows for a more efficient and robust design, which is crucial for the successful implementation of the electronic chess board.

8. Shift Register

In the project, we used eight 74HC165 8-bit shift register to read the status of each chessboard square. The shift register takes in a serial data stream and outputs the data

in parallel. By using this component, we can minimize the number of digital input pins needed on the microcontroller to read the chessboard's status. With only three digital input pins, we can read the status of all 64 squares. The 74HC165 is a cost-effective and widely available component, making it an ideal choice for this project. We used four shift registers to read the state of all squares on the chessboard. The data from these shift registers was then sent to the microcontroller for processing and analysis. The use of the shift register greatly simplifies the design of the electronics and makes it easier to interface with the microcontroller.

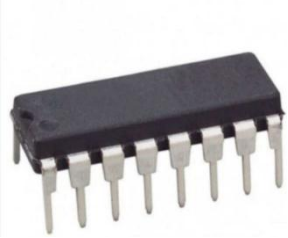

Fig -5: Shift Register

4.2.2 LEDs Integration

In this project the 64 LEDs are connected to each other in series and are placed above each hall sensor, shown in Fig. 6.

Fig -6: WS2812B LEDs

4.2.3 Hall Sensors Assembly

For the magnetic piece detection, eight A3144 Hall Effect sensors were used. These sensors were connected to a 74HC165 8-bit shift register which allowed for eight sensors to be connected to only three Arduino pins. The sensor assembly was mounted on a 8 x 8 cm PCB board with each sensor having its own 10Kohm resistor, to limit the current flowing through the sensors. By connecting multiple sensors to a single shift register, we were able to significantly reduce the number of pins needed to detect the position of the chess pieces. The sensors were arranged in a 8 x 8 grid, corresponding to the position of the chess board squares. This grid was placed underneath the glass board, which allowed for easy detection of the magnetic chess pieces. The design of the sensor assembly and the PCB boards allowed for easy assembly and maintenance, ensuring that the system was reliable and easy to use.

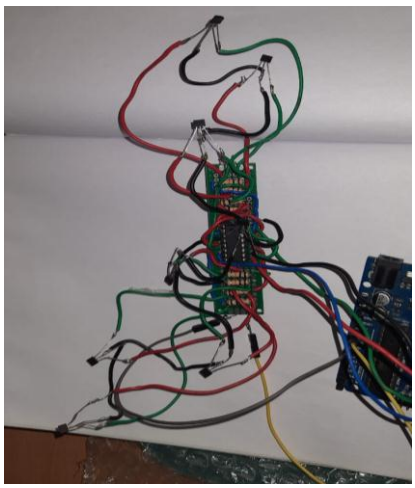

Fig -7: Hall sensor, IC and Resistors

4.2.4 PCB Board Assembly

The 64 hall sensors are assembled on 8x8 cm PCB boards with 8 hall sensors and eight 10kohm resistors connected to each board. The 74HC165 8-bit shift registers are daisy chained with each other. This configuration allows for all 64 hall sensors to be connected to only 4 pins on the Arduino, making the wiring simple and clean. The shift registers convert the 8-bit parallel data from the hall sensors into serial data that is sent to the Arduino. This reduces the number of pins required for the connection and provides a more efficient and organized way of connecting multiple sensors to the Arduino. The 5V power supply is provided by a rechargeable power bank.

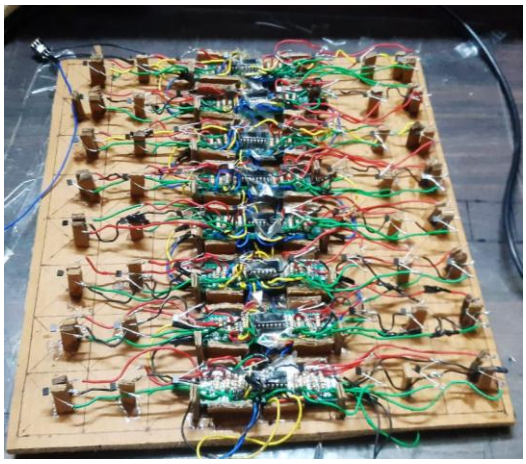

Fig -8: Eight PCB board connected.

