CHESSBOARD: An Interactive Chess Learning Aid

(Technical Report)

How International Collaboration in Scientific Research Persists in a Society of Geographical and Political Barriers

(STS Research Paper)

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By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Since 2020, chess has increased in popularity with the release of the Netflix show, the Queen's Gambit (Yang and Boulter 2023). During the COVID-19 pandemics, individuals quarantined at home began to adopt new hobbies such as chess. As a result, there has been a surge in account creation on chess-playing sites such as Chess.com where people learn the rules of chess and play against others on a virtual platform. For my Capstone project, my team introduces the Chess Helper, Evaluator, and Study Supporter to Boost Observation, Acumen, Reasoning, and Dexterity (CHESSBOARD). The goal of our project is to design and build a smart chessboard that will aid beginner players in developing their game playing skills using visual markers and hints. Instead of learning chess on computer or web applications, players may begin their learning with physical play on a tournament-size chess board. Because the teaching aspect is implemented through visual elements, our project can help everyone across the barriers of language and culture. The game of chess can be played by anyone. Professionals from different countries, cultures, and languages travel to chess tournaments to play against each other. Chess is a competition of great minds. But what does it look like when these people work together, rather than work against each other?

A medium where such a type of international cooperation occurs is scientific research. At conferences and research facilities, scientists and engineers travel from all over the world to share their intellect, collectively expanding human knowledge through scholarly production. These professionals come from different countries, speak different languages, and practice different work cultures. Yet, how does such international collaboration persist through so many geographical and political barriers?

Technical Project - CHESSBOARD: An Interactive Chess Learning Aid

The Electrical and Computer Engineering (ECE) major design experience (MDE) requires the project creation of a physical prototype utilizing a printed circuit board (PCB) and microcontroller as its primary components. In their Capstone projects, students are to employ the knowledge and skills gained from their semesters in the ECE curriculum. To satisfy these requirements, my team introduced CHESSBOARD. The purpose of CHESSBOARD is to streamline the learning process for chess players as they advance their skills from a beginner to intermediate level. CHESSBOARD teaches users how to set up a chess board, move chess pieces, develop game strategy, understand chess notation, and practice playing in timed games. The physical board is etched with icons to indicate how the chess board should be set up. To communicate the moves a player can make, light-emitting diodes (LEDs) light up underneath the board tiles, displaying where a player can move his or her selected piece. Other learning features include a hint button, undo button, and clock mode. When the hint button is pressed, tiles light up to indicate the best possible move a player can make during their turn. Because beginner chess players are expected to make mistakes, we also incorporated an undo button that allows players to revert back to a previous board state. If the undo button is pressed, tiles light up to indicate where the player must return their last moved chess piece. To familiarize users with chess notation and allow them to review their performance, a post-game transcription is made available for them to study and improve their strategy. As their skills develop to a more intermediate level, users can utilize the built-in chess clocks to practice faster thinking during a play under the pressure of time

The hardware is split into two modules: the main chess board and the clock box. The main chess board module is illustrated in the block diagram as seen in Figure 1 which constitutes the sensor boards and RGB LED arrays. Underneath each row of tiles is a PCB with eight Hall-effect sensors and an analog multiplexer, used to determine the current board state (which chess piece is above each tile). Within each chess piece is a magnet placed at a variable distance from the top of the board, associating the chess pieces with a certain magnetic field strength to be detected by the Hall-effect sensors. Underneath each row of tiles is also an array of eight LEDs. The sensor and LED subsystems connect to the clock box module by a D-Bus 15-pin connector.

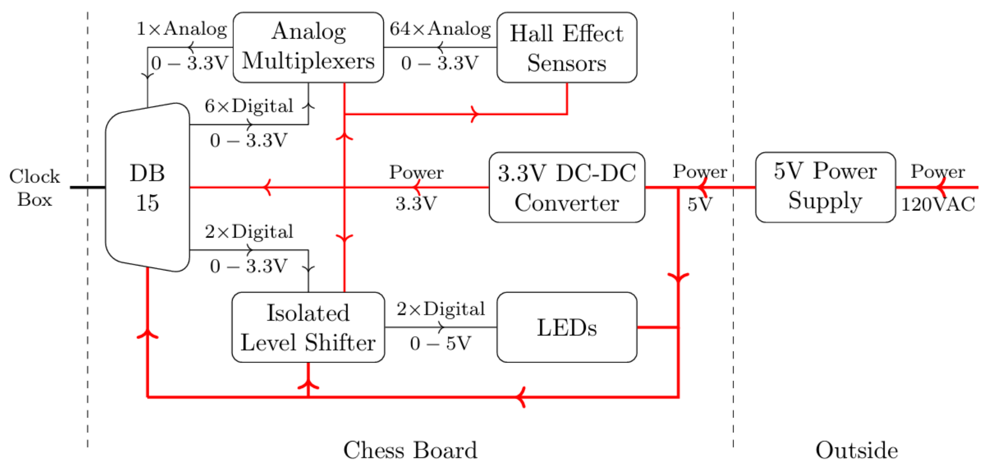

Figure 1. Block diagram of the main chess board module.

