Applications of RFID in Interactive Board Games

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***Abstract* — Radio Frequency Identification (RFID) can be used as a technology for coupling the physical and the virtual world in ubiquitous computing environments. In this paper, it will be seen that RFID is also a very interesting option for building augmented real-world games. In this paper, the use of RFID technology is motivated for the development of board games. Then we will put some researches done in this domain which are done already by researchers. Then some localization techniques are discussed. Afterwards, the author's idea to incorporate RFID system for developing a chess board is discussed. *RFID based Chess Board* is an attempt to design and build a useful sensory chessboard. It takes a look at various proximity sensors and how they can be applied to detect chess pieces. The chessboard is connected to a microcontroller allowing play in training mode and competition mode.**

***Key Words* — RFID, RFID tags, RFID readers, Localization, proximity sensors, key matrix, RFID game boards, Chess board**

I. INTRODUCTION

RFID applications are the keystone of the emerging 'Internet of Things'; that will connect objects and places. They will create many new opportunities for business and society, but first there are a number of political and social issues to be considered. RFID was first used in the late 1960's, but it has only become more widespread with advances in technology.

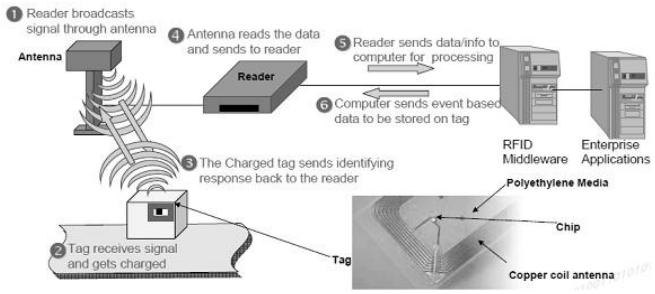


Figure 1. RFID system

A. How RFID works?

RFID is a generic term for technologies that use radio waves to automatically identify people or objects. There are several methods of identification, but the most common is to store a serial number that identifies a person or object, and perhaps other information, on a microchip that is attached to an antenna (the chip and the antenna together are called an RFID transponder or an RFID tag). The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to computers that can make use of it.

B. Components of RFID System:

1. RFID tag (transponder):

The identification device attached to the tracked item. A tag is programmed with a unique identification and descriptive information that can be read at distances ranging from one inch to approximately hundred feet.

There are three types of RFID tags.

- Passive tags are the simplest, smallest and cheapest version of an RFID tag as they do not contain a built-in power source and consequently cannot initiate communication with a reader. As the available power from the reader field diminishes rapidly with distance, passive tags have practical read ranges that vary from about 10 mm up to about 5 metres.
- Semi-passive tags have built-in batteries and do not require energy from the reader field to power the microchip. This allows them to function with much lower signal power levels and act over greater distances.
- Active Tags are battery-powered devices that have an active transmitter on board. They can communicate over longer distances (several kilometres) and have read/write capabilities allowing tag data to be rewritten or modified over the lifecycle.

2. A reader (transceiver):

A reader is a handheld or fixed device that uses —Radio to activate and obtain data from RFIDs in the vicinity. It can be seen as the tag's gateway to the data processing system. It scans multiple tags without requiring line-of-sight and communicates the results to the middleware. The power output and the radio frequency determine the range at which the tags can be read. Readers can be distinguished by their storage and processing capacity, and by the frequencies at which they operate.

3. An antenna:

A device attached to the reader to communicate with the RFID tag

4. RFID middleware:

Software used to consolidate, aggregate, process, and filter raw RFID data received from multiple readers to generate useful information for end-users. The middleware can also pass the processed data to back-end Enterprise applications.

5. Back-end RFID Enterprise service:

Receives filtered RFID data from the middleware and uses Application Programming Interfaces (APIs) to integrate

these with existing enterprise applications, such as POS, SCM, ERP, and CRM systems.

C. Frequency Concerns

Just as your radio tunes in to different frequencies to hear different channels, RFID tags and readers have to be tuned to the same frequency to communicate. Radio waves behave differently at different frequencies, so it's important to choose the right frequency for the right application. Different frequencies have different characteristics that make them more useful for different applications.

	Frequency	Distance	Example Application
LF	125 – 134 KHz	Few cm	Vehicle immobilizer
HF	13.56 MHz	1m	Building Access, Smart cards
UHF	860 – 930 MHz	~ 3m	Supply Chain and Logistics
MICROWAVE	2.45 GHz	10m	Traffic Toll Collection

Table 1 RFID Frequencies

II. RFID IN REAL WORLD GAMES

Radio Frequency Identification (RFID) technology already plays a major role in many areas. In business applications, for example, the idea of smart shelves or tables equipped with RFID technology has been around for some time now, especially for retailing. Current solutions, however, are designed to only identify objects in range, which is sufficient for most of the envisioned shop applications. For other uses, however, not only the identification, but also the exact position and orientation of objects would be interesting, if not necessary.

