

Assistive Chessboard

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1 Introduction

1.1 Objective

Chess is a game played by over 600 million players [1], however it can be quite difficult for a fresh player to learn. A common method for learning is to utilize online resources but this negates the experience and flexibility of playing with a physical board. Another option is to play with a friend on a real board, perhaps using an online guide as an aide, but this can be distracting. And while a friend may be a great source to learn from, playing with a friend might not be an option available at all times, and as already noted, resorting to an online neglects the experience of a real board.

Our solution is to design and build a chess board that can be this link between a physical board and an educational source by having it assist new players. This is done by having an RGB LED under each board square that will light up according to valid and invalid moves for the selected piece, pieces under threat, as well as a variety of other useful information. By giving visual aids to the new player, they will be able to see the basics of the game more easily, as 83% of what is learned is through the sense of sight [2].

1.2 Background

Currently, there do exist electronic chess sets that teach players of possible moves, but with the downfall of being pricey. One such example is the Excalibur King Master III [3], which states the move list on the LCD screen, which is small and not as intuitive. Meanwhile our chess board will give live feedback in the form of visual aids that result in a similar end goal. By highlighting the move list onto the physical board, the player can see the possible moves more prominently.

This shows that there is indeed a product space for an assistive chessboard that is cheaper and more visually stimulating such as ours. By incorporating LEDs into our design, we are able to communicate information to new players much easier. With a visual guide right on the board, a new player will be able to improve their grasp of the game with less effort as they do not have to actively seek such information; it is all displayed clearly before them and in the flow of the game.

Compared to virtual chess guides and tutorials found online, our solution allows a player to experience a game on an actual board. From personal experience as a unskilled player, it is easier to scope out a physical board than one online. The physical interactivity of a real board

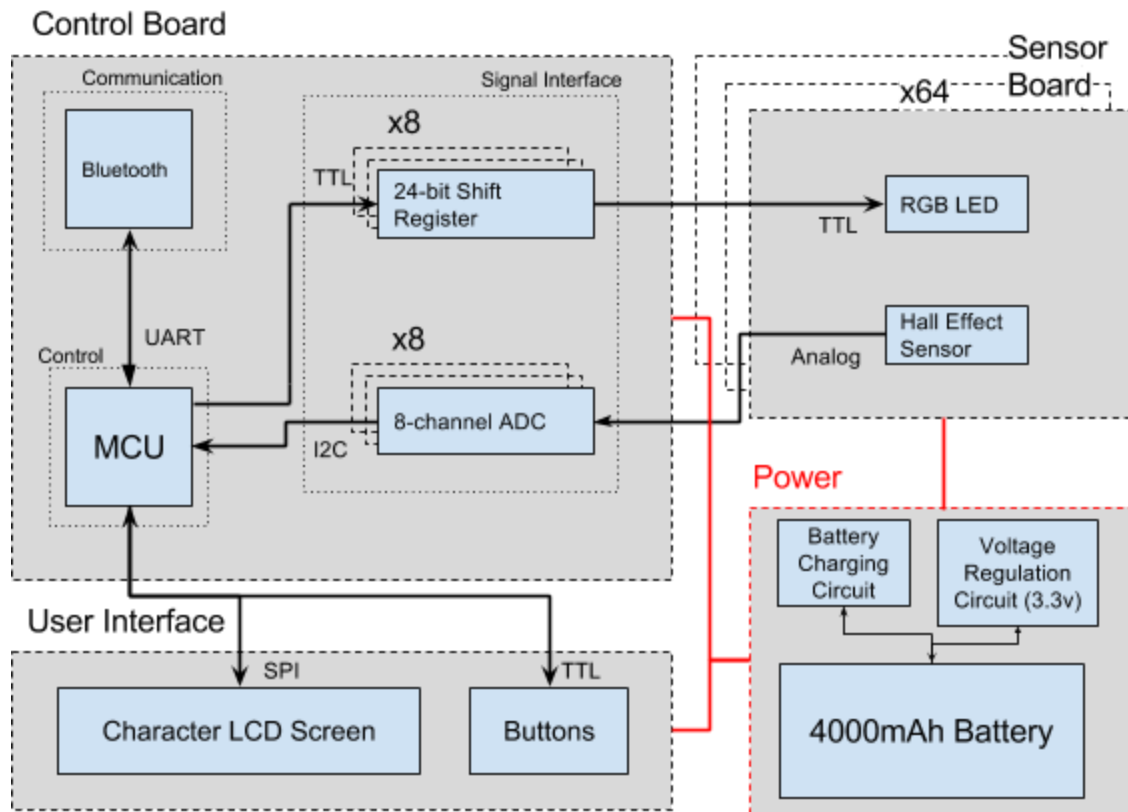
can allow a player to feel more comfortable as their moves are not hindered by a computer interface. Our product solution combines the pros of a physical board with the broad assistive abilities of computer chess.