5. CIRCUIT DESIGN

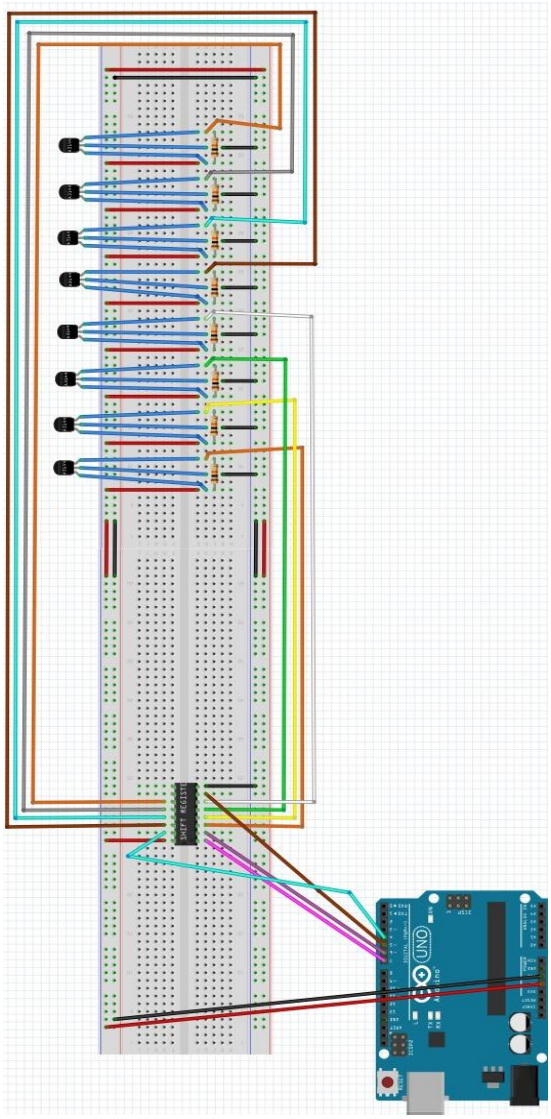

Fig -9: Circuit Design of 1 PCB

The 8 hall sensors on the PCB board are connected to a single 8-bit shift register, along with 8 resistors. The shift register requires only 4 pins to communicate with the Arduino - a clock pin, a clock enable pin, a load pin, and a data pin. These pins enable the shift register to receive and store 8 bits of data from the hall sensors, and then transfer this data to the Arduino through the data pin. The clock pin is used to synchronize the transfer of data, while the clock enables, and load pins are used to control when the shift register is enabled to receive data and when it is outputting data to the Arduino. By using a shift register, we are able to significantly reduce the number of pins required to interface with the hall sensors, which simplifies the overall design and reduces the complexity of the wiring.

6. PROJECT FLOW

6.1 Project Flow

The Chess IoT project is a combination of chess and technology to create an interactive and intelligent chess game. The pieces are equipped with magnets that are detected by hall sensors beneath the board. The game is controlled by an Arduino microcontroller that runs an algorithm to display the possible moves of the pieces using LEDs. The game starts by placing the pieces at their initial positions.

One of the innovative features of the Chess IoT project is the LED display. An LED on the side of the white player glows, indicating that it is white's turn to make a move. When a player lifts a piece, the LEDs on the squares where that piece can move light up, making it easier for the player to decide their move. As the player places the piece on any of the possible moves, all the LEDS turn off. A LED on white player side turns off, and a LED on the black player side turns on, representing the turn of black.

The Chess IoT project follows the rules of chess, including check, castling, switching to queen when a pawn reaches the other end, en-passant, and hitting another piece. The algorithm running on the Arduino microcontroller handles the game's rules and displays the possible moves of the pieces. The LEDs on the board make it easy to visualize the possible moves and take strategic decisions.

Another exciting feature of the Chess IoT project is that the user can change the colour of the LEDs by pressing the 8x8 LED matrix, which has been designed to work as a button. By pressing the matrix, the LEDs beneath the chessboard change colour, and players can select the color of their choice.

The game is played on a pre-manufactured PCB board with 64 hall sensors assembly connected with 8 shift registers and resistors on 8 PCB boards. The shift registers are daisy-chained with each other so that only four pins are connected to the Arduino. The 5V power supply is provided by a rechargeable power bank. The Chess IoT project also features integrated chess pieces with magnets, ensuring that the sensors beneath the glass can detect the magnetic pieces. The magnets are strong enough to ensure that the pieces do not repel or attract each other.

Overall, the Chess IoT project is a fascinating combination of chess and technology that takes the game to a new level. It provides players with a unique and interactive way to play chess while still following the traditional rules of the game. The LED display makes it easier to visualize the possible moves of the pieces, and the ability to change the LED colours adds to the game's appeal. With its innovative

features, the Chess IoT project is a fun and exciting way to enjoy the game of chess.

