Chessboard with Feedback for Learning Rules and Strategy

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Abstract
Learning a set of rules and strategy, such as for the game of chess, can be difficult. The optimal way for a person to learn is based on their primary learning style. Three of the learning styles have been classified as visual, kinetic, or auditory. Rules of chess are often presented as written or verbal instructions that may be of less benefit to people who are primarily visual or kinetic learners. Even computer chess games that only utilize the keyboard or mouse for user input may be of less benefit to kinetic learners. We are developing an interactive chessboard system that will benefit learners who are primarily visual and kinetic. The system has real chess pieces on a real board, with an internal digital controller that can light up selected square positions of the chessboard. The user selects a chess piece to potentially move by pushing down on this piece to activate a switch. Then all of the possible locations where this piece could move will be lit up. The kinetic interaction would be similar to that of a conventional chess game, not requiring additional user input of location and type of piece to the digital controller. The additional feedback of lit up squares should aid understanding the limitations of each type of piece and how the game might progress. The techniques used in this system will aid cognitive development for learning complex rules and strategy. Such development will enhance the future mastery of engineering tasks that also involve complex rules and strategy.

Introduction
Mastering game theory is difficult. One example of this is the board game of chess. To aid learning the rules and strategy, or to facilitate playing by oneself, many tools are available commercially, including text manuals, computer programs, hand held electronic devices, and electronic chess systems. Many people have become skillful chess players with the utilization of one or more of these tools. However, not all types of people are optimally assisted by these available tools. Different people have different optimal learning styles. Seven types of learning styles have been identified, which individuals use to learn or gain knowledge. Any combination of these styles can be used but individuals often primarily utilize one or two learning styles [1]. The following descriptions of learning styles classify the preference of an individual while learning. Social learners prefer to work in groups while solitary learners gain more working on their own. Aural learners use sound and music to learn while verbal learners use speech and words either written or spoken. Visual learners learn by seeing how something is done through either pictures or images. Logical learners learn by using reasoning or systematic processes. Physical learners use primarily the sense of touch through the use of their hands. Of these seven learning styles, experts have identified three main types of learning styles that different people have. Though elements of each style help a person to learn, many people benefit primarily from a single learning method. These three are visual, kinetic, and auditory [2].

Visual learners learn by seeing how something is done before they try it on their own. They function best with diagrams, pictures and colors, and excel with motion and video stimuli [3]. They are often more attracted to artistic scenery, patterns and aesthetic flow. This group would be most likely to say “Show me how this works” to learn about a new concept or procedure.

Kinetic learners benefit by being able to physically manipulate aspects of the concepts being learned. Examples include athletes, who continually manipulate physical objects and their own bodies to play their respective sport. Kinetic learners benefit by feeling, doing, and may have a tendency to tinker with whatever is in front of them. These learners would be most likely to say “Let me do this to understand how it works” [3]. Part of the learning method is trial and error.

Auditory learners benefit primarily from hearing about what they are trying to learn. They are typically oriented to musical or verbal stimulation, such as at a music concert or a lecture. These learners excel at interpreting what is said to learn new concepts. This group would most likely be heard saying “Tell me how this works” and learn by absorbing experience by listening to a more informed individual who they are communicating verbally with [3].

Learning a complex game like chess is difficult. A master of chess, who has plenty of time, patience, and ability to explain, may be the ideal teacher, but such cases are rare. Many systems are commercially available for chess education and training. Books and computer programs are widely available. Chess starter kits typically include a board, pieces, and a chess clock. Many electronic chessboards are primarily designed for playing against a computer opponent. Such a system can provide a good learning environment, but lacks instruction and advice on strategy or skillful play. These types of systems simply teach a player how to play one step at a time, as opposed to thinking several moves ahead, which is how masters develop strategy for the game.

