ECE 445

Senior Design

Project Proposal

Interactive Chess Teaching Chessboard

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Spring 2026

Group 49

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1 Introduction

1.1 Problem

Chess is a widely recognized educational game that promotes critical thinking, pattern recognition, and strategic planning, making it a common activity in elementary and middle school enrichment programs. However, the game has a relatively high barrier to entry for beginners, particularly children, who often struggle with understanding how each piece moves, determining which moves are legal, and recognizing when they are in check or checkmate. These foundational difficulties can slow learning, reduce engagement, and discourage continued participation, especially in group settings such as school chess clubs where instructor attention is limited.

While electronic and "smart" chess boards exist that provide real-time feedback and move guidance, these systems are typically expensive and designed for individual consumers rather than classroom environments. Their cost and complexity make them impractical for deployment in school clubs or educational programs that operate under tight budget constraints. As a result, there is a gap between low-cost traditional chess boards, which offer no instructional feedback, and high-end smart boards that are inaccessible to most schools. This project seeks to address this gap by developing a low-cost smart chess board that provides immediate, visual guidance on legal moves, helping beginners learn the rules of chess more intuitively while remaining affordable and suitable for educational use.

1.2 Solution

The proposed solution is a low cost, embedded smart chess board that provides real time visual feedback to assist beginner players in learning legal piece movement and basic gameplay rules. When a player lifts a piece from the board, the system will detect the change in a board state and illuminate all legal destination squares using LED lighting beneath each square. This immediate visual guidance reduces the cognitive load associated with memorizing movement rules and allows players to focus on strategy. Additionally, the board can optionally display a recommended move generated by an onboard chess engine, which can be enabled or disabled through a simple user interface to support different learning goals.

The system will be implemented using a ESP32 microcontroller to manage board state tracking, move validation and engine computation. Each chess piece will contain a small neodymium magnet, and each square will contain a reed switch sensor to detect the presence or absence of a piece. By continuously maintaining an internal board representation in memory, the microcontroller can determine when a piece is lifted and calculate all legal moves according to chess rules. Addressable LED strips, segmented into eight rows and daisy-chained for control, will illuminate specific squares based on computed legal moves. A small OLED display and push button interface will allow users to toggle engine assistance, handle special cases such as a pawn promotion, and provide feedback for illegal moves or system status. Power will be supplied through a mobile battery pack, with appropriate current management to support the LED load.