1.3 High-Level Requirements

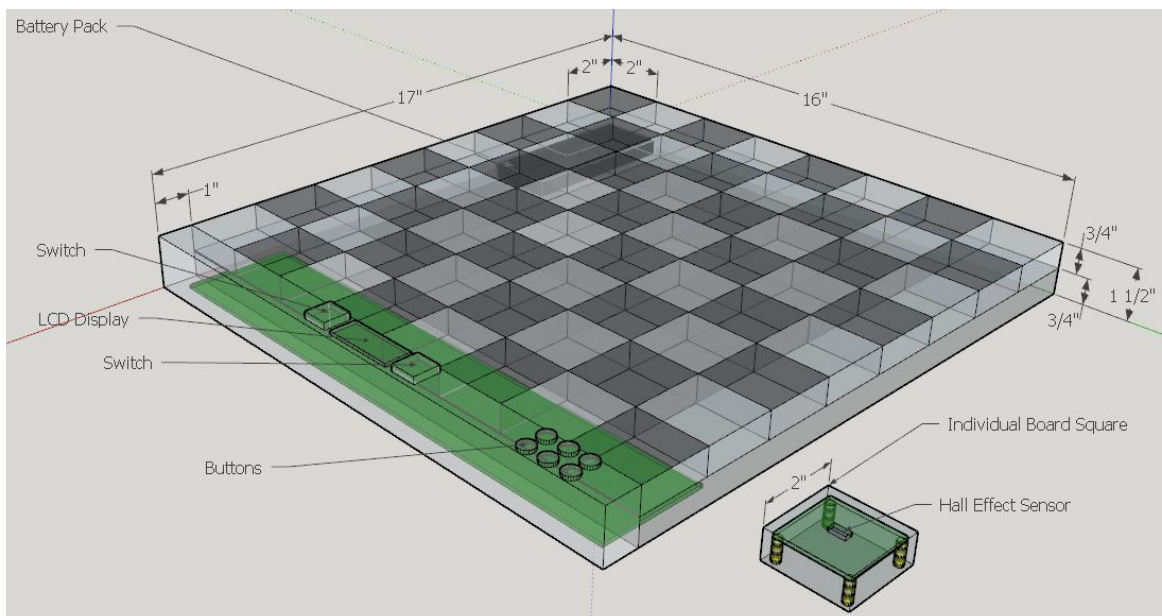
- Chess board must be able to detect where every piece is and what each piece is by the use of the individual hall-effect sensors placed under each board square.
 - a. Location must be detected with 100% accuracy
 - b. Piece type and color must be detected with 100% accuracy
- Chess board must be able to individually control each RGB LED under each chess board square to give an appropriate signal such as:
 - a. Potential moves for a piece with 100% accuracy
 - b. A red light under pieces in danger with 100% accuracy
 - c. A flashing Red if an under invalid move when it is made with 50% duty cycle at 1 Hz
- Chess board must be able to send game move history over Bluetooth to a connected device for data logging
 - a. Must be able to send at least 10 ft with 100% accuracy
 - b. Minimum data size (2 bytes per move - average game is 40 moves [5] - 80 bytes on average must be transmitted with 100% accuracy)

2 Design

2.1 Block Diagram



2.2 Physical Design



2.3 Block Descriptions

2.3.1 Control Board

The purpose of the Control Board is to manage the entire system. It takes in the analog signals from the sensor array and outputs signals for the LED lights. It also controls the LCD display and is interfaced with by the set of buttons in the User Interface block. Finally, the Control Board is responsible for managing the Bluetooth connection and sending game data through it to a connected device. The Control Board contains a MCU, a Bluetooth module, 8 24-bit shift registers (one per row of 8 sensor blocks), and 8 8-channel ADCs (also one per row of 8 sensor blocks)