The clock box module is illustrated by the block diagram in Figure 2, outlining elements such as the liquid crystal displays (LCDs), buttons, microcontroller, and RPi5. LCDs function as the game clocks, displaying player times. There are seven buttons with functions to request hints, change clock modes, end player turns, and undo moves. The software subsystems involve the MSPM0 Launchpad microcontroller and the Raspberry Pi 5 (RPi5), illustrated by the block diagram in Figure 2. The MSPM0 interfaces the hardware including the sensors, LEDs, buttons, and LCD. The RPi5 runs the Stockfish chess engine to manage the board state, communicating with the microcontroller via UART.

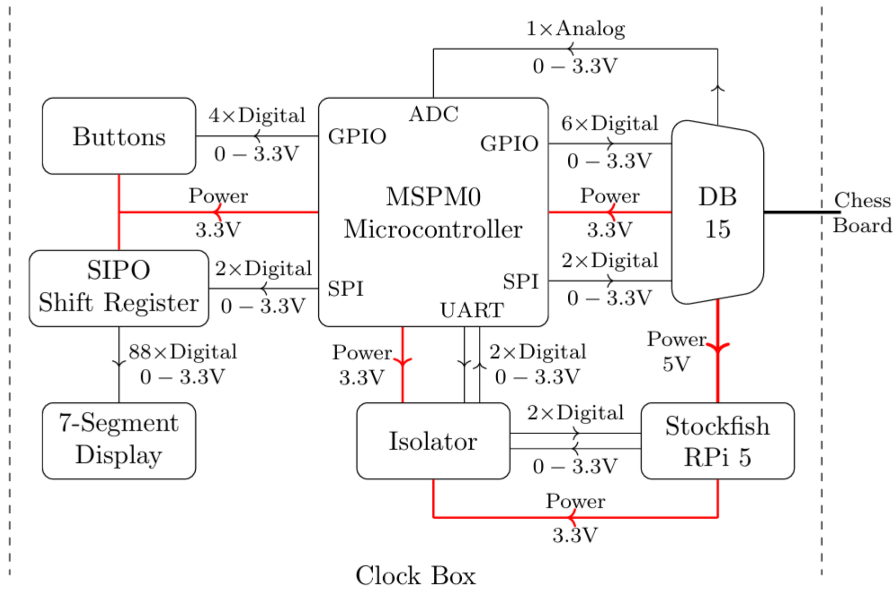

Figure 2. Block diagram of the clock box module.

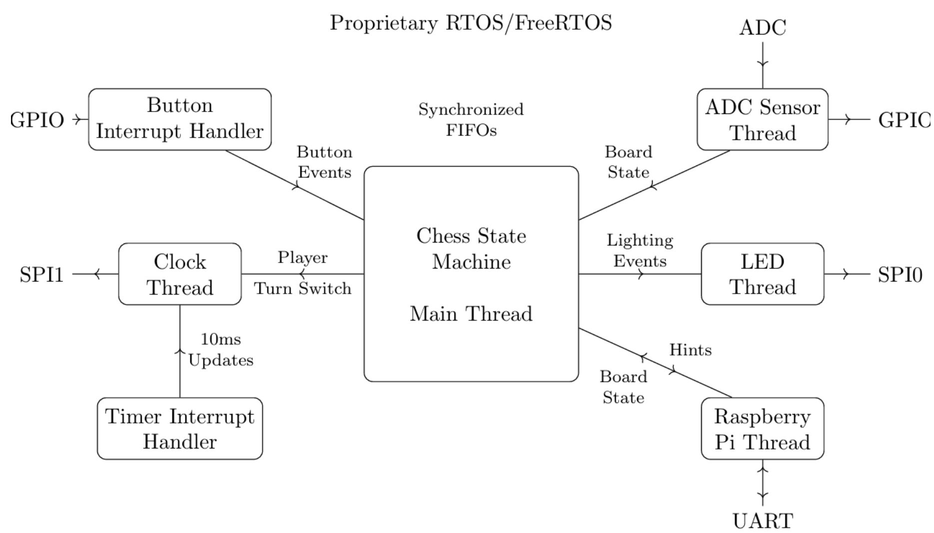

Figure 3. Software block diagram.

Similar smart chess boards have been implemented in the past and have been proven successful such as the Autonomous Chess Robot and the Tactile Chess project. The Autonomous Chess Robot was conducted at the University of Virginia ECE department in the Fall 2022 semester (Alchaar, 2023), and the Tactile Chess project was conducted at the Carnegie Mellon

University ECE department in the Spring 2023 semester (Balajee et al., 2022). The objective of the Autonomous Chess Robot was to help chess players develop their skills by practicing against a robot. The project utilized a gantry system to physically move chess pieces according to decisions provided by Stockfish, an open-source chess engine. An addition of a mechanical gantry module introduced a new complexity of motor operation control in both hardware and software systems. The objective of the Tactile Chess project was to produce a prototype that would allow visually impaired chess players to participate in physical game play. To facilitate the game, an audio module was used to communicate the player turn, legality of a move, and moves made by the opponent. Hall-effect sensors underneath each tile are used to determine the board state. To verify the legality of a board state, and the cases of stalemate or checkmate, the Stockfish was also used. At the end of the semester, each group produced a successful prototype.