Need and Proposed Solution

No available chess systems on the market optimally benefit both visual and kinetic learners. A system for chess that would provide a simple and easy way to understand using the visual and kinetic environment would help those types of learners understand and develop skill at the game of chess. This project designed, built, and tested a prototype of such a system. The design allows for kinetic learners to manipulate the pieces and for visual learners to see all the places where the selected piece can move. The board was designed to display all available moves for a selected piece to better illustrate the danger zones and safe zones for each move. This should help the player better visualize how the game might progress from each possible move. Kinetic learners will also benefit from this design through the way that they interact with the game. To select a piece the player pushes down on the piece to connect a switch. The system will then show where that selected piece can move, by lighting up those particular squares. The kinetic learner then learns the movement of the piece by moving the piece to one of the possible locations and pushing down on that location to finalize the move. This method will help a user learn the movement of each type of piece, not just visually but by physically manipulating the pieces on the board. This prototype was designed to keep all of the classic chess set design and interaction, while integrating a computer program to assist the learner. Thus, the user interacts directly with the chess pieces and does not directly use a computer program or graphical user interface (GUI). The low cost and ease of use will enable widespread application of the system, including people who are primarily visual and kinetic learners, to begin learning the game of chess.

Materials and Methods

User interaction with the system is less like that of a computer game, and more like the actual game of chess, using a physical chessboard and chess pieces. Instead of the player using a keypad to tell the microcontroller where the piece will move, the player will simply press down on the desired chess piece to “select” that piece and move it. When the player presses down on a piece, the force exerted will create a connection in the keypad below the board surface. Each of the rows and columns of the chessboard will be connected to a keypad input chip which constantly scans for these button press connections. Once a connection is detected, the keypad input chip outputs a signal to the microcontroller with information on the location of the pressed button.

The microcontroller will then access its memory containing the location of each piece. If the location sent to the microcontroller does not contain a piece, then the microcontroller sends a command back to the board to notify the player that there is no piece at this location. If there is a piece at that location, the microcontroller will then identify the piece and determine where that piece can move or its “path”. The microcontroller then sends this “path”, corresponding to empty squares or squares of attack on opposing player’s pieces, to the LED driver chip. The LED driver chip will then light up each of these individual squares until the player either moves the piece by moving it to one of the lit squares and pressing down on that new square to “select” the move or until the player deselects the piece by pressing down on it again in its original location. The keypad input chip detects the player’s move selection and sends this information to the microcontroller. If the selected square is one of the lit up options, the microcontroller will calculate the new moves for this piece at that location on the chessboard, and light up these new paths in the same manner. These ‘secondary moves’ are shown to help the player strategize where they can move their piece on their next turn, if they move it to that location. If the player selects the same square again, then the microcontroller will update its memory with the new location of the current board pieces. If the player chooses not to move to that location, the original move paths will be shown, allowing the player to strategize their game via visualization of first and secondary moves.

Digital Design

Commercially available technology can be utilized for implementation of such a digital chess system. Modern computer keyboards contain much technology that is applicable to the envisioned chessboard system. Their ability to detect multiple (100+) key presses, small physical size, and optimized circuitry, make modern keyboards a useful reference for the design of the chessboard system. Advances have allowed for these operations to be implemented with minimized system size, complexity, and energy usage. Application of new materials and methods enable alternative designs for chessboards, in terms of physical appearance, construction, and material specific benefits which could enhance the product.

At the heart of the design for the chessboard prototype is the Texas Instrument MSP430 microcontroller. The EZ430-RF2500 microcontroller module was chosen for several reasons. The size of the evaluation board is approximately the size of a quarter and can be physically integrated into the small-scale design application. The MSP430 has low power consumption and draws 270uA of current while in the active 1MHz mode, and also has several even more low-power modes which draw as little as 0.7uA of current [4]. Low power consumption is desired for mobile devices. The MSP430 can be programmed with C++ code. The evaluation board supports SPI and RS-232 protocols that are needed to communicate with other IC chips used in this design.

The chess piece selection circuit design is based on the switching design of keypads. A circuit of a typical keyboard includes a matrix with rows and columns of wires. Each key acts like a switch to connect a row wire with a column wire. When a key is pressed, a column wire makes contact with a row wire and completes a circuit. The keyboard controller detects this closed circuit and registers a key press. [5]. A digital logic circuit translates a particular key press into equivalent ASCII code, and outputs that ASCII code to the serial data pin. This keypad matrix and logic circuitry was the base design for this chess system.