1.3 Visual Aid

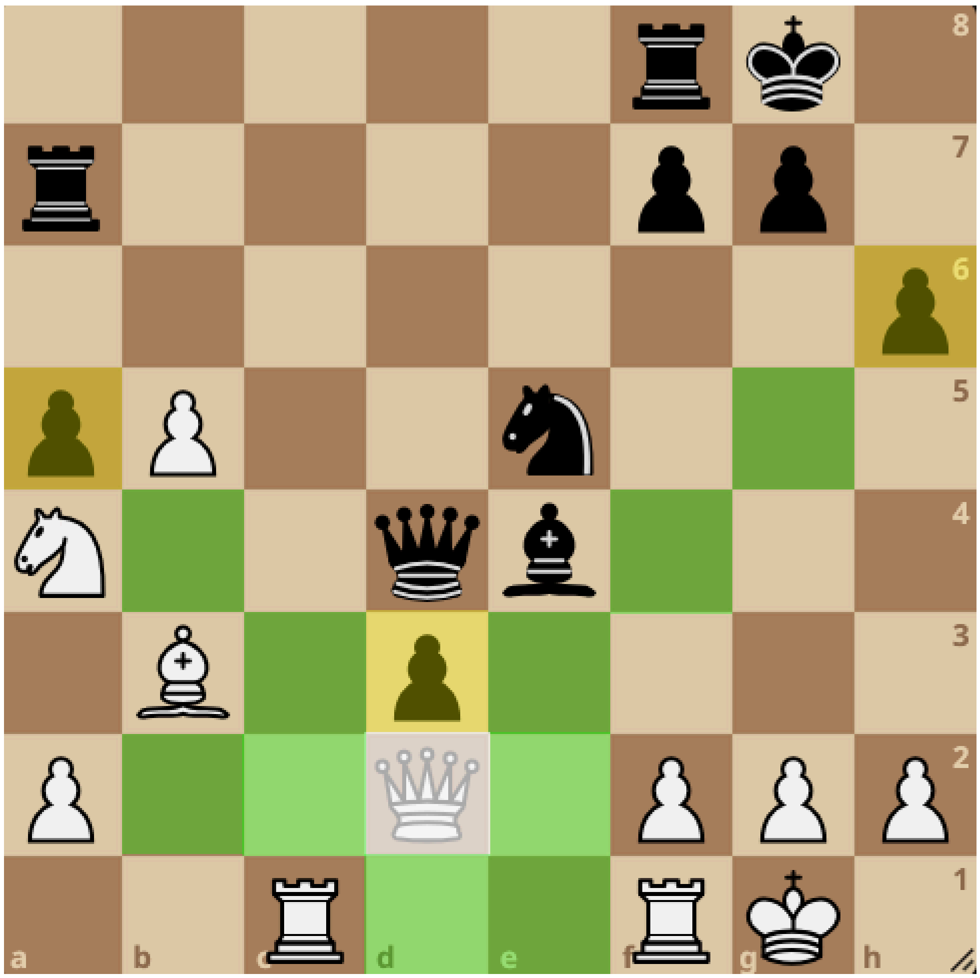

Figure 1: Visual Aid

The white queen is picked up, which will be indicated by a light underneath. The legal moves the queen can make are all lit up by LEDs but moves that result in a capture are indicated with a different color.

1.4 High Level Requirements List

1. Correctly display moves that are legal in chess at the current position and the best move (if turned on) within 5 seconds
2. Detect when board reaches an error state and execute subroutine to return to valid state
3. Whole system can run continuously for 1 hour without intervention

2 Design

2.1 Block Diagram

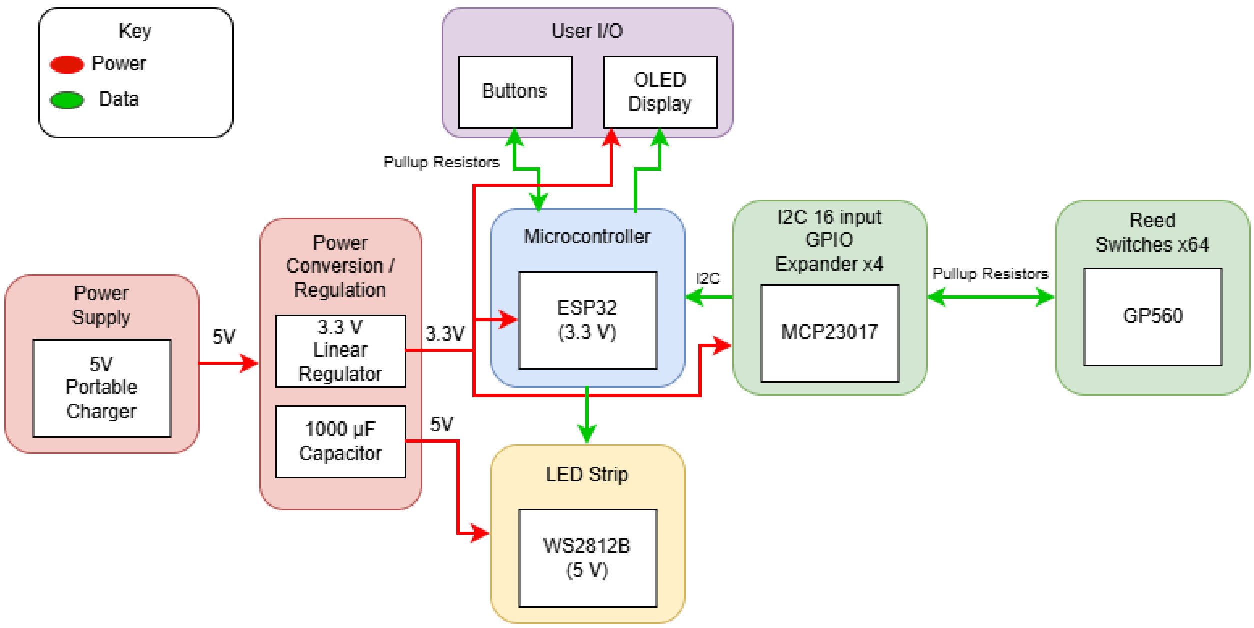

Figure 2: Block Diagram

2.2 Subsystem Overview

2.2.1 Power Supply and Conversion/Regulation

A portable charger supplies 5V to the entire system. The portable charger that we intend to use is a power bank from VOLTME with a capacity of 10000 mAh. This should be able to supply 3A to our system for a little over three hours. Since we wish to target players who are at a beginner level, this should be sufficient. The power bank can also easily be swapped for one with full charge when the charge of one has been depleted.

A linear regulator receives 5V from the power supply and steps it down to 3.3V. This voltage level is required by the OLED display, microcontroller, and GPIO expanders. The power supply also directly charges a 1000 uF capacitor. This capacitor provides power to the LED strip. Providing power to the LED strip will protect the LEDs from sudden surges or dips.