- **MCU:** The MCU (Microcontroller Unit) stores and updates the board state in its flash memory. Using this it is able to output the appropriate LED signals to perform the board's signalling functions (by TTL signalling to the 24-bit shift registers). It updates the board state by reading the digital sensor readings through an I2C communication from the ADCs. It is also responsible for temporarily storing the moves of a game in its flash memory and then to send that to the Bluetooth module to be transmitted through an UART connection. Finally, the MCU must manage the chess clock settings and time by sending data to the LCD screen and reading inputs from the buttons (TTL signaling).
 - Requirements:
 - i. 128KB flash-like memory
 - ii. UART interface capabilities
 - iii. I2C interface capabilities for connection to ADCs (separate addressing for each row)
 - iv. SPI interface capabilities for connection to LCD display
 - v. 3.3V operating mode
- **Bluetooth:** The Bluetooth module (HC-06) is responsible for managing the connections and data transfer to a Bluetooth enabled device. This will facilitate the transfer of game data so that it can be stored and referenced by some other device at a later time.
 - Requirements:
 - i. UART interface
 - ii. 3.3V operating mode
 - iii. Connection range of at least 10ft (Bluetooth Class 2 power level)
 - iv. Bluetooth version 2.0 + EDR
- **ADCs:** The ADCs convert the analog hall-effect sensor outputs into a digital form that can be sent to the MCU over a single line through I2C communication. There will be 8 8-channel ADCs, one per row of sensors on the board. Each ADC will take the 8 sensor outputs of its row as its input.
 - Requirements:
 - i. 8-Channel
 - ii. At least 6-bit digital output
 - iii. 3.3V operating mode

- **Shift Registers:** The purpose of the shift registers is to reduce the amount of connections needed to control the RGB LEDs. Like the ADCs, there will be 8 24-bit shift registers, each for one of the 8 LED lights per row. Since the LED lights take 3 inputs (RGB), 24-bits are needed per row.
 - Requirements:
 - i. At least 24-bits
 - ii. Parallel output
 - iii. 3.3V operating mode

2.3.2 Sensor Board

The sensor board is a 1 in. x 1 in. PCB that sits underneath each square on the chessboard. It contains a Hall-effect sensor and an RGB LED, along with control circuitry (i.e. transistors) for the LEDs. The connection to each board will be a 4-wire connection (3 for the RGB LED and 1 for the analog output of the sensor) along with a 2-wire connection for the power and ground line that will be daisy-chained along each of the 8 rows.

- **Hall-Effect Sensor:** The hall-effect sensor will operate at 3.3V and be able to detect polarity of a magnetic field. It will also need to exhibit a linear relationship between output voltage and magnetic field strength in order to be used to detect which piece is what.
 - Requirements:
 - i. Analog output in range of 0-3V
 - ii. Linear relationship between magnetic flux and output voltage
 - iii. 3.3V operating mode
 - iv. Low-current pull (<0.1mA/sensor)
- **RGB LED:** The RGB LEDs are responsible for signaling to the user based on the user's actions. When a piece is picked up, they will signal the possible moves that can be made with that piece. If the piece is placed in an invalid square, the LED will alert the user by flashing red on that square. The LEDs will be controlled by a transistor and resistor for each color that will receive an input from the Signal Interface block.
 - Requirements:
 - i. 20mA current draw
 - ii. Must be visible under frosted acrylic (>1000 mcd should be sufficient)
 - iii. 3 independently controlled color channels

2.3.3 User Interface

The user interface serves to display outputs and take user inputs. It will feature an LCD screen that will show the chess clock as well as the menu for selecting different operation options (such as clock setting or hint toggling).

- **Character LCD Screen:** Character LCD screen to display the chess clock and options menu to an user.
 - Requirements:
 - i. Backlit
 - ii. 8x2 Character Space
 - iii. SPI communication interface
 - iv. 3.3V operating power
- **Buttons:** 6 general buttons + 2 higher accuracy switches that will allow the user to interact with the board settings. The 6 buttons will be used for “shift menu left”, “shift menu right”, “select”, “back”, “sync Bluetooth”, and “toggle hints”. The higher accuracy switches will be used for manual stopping of the chess clock.
 - Requirements:
 - i. Pressable buttons
 - ii. Responsive switches for chess clock stop switches (ie. mechanical switch/touch sensor - the user knows exactly when the switch is triggered)

2.3.4 Power

The maximum current draw of the board given the maximum draw from each component is a little under 4 A therefore we need a battery solution that can provide at least 4000mAh to insure 1 hour of operation while realistically providing around 4+ hours of operation. The Power block will also include a charging circuit and a voltage regulator.