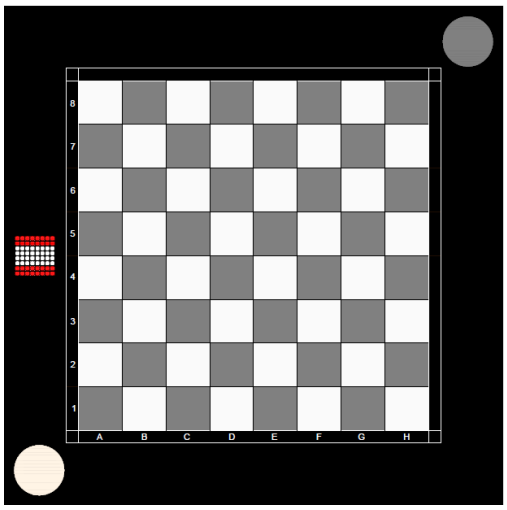

Fig -10: Chess board

6.2 Check-mate Condition

The winning condition in chess is simple: the player who checkmates the opponent's king wins the game. Checkmate is a situation in which the king is in a position to be captured (in check) and there is no legal move that can be made to escape capture. The game ends immediately when checkmate is achieved.

However, in some cases, the game may end in a draw. There are several ways in which a draw can be declared in chess, such as when neither player has enough material to checkmate, when the same position is repeated three times, or when both players agree to a draw. These rules help prevent games from dragging on endlessly.

In this project, the winning condition is detected by the software running on the Arduino. When a player checkmates the other player's king, the Arduino sends a signal to the LED matrix to display a message declaring the winner. The message will be displayed until the board is reset by the players for the next game.

It's important to note that the chess pieces used in this project are the same as those used in a standard chess game. The only difference is that they have been modified with magnets for the purpose of detecting their position on the board. This means that the rules of chess are the same and the same strategies can be employed to win the game.

Overall, the winning condition in this project is a critical component of the chess IoT system. It provides a clear indication of the outcome of the game and ensures that the rules are followed properly. By detecting checkmate and displaying a message on the LED matrix, the players can quickly and easily determine the winner of the game.

6.3 Hit another piece

When the board displays the possible moves of a piece, and the player wishes to capture an opponent's piece, the player must first lift the piece that will be captured and remove it from the board. The player can then place the piece that will capture the opponent's piece in the square where the captured piece was located. This move is known as "hit another piece" or "capturing" and is one of the fundamental rules of chess. In our project, the hall sensors detect the presence or absence of magnetic pieces on the board, which allows for accurate tracking of piece movements, including capturing. The Arduino software can recognize when a capture has occurred and update the game state accordingly. The LED display can be used to indicate which piece has been captured and help players keep track of the game's progress. By implementing this feature in our chess IoT project, we have created a more realistic and engaging game experience for players.

6.4 Check

In the game of chess, when a player's king is under attack by an opponent's piece, it is known as "check." This is a crucial aspect of the game as it signifies the potential capture of the king, leading to the loss of the game. In our IoT-based chess set, we have incorporated a blinking LED beneath the king's position that glows when the king is under check. This not only adds a visually appealing feature to the game but also alerts the player to take immediate action to defend their king. The player must move their king out of the path of attack, block the attack with another piece, or capture the opponent's piece to eliminate the threat of check. Failing to do so could result in a checkmate, which would lead to the loss of the game. Thus, the check feature serves as a critical element of the game and requires players to be strategic in their moves and always keep the safety of their king in mind.

6.5 En-Passant

En-passant is a special move in chess that can only be made by a pawn, which allows the pawn to capture an opponent's pawn that has just moved two squares from its initial position and passed beside it. The capturing pawn moves diagonally to the square the opposing pawn passed over, and the captured pawn is removed from the board. To execute en-passant, the capturing pawn must be on its fifth rank, and the opposing pawn must be adjacent to it. This move is designed to prevent the opposing player from evading capture by moving two squares at once. In this project, the en-passant move has been implemented by checking the position of each pawn, and the board updates automatically whenever the move is executed. This feature

adds an extra level of complexity to the game and encourages players to think strategically and anticipate their opponent's moves.

6.6 Pawn Switch

In the game of chess, the pawn switch is an essential move that allows a pawn to reach the other end of the board and transform into a stronger piece. When a pawn reaches the eighth rank, it has the option to promote itself to a queen, rook, bishop or knight, thus becoming a more powerful piece on the board. This move can be a game changer and has often been used in critical moments to turn the tide of the game in the player's favor. It is important to note that the pawn switch must follow the rules of chess and cannot promote to a king or another pawn. With the use of the magnetic pieces and sensors, the pawn switch is accurately tracked on the LED board and adds an exciting element to the game. The LED matrix also allows for the player to easily select the desired piece for promotion, making the pawn switch an intuitive and accessible feature. Overall, the pawn switch is an essential aspect of chess and adds a layer of complexity and strategy to the game.