The chessboard 'keypad' matrix is fabricated using three layered sheets of mylar with silver-paint painted tracers. The base layer includes one set of circuit tracer pattern, with circular shaped conductive contact pads at each spot where a key will be located. A second layer overlays the first, and does not have any circuit tracers, but does have holes aligned over the circular conductive pads of the first layer, where the keys are located. A third layer has a different printed circuit pattern with circular conductive pads that align with the pads on the first layer. The middle layer separates the two circular conductive pads. When a key is pressed, the upper contact makes physical and electrical connection with the lower contact and completes the circuit. The layered 'keypad' matrix has the advantages of being simple and cost effective to make, as well as being flexible while maintaining electrical conductivity.

In order to determine which piece is being chosen by the player, an 8x8 keypad matrix IC chip is being used. The eLab EDE1188 Keypad Encoder (eLab Digital Engineering, Independence, MO) has input lines connected to this matrix and a single output line to the MSP430. The keypad matrix is a grid of 8 rows and 8 columns of electrical connectors. Where each row and column intersects is considered a switch, triggered by mechanically forming a connection, which is termed a "key press" in this design. Keypad matrix theory is illustrated in Figure 1. The eLab chip is capable of detecting a single key press from up to 64 individual keys via its own internal algorithms [6]. The output of the keypad encoder chip is utilized for the chessboard design using the RS-232 serial output, requiring just one communication line between the microcontroller and the encoder chip. The eLab chip performs functions for scanning and detection, as well as handling the key repeat, delay, and contact debouncing. Use of this chip reduces computational load on the MSP430 microcontroller, allowing it to perform other operations, and to run at a slower clock speed, which reduces power consumption.

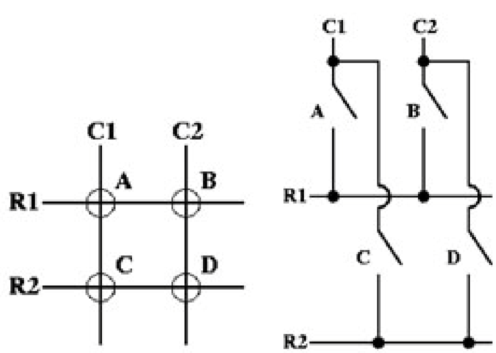

Figure 1: Keypad Matrix Theory. (left) Intersections. (right) Switches.

Indicating chess moves to the player is being done via lighting up the individual squares. Just like the keypad encoder chip, ICs also exist for decoding and driving light sources. The austriamicrosystems AS1107: 8-Digit LED Display Driver (austriamicrosystems USA, Inc., Raleigh, NC) was chosen for the chessboard design. The chip is designed to light up 7-segment LED displays, but can be used to implement an 8x8 LED matrix (one LED for each of 64 squares on the chessboard). The AS1107 chip connects to the microcontroller via a 3-wire serial interface, SPI [7]. This chip also contains the output algorithms that will cycle the rows and columns of the matrix in order to light up selected LEDs. Once the code is sent from the microcontroller to the chip, the chip will continuously light the indicated light pattern, until the microcontroller sends a stop signal, thus reducing the computational load on the microcontroller.

Two physical lighting options have been considered for the design, light emitting diode (LED) and electroluminescent wire (EL wire). Although LEDs are inexpensive and power efficient, the EL wire has even lower power and cost (Table 1). Moreover, the EL wire is aesthetically pleasing, and disperses more light than LEDs for a square of the chessboard. One challenge with EL wire design is the requirement for a $120V_{AC}$ power source. However, the required current for this power is low. A DC inverter generates a $120V_{AC}$ signal and could be run off of several batteries for many hours of operation. A TRAIC circuit has been developed for use of the EL wire with the AS1107 LED driver chip. The TRAICs function as logic activated AC switches which, depending on the DC signals from the AS1107 wiring grid, would allow the AC voltage to flow through and light the EL wire.

	Amount	Power (mW)	Cost ($)
LED	1 - 3	70 - 210	0.44 - 1.32
EL Wire	1 - 4 inch	20 - 105	0.08 - 0.33

Table 1: Lighting Analysis (Per Square)

For means of simplifying the fabrication of the chessboard, alternative materials and methods have been explored. Fabrication of the prototype system involved silicone molds to make the chessboard. This method requires the molds to be machined once, and then the molds could be used many times. The internal system components (the wires and lights) for each square are placed into an empty mold. Then liquid silicone is poured into the mold and allowed to dry. Use of silicone has the added benefits of being transparent and mechanically flexible. The main objective of the board does not require such flexibility, but being able to roll the board up for storage would be advantageous for many users.