A. Miniature war game:

A good example is miniature war game [15], where the current game state usually depends on what objects are located where, and, in some cases, how these objects are oriented.

B. Playing Cards:

Christian Floerkemeier and Friedemann Mattern presented a paper on Smart Playing Cards[16] – Enhancing the Gaming Experience with RFID a card game that is augmented with information technology to advise novice players and to relieve the players of mundane tasks, such as score keeping. The paper shows how appropriate RFID system design results in a portable solution which requires minimal changes and disruptions to the conventional game flow and which works reliably

C. The Smart Jigsaw Puzzle Assistant:

Jürgen Bohn designed and prototypically implemented a smart jigsaw puzzle [17] game based on latest RFID technology. For that, he tagged the single pieces of a puzzle game with small miniature tags and developed a smart game application we call the *Smart Jigsaw Puzzle Assistant* (SJPA). The SJPA application is executed on a computer (laptop or desktop PC) and closely monitors the current status of the physical jigsaw puzzle. Whenever the player chooses a new piece of the physical jigsaw game to be added to the previously combined pieces on the table, he or she scans it with a handy RFID reader connected to the computer. The SJPA then automatically recognizes the added piece and updates the status of the jigsaw game on the computer screen.

III. RFID BASED LOCALIZATION

The benefits of RFID motivated many researchers in exploring its potential for indoor localization. RFID positioning systems can be broadly divided into two classes depending on the RFID component type of the target as;

A. Tag Localization

In tag localization schemes, readers and possibly tags are deployed as reference points within the area of interest and a positioning technique is applied for estimating the location of a tag.

B. Reader Localization

If the target is a RFID reader, usually passive or active tags with known coordinates and possibly readers are deployed as reference points and their IDs are associated with their location information.

C. Our Motivation

Apparently, selecting a best scheme is not trivial since it depends on several factors such as deployment cost, processing requirements, time and power constraints, scalability issues, etc. As finally the project is on ―RFID based board game; it is required to find out the things, i.e.

- Location sensing i.e. what are the (x, y) coordinates of all the Passive Tags available on the board for a given instant.
- Activity sensing i.e. which tag out of the available tags is being picked for the given instant along with its coordinates.

IV. PROPOSED WORK

RFID based chess board

The reason for choosing chess is that; researchers and educators have done various studies. And they have found tremendous development in the kids. The Venezuelan study claimed: ―Chess develops a new form of thinking, and this exercise is what contributes to increase the intelligence quotient. It also helps for memory improvement. There was a significant correlation between the ability to play chess well, and spatial, numerical, administrative-directional, and paper work abilities.

In the eighteen century the idea of creating a chess playing machine arose with The Turk [19], a fake chess automaton that became famous before it was exposed as a fake. It was

basically a mechanical illusion created by hiding a person with high chess knowledge inside the machine who would operate it. Only in 1912 did a real automaton appeared under the name of "El Ajedrecista" [22]. It used electromagnets under the board and automatically played a three chess piece endgame by moving a King and a Rook, against the human opponent. In the late 1940s, the field of mechanical chess research faded as first computers appeared. Since then, computerized chess became an important research subject: if a computer could play chess, then other problems that require human intelligence could also be solved. In less than fifty years, chess programming evolved to the point that a chess engine (Deep Blue) could beat the best human player in the world at that time [11] (Kasparov).

Using radio frequency identification (RFID) technology for detecting tagged objects on surfaces such as shelves or tables has been subject to some research in recent years. Scenarios such as smart shelves in retailing [1, 3] or tabletop gaming applications [2] can greatly benefit from this unobtrusive localization and identification technique. For many applications, it suffices to know whether a given object is in read range of the antenna (i.e., whether the object is *there*), but some require further information such as where an object is exactly and maybe even how it is oriented.

B. Design Challenges

1. Interference Problems

Here all the tagged pieces are placed very close to each other. If only RFID tags are used to locate the piece; then each antenna must read the only tag which is in the same matrix. But range of antenna is much larger. Therefor either some remedy is to be found out or another option is to be tried. The feasibility of using a certain sensor scheme over another for the project required some research.