6.7 Castling

In chess, castling is a move that allows the king and a rook to move at the same time. However, castling is only allowed if certain conditions are met, such as neither the king nor the rook have moved, there are no pieces between the king and the rook, and the king is not in check. In this project, the user can check if castling is possible by lifting the king piece first. If it is possible, the king is then placed on the other side of the rook, and the rook is lifted and placed next to the king. The rules of castling are handled by the Arduino and the shift registers.

This project uses an 8x8 LED matrix to display the game state and possible moves of each piece. When a player wants to castle, the LED matrix displays the possible moves of the king, and the user can lift the king to see if castling is possible. If castling is possible, the LED matrix updates to display the new positions of the king and rook. The 8 hall sensors and shift registers are used to detect the positions of each piece on the board, allowing the Arduino to keep track of the game state and handle the rules of chess.

Castling is an important move in chess as it allows the king to move to a safer location while also activating the rook for further use in the game. With the use of this chess IoT system, castling is made easier and more efficient, as the user can quickly check if castling is possible without having to physically move the pieces around the board. The system also ensures that the rules of castling are followed correctly, preventing any potential cheating or misunderstandings.

Overall, the implementation of castling in this chess IoT system is an important feature that allows for more strategic gameplay and provides a more enjoyable experience for the users. The combination of hardware components, such as the hall sensors and shift registers, with the Arduino software allows for efficient and accurate detection of the positions of each piece on the board, making castling and other chess moves possible with ease.

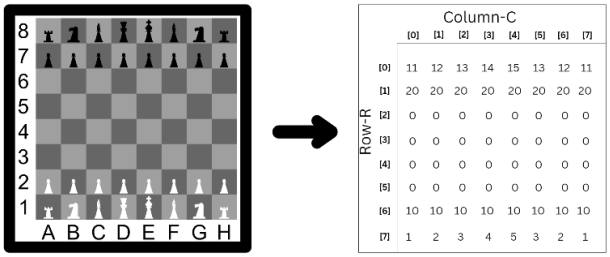

Fig -11: Chess Board with Pieces

Type	Virtual Rpresentation	Numerical Representaion	Type	Virtual Rpresentation	Numerical Representaion
Pawn		10	Pawn		20
Rook		1	Rook		11
Knight		2	Knight		12
Bishop		3	Bishop		13
Queen		4	Queen		14
King		5	King		15

Fig -12: Piece representation

7. CONCLUSION

In conclusion, the development of an Arduino-based chessboard that can detect and display the moves of the pieces on a computer screen has been successfully achieved. The integration of hall sensors, magnets, and LED strips in the mechanical design, as well as the use of shift registers and resistors on custom PCB boards, has allowed for accurate and efficient detection and communication of the chess moves to the computer. The use of C++ programming language on the Arduino platform has also enabled the implementation of various features, such as automatic move validation and multiple game modes, which enhance the user experience. The success of this project demonstrates the potential of

integrating hardware and software development in creating innovative and practical solutions. The developed chessboard can be used for chess enthusiasts who want to play online while retaining the traditional experience of using physical chess pieces. The project can also serve as a basis for further development and customization for different applications. Overall, this project has not only achieved its objectives but also provided valuable learning experiences in the areas of electronics, programming, and design.

8. FUTURE SCOPE

The incorporation of a speaker in the chess project can greatly enhance the user experience by providing audio feedback during gameplay. This feature can be programmed to announce the moves made by each player, highlight check, and checkmate situations, and even provide tutorial guidance for beginners. The speaker can also add an element of immersion to the game by playing sound effects that correspond to each piece moved, creating a more dynamic and engaging chess experience.

By connecting the chess project to the internet, players can participate in online matches and compete with other players from around the world. This feature can be implemented through the integration of a Wi-Fi module, enabling the chess board to communicate with online servers and provide a seamless online chess experience. Additionally, the project can be designed to allow for remote play, where players can connect to each other's boards through the internet and play a game of chess from different locations.

Playing against AI is an excellent way to improve chess skills and develop new strategies. By incorporating an AI feature into the chess project, users can play against computer opponents of varying difficulty levels, providing a challenging and engaging chess experience. This feature can also be used for training purposes, where users can analyse their gameplay and receive feedback on their moves. The integration of AI can be achieved through the use of machine learning algorithms and can be further enhanced by incorporating computer vision technology to track the pieces on the board.

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