Results

A prototype of the chessboard system has been fabricated. The prototype system will be tested for full system functionality. Testing for instruction as well as playability can be done with human test subjects. The board will be evaluated for its ability to teach people new to the game of chess, as well as novices, how to play the game. Physical testing will also be done for battery life, heat testing, and durability. Throughout the design process, several smaller modules were constructed to test specific aspects and components of the design. The results of these modular tests are as follows.

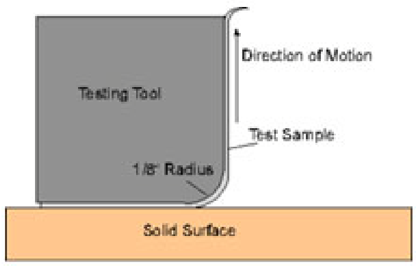

Figure 2: Conductive Pathway Testing Radius

The design of the prototype chessboard was mechanically flexible and thus required flexible circuitry. Using simple wires to connect each square of the chessboard for the buttons and lights would not be ideal. Instead conductive paint or a metallic tape was considered in order to enable a more cleanly laid and reliable system. Three types of conductive paint were tested: 18% Silver Paint, 35% Silver Paint Pen and 50% Silver Paint. In addition to these three conductive paints, Copper Foil Tape was also tested. Conductive paints were applied to layers of Mylar sheets with a circuit length totaling 20 inches. After the paints dried the resistance of the conductive paint traces and metallic tape were measured. After the unstressed resistances were measured, the durability and adhesion of the paints was challenged by having the sheets bent repeatedly. The maximum flexure that was tested was bending the entire sample over a 1/8 inch radius (Figure 2) five times with the conductive pathway facing upwards and then bent over the same radius five times with the conductive pathway facing downwards. This is to simulate the maximum stresses that the chessboard would be likely to endure. Upon the completion of testing, each of the samples was examined for visible cracks, wear, and damage to the conductive pathways. The 18% Silver Paint and 50% Silver Paint appeared to have withstood the flexing without damage. The 35% Silver Paint Pen, however, had several hairline cracks perpendicular to the circuit path, resulting in flaking of the circuit. The Copper Foil Tape also appeared to have withstood the flexing but the tape buckled in several locations indicating high probability future failure. The results from this test suggested that the chessboard prototype should use the 50% Silver Paint on textured Mylar due to its high durability and also low resistance (10 ohms to 100 ohms).

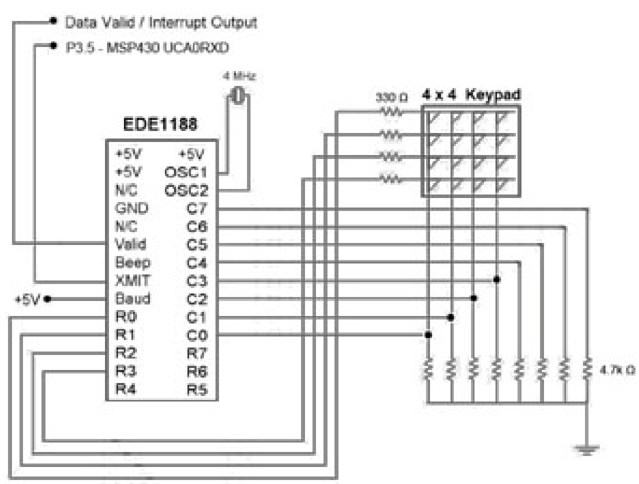

Figure 3: 4x4 Keypad Test Module

The keypad encoder chip (eLab EDE1188) was connected to an external 4x4 keypad module as well as to the MSP430 microcontroller, as seen in Figure 3. Code was written and debugged using the Code Composer Studio computer interface. The values obtained by each key press were stored in the microcontroller's memory and analyzed for their expected values. After testing individual key presses, multiple keys were then pressed at the same time. Due to the scanning algorithm of the encoder chip, the lowest value was registered and transmitted to the microcontroller each time. When a key press was not released, the encoder chip continuously output the value to the microcontroller. To eliminate this effect, code was written to have the microcontroller only receive one transmission on the RS-232 port. Testing of the keypad module verified that the expected values were received by the microcontroller.

