**Design and Construction of Robotic Gantry System Capable of Playing Checkers**

(Technical Paper)

**The Efficacy of Historical Narratives in STEM Education**

(STS Paper)

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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

The technical project encompasses the design and implementation of a robotic gantry system capable of playing checkers. The project fulfills the major design experience (MDE) requirement of the computer and electrical engineering programs. The requirements of the MDE are that the project uses a printed circuit board (PCB) and microcontroller (MCU), is sufficiently complex to entail a semester's worth of work from a team of 3–5. The project has been broken into various subsystems: checkers engine to calculate computer moves, gantry system to move pieces, image analysis algorithm to determine the current board state, lights and buttons for user interface, and communication between the two processors. An interesting use case for the robot is in STEM education and outreach. The result of the project is an effective hands-on demonstration of engineering. Additionally, high school students with programming experience could experiment with the two programmable processors included in the design, implementing their own checkers engines or image analysis algorithms.

The STS topic is based on the connection to STEM education. This prospectus will explore the benefits of incorporating historical narratives into STEM education. The benefits fit into two categories: improvements in retention and engagement for the technical topic, and improvements in STS education. Extensive studies have been conducted showing the efficacy of this historical-philosophical approach to science education (Schiffer & Guerra, 2015). Every development in STEM is situated within a social and technological context. Extending the lesson plan to include not just the development but also the context would allow for the seamless inclusion of STS concepts throughout the non-STS classes in the program. Additionally, students will be more likely to internalize these lessons as they are based on examples in their chosen major.

## Design and Construction of Robotic Gantry System Capable of Playing Checkers

During the pandemic, many found their phones and other screens as their only source of entertainment and relied heavily on them. Unfortunately, the blue light produced by these screens can harm sleep quality (Kimberly & James R., 2009) and this entertainment is often passive. A checkers robot provides a tactile, active source of entertainment that does not require any other participants. As previously mentioned, this project will be built up of many subsystems: motorized gantry, image analysis, checkers engine, communication protocol, electromagnets.

Starting with the system overview before delving into the subsystems. The robot will consist of two processors: a Raspberry Pi and an MSP 430. The Raspberry Pi will control the camera to take images of the board, analyze those images to ascertain the board state, and generate the robot's response. The MSP 430 will receive move instructions from the Raspberry Pi, drive the motors to execute the moves, accept input from user-facing buttons, and drive light emitting diodes (LEDs) to convey valuable information to the user. A block diagram of the system is shown below (Figure 1)

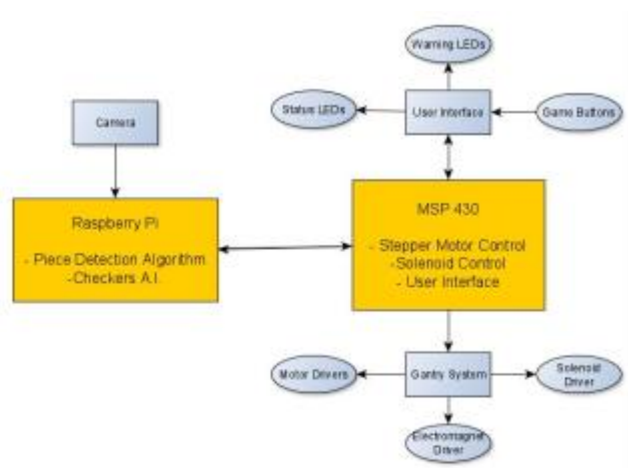


*Figure 1: Block diagram of system*

To pick up and place pieces, a combination of two electromagnets will be used. A solenoid will be used to raise and lower a second electromagnet, which will be capable of picking up checkers pieces as they will have metal disks embedded within them. Electromagnets work well for this as their magnetism can be turned on and off electronically, allowing it to both pick up and drop the checkers pieces.

The gantry (design shown in Figure 2) will be constructed primarily from aluminum and 3D printed parts. The gantry must allow for the positioning of the electromagnets above any particular square and the playing area. It must also provide a mount for the camera. It is important that the gantry is extremely rigid to allow for a high degree of accuracy when controlling the position of the electromagnets. The gantry subsystem will use stepper motors as they can be precisely controlled, allowing for sub-millimeter accuracy in positioning.

*Figure 2: 3D CAD of the gantry*

The checkers engine will implement a minimax algorithm. This algorithm is not too different from the one put forth in Claude Shannon's paper on programming a computer to play chess (Shannon, 1950). The basic idea is that the computer will go through every possible sequence for the next however many moves, evaluate all the positions reached after the moves, and choose the move that leads to the most favorable outcome, assuming optimal play from the opponent. A particularly crucial part of this algorithm is the evaluation function: given a board state, is this good for the computer player? A set of heuristic functions are used to answer this question. For example, one function evaluates the board by adding all of the red pieces and subtracting the blue pieces with kings weighted twice as much as regular pieces. The heuristic functions were taken from a pre-existing code base (Sankesara, 2019/2022).