2. Data Management

Controller has to keep the record of all the moves. Large amount of data is to be handled. So it must be fast enough to collect the data, to process on collected data, and to take the actions accordingly. Lot of pervasive computations is involved. Also there are various types of pieces, each having specific rule to move. For example

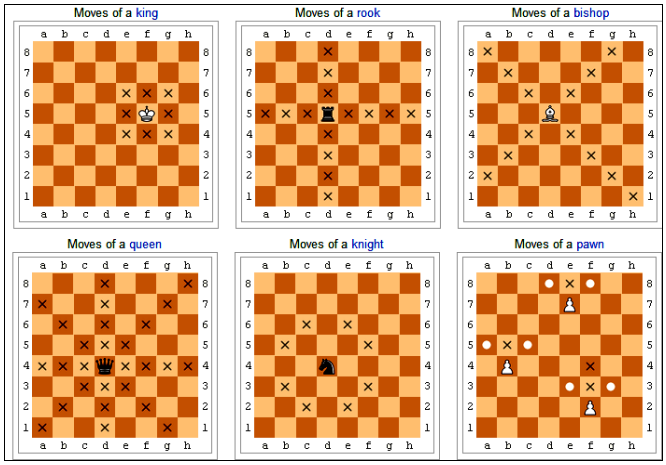


Figure 2. Moves of various pieces in chess
(taken from http://en.wikipedia.org/wiki/Rules_of_chess)

C. Specifications of the project:

After looking at commercial chessboards, it became clear what the specifications should be.

1. Move Detection

The board must be able to detect the presence/absence of a piece on chess square. The sensitivity of the sensors need only be great enough to tell if a piece is above the square or not. The board need not be able to distinguish between different piece types or colour. Intelligent software will allow a game to be played by using the last known position of the board and detect piece movements thereafter. The sensors must be multiplexed in some way to allow a microcontroller to read all of the sensors efficiently.

2. Move Feedback

The chessboard must be able to indicate the operation of the sensors as the piece is moved. This feedback is essential for the user of the board. The squares on the board will indicate where a piece is picked up and where it is moved to. They will also show where the other player (human or computer) has moved. LEDs are the most logical choice. A large array should be the best way to display opponent moves, while also providing reassurance that the sensors are working. An LCD screen to display the messages and clock timings.

3. Microcontroller Specifications

The chess will be run by an on-board microcontroller. The microcontroller must fulfil three basic requirements. One, it must read the sensor array. Two, it must run the feedback system. Three, it must communicate with the RFID reader. There must be enough input and output pins on the chip to control and read 64 sensors as well as a large LED array. A serial communication interface is required for communication; however speed is not an issue for this project. A low cost 8-bit microcontroller should be more than capable as the chessboard need only read send and display moves, not play the game of chess itself.

4. Board Properties

The Electronic Chessboard should be a sturdy board and built around a printed circuit board. This is to ensure the strength and reliability of the board rather than have sensors and LEDs glued to the underside of the board. The board should be of a reasonable size, although sensor design and PCB cost will dictate the size of any prototype

5. Block Diagram

Based on the above specifications, the basic blocks of the proposed system are;

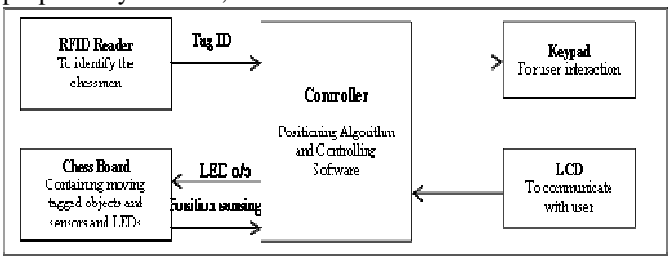


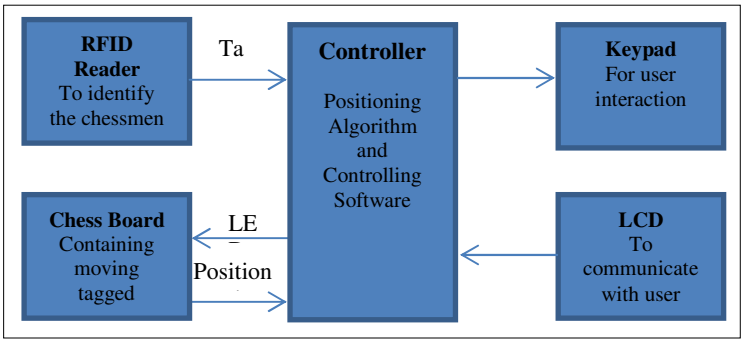
Figure 3. Block diagram of the proposed system

V. HARDWARE IMPLEMENTATION

The hardware must fulfill the main goals of the project, namely to sense, communicate and display chess moves. The sensing system was where most development time was spent.