In another module, the LED driver chip (AS1107) was connected to an external 8x8 LED display module as well as to the MSP430 microcontroller (Figure 4). Code was written to light up specific LEDs on the 8x8 matrix display. Testing verified that the LED driver could be used for lighting control of the chessboard design. The chip was capable of individually lighting all 64 individual LEDs, as well as any combination of the LEDs.

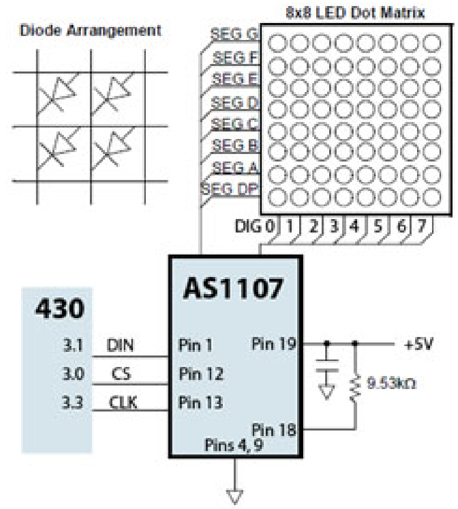

Figure 4: LED Driver Test Module

EL wire was tested in another module using a microcontroller, triacs, DC-inverter, and EL wire. A test module was built that had controlled lighting of the EL wire. However, controlling illumination of the EL wire with the actual LED driver chip presented new challenges related to controlling an AC-power matrix. Several solutions were investigated. Although the EL wire is less expensive per square, the power circuitry would be more complex than using only LEDs. For the prototype chessboard system, only LEDs were implemented, not EL wire.

Discussion

By using our chessboard learning system, learning the complex rules and development strategies for chess would improve for people who are primarily kinetic or visual learners. At each step of the game, the potential moves and limitations of each piece are shown in a simple and visually stimulating format. The system shows the possible moves, yet does not push the player toward any specific move. This allows the player keep an open mind while developing their strategies. Such development of strategic thinking would not only improve skill for the game of chess, but also for other challenges. For an engineer, such development of strategic thinking would help development of alternative designs to solve problems. An example from within this project is the silicone based roll-up keyboard. This alternative design alleviates certain disadvantages of using conventional keyboard structure for the switches, including size and stiffness that would hinder mobility of the system. Engineering students who use the chess learning system may further develop their strategic and logical thinking abilities that later help them design solutions to challenging problems.

Moreover, the methods used to develop this chess learning system could be applied to develop learning systems for mastery of specific engineering skills. Examples of engineering skills that involve rules and strategy to optimize certain parameters would include: circuit board layout for minimization, algorithm design for low computational cost, and system design for noise reduction. A learning system for such skill development could be developed using techniques similar to the ones used in this project to develop the chess learning system.

Acknowledgements

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Biographies

Tyler J. Martin graduated from Wentworth Institute of Technology (Boston, MA) in 2010 with a Bachelor’s of Science in Electromechanical Engineering. He has interests in renewable energy technology as well as research and development for mechanical solutions. On this chessboard design, Tyler has researched flexible board and circuitry materials and processes as well as assisted in alternate board lighting solutions such as LEDs, electroluminescent wires, and fiber optics. Tyler also provided insight on coding the algorithms which are used to calculate the available moves for each chess piece. (martint2@wit.edu)

Matthew S. Jolda graduated from Wentworth Institute of Technology (Boston, MA) in 2010 with a Bachelor’s of Science in Electromechanical Engineering. He has interests in art and engineering as well as engineering research and development. On this chessboard design, Matthew was involved with coding and interfacing of I.C. devices with the microcontroller. He aided in the development of alternate lighting solutions and built modules testing these designs, as well as the LED display module and the keypad input module. (joldam@wit.edu)

Christopher M. Linden graduated from Wentworth Institute of Technology (Boston, MA) in 2010 with a Bachelor’s of Science in Electromechanical Engineering. His interests include robotics as well as electro-magnetic technologies. For this chessboard design, Christopher has done research into current chessboard teaching solutions and solutions for alternative board lighting and power, as well as assisting in board design and manufacture. (linden@wit.edu)

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