2.2.2 User I/O

Along with the physical chess pieces, users interact with the chess board through buttons and an OLED display. The OLED display communicates information about the overall system. The buttons allow the user to change the behavior of the system based on that information. For example, if there are issues with the function of the chess board, a recovery protocol can be initiated through this subsystem to address those issues. The user can also interact with this subsystem to select an option to show the best move that can be made based on the current board state. The best move is determined by the microcontroller using a chess engine and this information is conveyed through the LED strip.

2.2.3 Microcontroller

The microcontroller, an ESP32-S3, uses sensor data to determine the location of the chess pieces and outline the state of the board. The microcontroller also stores this information and uses that data to determine all of the possible moves for a specific piece. If requested, it will also determine the best move based on the current state of the board. The microcontroller polls the reed switches to receive data on the location of each piece on the board. The buttons on the board also send information to the microcontroller. It then controls the OLED display and the LEDs on the LED strip.

2.2.4 LED Strip

An addressable LED strip, divided into eight segments, is placed under the board. Each segment is divided further into eight smaller sections, one for each square in the rank. Each LED receives signals from the microcontroller that determine when the LED turns on and the color that the LED displays when it is on. The color of the LED will convey different kinds of information that are relevant to chess.

2.2.5 Sensor System

Reed switches will detect when a chess piece has been placed on or removed from a specific square by reacting to magnets embedded in the pieces. There will be 64 reed switches, one for each square on a chess board. Every reed switch will be connected to a GPIO expander. This will allow information about piece location to be sent from the reed switches to the microcontroller.

Four GPIO expanders are required because the chosen microcontroller cannot natively support receiving data from all 64 reed switches. One GPIO expander is connected to 16 reed switches. The GPIO expanders use I2C (Inter-Integrated Circuit) to send sensor data from the reed switches to the microcontroller.

2.3 Subsystem Requirements

Power

- The regulator must always provide 3.3V ± 0.2 V to the 3.3 V components even if the LEDs suddenly draw a lot of power
- The whole system should be able to run stably and continuously for at least 1 hour

User I/O

- When an I/O button is pressed once, only detect one button press by using software debouncing
- User actions (Selecting an option, agreeing to a prompt) should be reflected on the OLED display within 0.2 seconds

Microcontroller

- Find a viable legal move for every legal chess position
- Poll all 64 squares, debounce the inputs and update the internal board state within 0.1 seconds

LEDs

- Every chess board square can be clearly and independently lit up

Sensor System

- A chess piece placed on a chess square will always be detected and only trigger the reed switch of that corresponding spot

2.4 Tolerance Analysis

Reed Switches

One critical concern with the reed switches is how close the magnets under the chess pieces need to be to activate them, and if a magnet that is too strong will activate the reed switches on adjacent squares. The reed switches that we plan to use are the SW GP560/15-20 AT, which are activated by 15-20 Ampere-Turns. Calculating this exactly is very difficult so we will need to use some assumptions and approximations. First finding magnetic strength is usually in units of Gauss not Ampere-Turns, and there is no simple way to convert from Ampere-Turns to Gauss. According to an article about the problem of relating the Ampere-Turns units of a reed switch to Gauss, you can assume that about 1 Gauss per reed switch Ampere-Turn will activate the reed switch when both magnet poles are near the two ends of the switch [8]. This approximation assumes optimal magnet reed switch configuration where the magnet is sitting vertically positioned above a horizontally positioned reed switch. Using this, in a worst case scenario the reed switch must be activated by 20 Gauss. To get a good picture of what the magnetic field of our N42 magnets looks like, we used a website which uses collected measurements of real magnets to generate a plot of magnetic field versus distance for given magnet dimensions [10]. We plugged in the dimensions and grade of our magnets[9] and found that our worst case distance to get 20 Gauss is about 7mm. Since our sensors will be right under our chess surface, and the surface needs to be thin to let light through, this distance is achievable. For seeing if magnets will activate adjacent switches we will assume that it takes a worst case 15 Gauss. Assuming that the reed switches are only 3mm under the surface of the chess board, then a reed switch located a distance of 5.9 mm away would be at 15 Gauss. This means the space between our reed switches needs to be larger than ~6mm, which is totally doable as a chessboard with that spacing is incredibly small. Overall, getting our magnets close enough to activate the reed switches is a possible concern and pieces activating adjacent reed switches is extremely unlikely and not something we need to worry about.

Power Consumption

According to the WS2812B datasheet and component documentation from Cirkit Designer [3], each WS2812B LED can draw up to about 60 mA at full brightness when all three color channels are driven at maximum drive current (approximately 20 mA per channel). If we light only 1 LED per square, this means 64 LEDs total. In the worst case: $I_{max} = 64 * 60mA = 3.84A$. This would exceed our power bank max output of 3A from just the LEDs alone. However, based on the use case of lighting up legal moves, we would light up at most 28 LEDs at once if we placed a queen in the middle of the board. This results in a max current draw of 28 * 60mA = 1.68A. So in our worst case scenario, we would be well under the specifications of the power bank. Additionally, we will likely run the brightness at 50% or under further bringing down the current draw to 0.84A.