A few buttons are included for user input. There are buttons to indicate when the robot should make its move, prompting the robot to recalibrate its camera or motor systems, and starting a new game. The LEDs are to indicate when the robot is in the process of making a move, when the human player is capable of capturing, and when an illegal move has been made.

To determine the current board state, the Raspberry Pi will take a picture of the board. The picture is then analyzed using OpenCV, a library for image analysis. It finds all of the red, blue, and yellow (for kings) pixels and clusters them, finding groupings. It can use the positions of these groupings to determine the position of each piece. Additional OpenCV functionality is used to determine the position of the checkers board and to undistort the image.

The MSP430 and Raspberry Pi will communicate with each other via universal asynchronous receiver-transmitter (UART). Both the MSP430 and the Raspberry Pi have built-in support for UART, making it ideal for this project. UART will allow for the Raspberry Pi to communicate to the MSP430 what moves it should make, and the MSP430 will be able to communicate any error flags.

**The Efficacy of Historical Narratives in STEM Education**

Often in engineering curricula, technical facts and methods are taught without any reference to the historical context of these engineering developments. Teaching through historical narratives and incorporating the context could be beneficial to STEM education. Not that this should be done for every single topic covered in every course, but for some of the major points in each course. This could benefit the students in several ways: these historically based stories will improve the memorability of the technical topics, make the material more engaging, and improve their understanding of the interplay between technology and society. Producing engineers with better technical and STS backgrounds would be massively beneficial overall as engineers are responsible for the technological advances that drive humanity forward. However, these days it is becoming increasingly clear that engineers should have an STS frame of mind as the potential consequences of technology are mounting; climate change and the increasing amount of our lives occurring on devices are prime examples.

Historical narratives will improve retention of material. Human memory is often compared to a web. Ideas with many tie-ins with other concepts will be better retained and easier to memorize. People find it easier to recall stories as opposed to floating facts. Giving students narratives to tie the facts to helps them remember the facts. This is reflected in common strategies for memorization that feature creating stories out of the material (Rust & Blick, 1972). Beyond the intuitive support of this point, studies have been conducted to empirically confirm the improvements to retention (Oaks, 1995). The study shows significant improvements to both short term and long term (5 weeks) retention of information when taught via a narrative.

The occasional historically based story will improve student engagement. People like hearing stories, especially ones related to their field of interest, so they are going to engage in narrative-based lessons. Additionally, it would be a refreshing change-up relative to the typical class. These ideas have also borne out empirically. Taylor et al. (2018) is primarily focused on digital storytelling but draws conclusions general to the efficacy of storytelling and found improvement in student engagement. An overarching narrative does an excellent job at holding the attention of students. It also ensures students understand the significance of what they are learning.

Beyond the benefits to the technical topic, this would also introduce an STS component previously absent from these courses. Any recounting of a major development in an engineering field will come with some good examples of the interplay between society and technology. This is easily demonstrated by looking at a couple of examples.

In ECE 2630, the concept of alternating current (AC) is covered. This relates to what has been dubbed The Current War (Ings, 2019), a bitter dispute between Tesla and Edison to determine whether AC or DC would become the standard going forward. Edison funded the invention of the electric chair in order to tarnish the reputation of AC despite publicly denouncing capital punishment (Holodny, 2014). Now that all is settled, AC is used to transfer power across large distances, and DC is used to power most devices. This is a good example of the far-reaching consequences of developments in the field, and it shows that two ideas thought to be opposed would go on to be used in tandem to completely revolutionize the world.

In ECE 3209, transmission lines are covered. Prior to the first trans-Atlantic transmission line, communication between the Americas and Europe meant letters via ships. Additionally, the story of the first trans-Atlantic transmission line is representative of a transition in the field of electrical engineering: from an art of intuition to embracing mathematical models based on physics. Central to the story are Lord Kelvin and the head engineer, Whitehouse. Whitehouse did not believe the analysis performed by Lord Kelvin and this led to the premature end of one of the early attempts (Klassen, 2007). Subsequent developments in theory brought us past the original transmission times, which were measured in minutes per word, and enabled the current state of globalization.

## Research Question and Method

I plan to research the efficacy of historical narratives in STEM education. For this prospectus, the necessary research has been done to give credence to the idea that this is beneficial. However, the prospectus only scratched the surface. To fully understand this question, research would need to be conducted on educational frameworks, common pitfalls (Norris et al., 2005), and more research on the concrete benefits. If possible, I may also interview a couple of professors on the subject or integrate such a lesson into my work as a teaching assistant and interview some of my students after. I would also like to flesh out one or two lesson plans to serve as examples and for future testing.

## Conclusion

To address the lack of non-screen based single-player entertainment, a checkers playing robot will be designed and built. To improve engineering education to prepare us for the increasingly complex engineering problems associated with technology more thoroughly integrating with society, a historical narrative-based approach to lessons will be put forward in the STS paper. This prospectus has shown preliminary research done to support the potential benefits of introducing historical narratives into engineering classes, and the conceptualization of the checkers playing robot.

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