- **Batteries:** Rechargeable battery to power whole board.
 - Requirements:
 - i. Minimum of 3.3V
 - ii. >4000mAh power
 - iii. Rechargeable
- **Charging Unit:** Acts to allow the battery to be charged. Will contain a power jack to allow the battery to be charged from a wall plug.
 - Requirements:
 - i. Takes an input of 5V
 - ii. Regulates the battery voltage level to ensure complete charging
 - iii. Consumes minimal power when not operating
- **Voltage Regulator:** Regulates the voltage output to the rest of the circuit at 3.3V and provides over-load safety features.
 - Requirements:
 - i. Takes the voltage of the battery as an input
 - ii. Outputs 3.3V \pm 5%
 - iii. At least 75% efficient

2.4 Risk Analysis

The sensor board poses the greatest risk for completion of this project. For consistent sensing of the magnetic fields of the different magnets in each piece, all 64 sensing boards must be physically placed at the same height. It is also unknown to what level of accuracy the field strengths will be able to be distinguished; testing and further mathematical analysis is required to determine the minimum difference we need in the strengths of the magnets in the pieces for them to be distinguished. Even if one board starts to malfunction, the entire game could be at risk since the moves to that square and every subsequent move cannot be tracked or logged. This also includes the fact that each of the 64 boards must be hand-soldered, which could be vulnerable to mistakes. We must also consider the placement of the piece above the sensor. If the piece is offset by a significant distance, the magnetic field strength might be interpreted as a different type of piece, thus leading to errors in game tracking. This level of uncertainty and the fact that this is the main source of gathering board state information means that this poses the greatest threat to completion of our project.

3 Ethics and Safety

The biggest concern for our project, in terms of ethics and safety, will come from the battery type we select. Most lithium-ion batteries (most likely choice for us) are generally safe but the charging circuit must be properly designed to prevent overcurrent or charging the battery beyond safe levels. Warnings will be placed on the product to inform users of potential hazards due to a lithium-ion battery being used. This will fulfill the IEEE Code of Ethics Conduct #1 [4].

The safety risks in magnets will be mitigated by ensuring that the housing for each piece is safeguarded from causing harm to the user. For example, a common problem when dealing with magnetic objects is having skin being pinched between objects, which would result in harm to the user. This will be mitigated by having lower strength magnets and housing the magnets in a safe way. Using the IEEE Code of Ethics Conduct #9, the primary factor driving the decisions for the housing will be the safety of users.

Our driving purpose for the project stems behind IEEE Code of Ethics Conduct #5. By improving the way the public perceives the role of technology in games, we can build a modern way to learn and play classic games. Many people are hesitant to incorporate technology into “the way things are done”, but, being shown how technology can be included to not only improve the way games are played but also can be completely non-disruptive to the traditional feel, the public perception of technology can be revised.

Other ethical issues we will handle include non-discriminatory practices and having a cohesive team according to IEEE Code of Ethics Conducts #8 and #10. We will operate as a team in a non-discriminatory way, assigning work fairly and assessing progress only on quality. We will treat everyone that we interact with through the work on this project fairly. We will also work together with our TA to ensure that we are delivering the best possible product that we are capable of and that each team member's ideas are considered and implemented.

4 References

- [1] <http://en.chessbase.com/post/che-redux-how-many-people-play-che->
- [2] <http://files.eric.ed.gov/fulltext/EJ1079541.pdf>
- [3] https://www.amazon.com/Excalibur-911E-3-Master-Electronic-Checkers/dp/B0042VIHMQ/ref=pd_sbs_21_3?encoding=UTF8&pd_rd_i=B0042VIHMQ&pd_rd_r=39KGZJC21D9GEFQAXMZE&pd_rd_w=1ojli&pd_rd_wg=Zmt4H&psc=1&refRID=39KGZJC21D9GEFQAXMZE
- [4] <http://www.ieee.org/about/corporate/governance/p7-8.html>
- [5] <http://www.chessgames.com/chessstats.html>