STS Project - How does international collaboration in scientific research persist in a society of geographical and political barriers?

The International Chess Federation (FIDE) is known for sponsoring the World Championship and other events where professional chess players travel internationally to compete in chess tournaments. Chess players from different geographical, linguistic, and cultural backgrounds often play against each other in competitions. Because the game of chess itself can be played by anyone and everyone, its universality establishes it as a technology that can promote internationalism. A similar mode of internationalism is scientific research where scientists and engineers from different countries and backgrounds work together to expand the collective understanding of how the universe works. These professionals may network with each other at conferences, present their research to each other, or conduct research with each other at a laboratory. For my Science, Technology and Society (STS) research topic, I investigate the universality of scientific research and how it facilitates international collaboration that persists in a society of geographical and political barriers?

My STS research will analyze the importance of international collaboration in scientific research and how it persists through geographical and political barriers within the framework of social constructivism. Social constructivism entails the creation of knowledge and phenomena due to social interactions and relationships, rather than natural laws. Social constructivism can be used to support the importance of international collaboration in scientific research and technological advancement that affect the greater majority. To consider how these developments may affect populations worldwide and implement such considerations in the technologies they produce, it is beneficial for contributing parties to have an array of perspectives that come from diverse geographical, political, and cultural backgrounds. Research by Cech et al. (2017) uses a social constructivist framework to investigate the epistemological dominance that marginalizes Native American students in higher education. This may be used to support the importance of international collaboration in scientific research which promotes the inclusion of minority backgrounds and perspectives.

Social constructivism may also be used to analyze the ways in which international collaboration persists through geographical and political barriers with the support of funding agencies. Preliminary research shows how funding agencies play an active role in the materialization of international cooperation. Funding agencies invest in programs that promote international cooperation, inviting scientists and engineers from other countries to work in domestic research institutions, as well as encouraging domestic employees to perform research in other countries (Feitosa et al., 2023). Funding allows researchers to overcome geographical barriers more easily with reduced travel expenses. In some instances, governments even encourage international work with foreign adversaries, and it is worthwhile to investigate their motivations.

In the past, governments have relaxed policies in order to allow international conferences and research to take place. A significant example is when the United States and the Soviet Union allowed members from the other countries to attend high-energy physics conferences within their borders, despite the high political and military tensions during the Cold War (Hoff, 2024). Because so many actors invest money in international research, and even prioritize international collaboration over national security, these institutions must believe international collaboration in scientific research to be necessary. It has been seen in the past that such collaborations have led to the emergence of new fields including high-energy physics. I argue that internationally collaborative research, compared to domestic research, is the gateway to technological advancement and scientific discoveries.

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To understand how individual scientists and engineers participate in international collaboration and overcome geographical and political barriers, I explore the process of international research through a commodity chain analysis lens by treating the researchers as the target commodity. This will involve the investigation of the process by which individual researchers and institutions initiate international collaborative research and how they conduct it, as well as the challenges they face and how they overcome them. There are several studies examining the obstacles that scientists and engineers face when engaging in research with international collaborators, and the frequencies at which obstacles they occur (Matthew et al., 2020). Research by Mathew et al. (2020) surveyed 9,422 biologists and physicists from eight different countries to examine the types of obstacles faced when working internationally and how these barriers impact work. They categorized these into political, logistical, and cultural issues and discussed the discrepancies in researchers' backgrounds that result in these issues. Political barriers involve national security risks, bureaucratic processes, and nationalism. Geographical barriers mostly concern time differences and travel expenses. Work by Jang and Ko (2018) investigates the process by which countries less advanced in scientific research, specifically high-energy physics, catch up to leading countries. They discuss the barriers that caused latecomer countries to lag behind in scientific innovation, and attribute their recent growth to international collaboration.

To measure the successes of international collaboration in scientific research, several studies look at scholarly outputs such as publication rates of scientific articles co-authored by researchers from different countries, and the number of citations received. Feitosa et al. (2023) compared the success of international collaborative research made under institutional agreements to domestic scientific research and those made without agreements. They evaluated scholarly production in terms of quantity by the number of research publications made, and quality by the number times a publication has been cited.

Conclusion

For the technical project, my team designed and manufactured the CHESSBOARD to teach beginner chess players how to play the game and develop their skills through the use of visual cues and hints. We found our implementation to be successful. Because the primary mode of communication is through LEDs and chess clocks, CHESSBOARD can be used by any demographic, much like the game of chess itself. At chess tournaments, professionals travel from all over the world to compete against each other, despite geographical and political differences. Much like chess, scientific research brings together scientists and engineers who collaborate internationally, despite geographical and political barriers. To further investigate the geographical and political barriers of international collaboration in science, we may examine the proceedings of international chess tournaments in a similar political climate during the Cold War. We investigate how international collaboration persists through such obstacles with the help of funding agencies and individual action.

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