The power bank is specified at 10000mAh for the internal lithium battery at 3.6V. Actual power output is 10Ah * 3.6V = 36Wh (Energy = Capacity * Voltage). We can assume that the internal converter is not 100% efficient and assume a conversion efficiency of 80% based on estimates used by TexasInstruments [4], and take the usable power at 36Wh * 80% = 28.8Wh.

The LEDs will draw at max 840mA at 5V for 5V * 840mA = 4.2W. According to datasheets [6], the ESP32-s3 with Wi-Fi and Bluetooth disabled, actual active CPU current will be lower than the listed RF-receive current 91mA. This means for the MCU, power draw is 91mA * 3.3V (input voltage) = .3W. The OLED draws just .04W during normal operations according to the datasheet [5]. The GPIO expanders datasheets show that they draw 1mA when active [7]. Multiply with the input voltage of 3.3V for 3.3mW of power draw. Added together, 4.2W + .3W + .04W = .0033W = 4.5433W. To get the operating time, we divide the watt hours by the watts used: 28.8Wh/4.5433W. = 6.34 hours of operation. This should be sufficient to reach our goal of one hour of continuous operation.

3 Ethics and Safety

3.1 Ethical Considerations

This project involves the design and construction of a smart chess board using embedded electronics, sensors, and software to assist users during gameplay. While the system does not collect personal data, several ethical considerations are relevant during both development and potential use.
In accordance with the ACM Code of Ethics [2], computing professionals are obligated to avoid harm (ACM Section 1.2) and to be honest and trustworthy about system capabilities and limitations (ACM Section 1.3). In this project, the chess engine provides recommended moves based on algorithmic evaluation, which may be imperfect or constrained by computational limits. To comply with ACM Section 1.3, all documentation and user interfaces will clearly state that move recommendations are advisory and not guaranteed to be optimal or correct. No claims will be made that exceed the system's verified capabilities.

The ACM Code also emphasizes careful evaluation of risks associated with computing systems (ACM Section 2.5). During development, risks related to incorrect piece detection, sensor failure, or misleading visual feedback will be analyzed and documented. Design choices such as redundant sensing checks and clear error states will be used to reduce the likelihood of misleading outputs.

The IEEE Code of Ethics [1] places primary responsibility on engineers to protect the safety, health, and welfare of the public (IEEE Principle 1). Although this is a low-voltage, non-commercial system, the project will be designed conservatively to minimize electrical, thermal, and mechanical hazards. Additionally, IEEE Principle 3 requires engineers to be honest and realistic in stating claims or estimates based on available data. This principle directly informs how system accuracy, detection reliability, and limitations are described in the proposal and final documentation.

No personal data collection, surveillance, or user profiling is involved in this project, reducing concerns related to privacy or data misuse. All third-party software components, such as chess engines or embedded libraries, will be used in accordance with their licenses and properly cited, consistent with ACM Section 1.5 on respecting intellectual property.

3.2 Safety Considerations

Electrical and Power Safety:
The system is powered by a consumer-grade mobile power supply operating at low voltage (approximately 5 V), which significantly reduces shock risk. However, LED strips represent a relatively high current draw. To address this, current-limiting, appropriate wire gauge selection, and capacitors rated well above operating voltage will be used. These measures align with IEEE Principle 1, which emphasizes responsibility for public safety.

Thermal Safety:
Sustained LED operation and voltage regulation may generate heat. Components will be operated within manufacturer-specified limits, and physical layout will allow for heat dissipation to prevent overheating or damage.

Magnetic Safety:
Neodymium magnets embedded in chess pieces pose a minor risk if exposed or removed. Magnets will be permanently enclosed within the pieces, and the system will be labeled as not intended for young children. This supports IEEE Principle 1 by mitigating foreseeable physical hazards.

Development and Mechanical Safety:
During construction, soldering, sharp leads, and exposed conductors present risks. These will be mitigated through proper lab practices, enclosure of electronics, and compliance with campus laboratory safety policies.

3.3 Regulatory and Standards Considerations

This project complies with applicable campus safety policies governing electronics prototyping, soldering, and battery usage. Because the system is not intended for commercial distribution, formal FCC certification is not required; however, reasonable electromagnetic interference mitigation practices will be followed due to the ESP32 MCU’s wireless capabilities.

Overall, by adhering to the ACM Code of Ethics [2] (Sections 1.2, 1.3, 1.5, 2.5) and the IEEE Code of Ethics [1] (Principles 1 and 3), this project aims to demonstrate responsible, safe, and transparent engineering practice while minimizing the risk of harm or misuse.

4 References

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