A. Sensing system:

The sensor array is the core of this project and the specifications. This following section compares different sensor schemes that could be employed. It was found that there are many possible options of detecting a chess piece over chess square. The different options available were optical, inductive, force, resistive, capacitive and magnetic sensors. Then the method to read the keypad was studied in detail. And it was decided to choose the matrix type of keypad with 64 switches sensing the chessmen. The simplest type of switch is one where two electrical conductors are brought in contact with each other by the motion of an actuating mechanism. Two conductors are brought on the board. When a piece is kept on the square, the contact would be made automatically. To achieve this, a conducting metal is placed on the bottom surface of each piece in the chess.



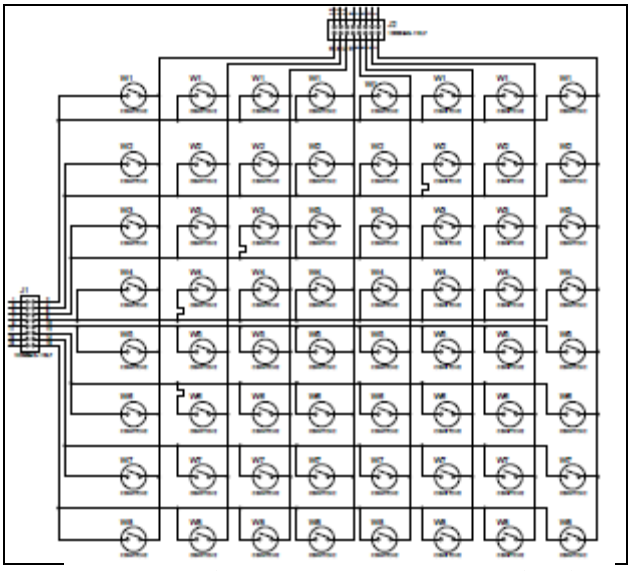


Figure 4. Schematic of Matrix of switches/keys

B. Indications:

The indicator array is important to provide feedback to the user and display the moves. The method chosen for this project is to use a LED array. The array will be 8x8 allowing a LED in the corner of each chess square. The arrangement of LEDs is same as shown for the matrix keypad. Besides the LED matrix for communication, 16x2 LCD is also used that will convey the messages to user and will show the clock time.

C. Communication Systems

Serial Communication: Microcontroller communicates with RFID reader via serial cable. The Reader reads the ID of the tag that comes in the vicinity of the reader and transfers the ID on the serial port. Once the controller receives the serial number, it identifies which is the piece that has been picked up. Wireless Communication: Tag communicates with the reader using the RFID protocols.

D. Microcontroller:

The microcontroller is the centre of the entire design. It must sense the exact position of the chessmen, return the possible moves using LEDs and communicate with the user while consuming minimal power. Atmel's ATmega32 is selected.

VI. SOFTWARE IMPLEMENTATION

The complete software runs on Atmel microcontroller. Consist of two modes, *teach mode and competition mode*. In teach mode, the board will guide the user how to play the chess. It includes initial position arrangement and movement detection. The simple switches on the chessboard are designed to detect the presence or absence of a chess piece. Each switch on each square must be read separately and thus

the microcontroller must scan the entire array. A solution was found by arranging all the switches in matrix form. Then, microcontroller scans the matrix repeatedly. If the difference has been found, then a piece is deemed to have moved from that square. The system needs to know the initial piece positions to operate correctly. The board cannot distinguish between a pawn and a queen, or white and black. It only sees pieces with metal foil. *Chess on a PCB* has to sense any changes in board position soon after they happen. The microcontroller therefore polls the sensing array regularly to check if a move has been made. Chess games come in many forms, from lightning fast games to long, intricate battles lasting hours. At times players may make moves extremely quickly, and sometimes a move may not be made for an hour.

A. *Initial position Algorithm:*

Step 1. Check if the board is empty.
Step 2. If yes, goto step 4
Step 3. Else on LCD print the message, "clear the board".
Step 4. On LCD print the message, "Pick up the piece".
Step 5. Bring the piece near RFID reader
Step 6. Display the position of the piece by lightening the LED on the Square where the picked up piece is supposed to be.
Step 7. Check if the piece is kept properly by reading the key matrix (feedback). If yes, then goto step 4. else, print error message on LCD.
Step 8. Check if all the pieces are arranged, if yes, goto the GAME else goto step 4.
Step 9. End

B. *Move detection Algorithm:*

Step 1. Display message "Start the game"
Step 2. Display message "Start with white "
Step 3. Display message "Pick up the piece"
Step 4. By reading the key matrix continuously, controller will come to know about which piece has been picked up. Controller will calculate the possible moves of the piece that has been picked up. And will display with the array of LEDs on the board.
Step 5. By taking the feedback from the key matrix, controller will check if the user has kept the piece at proper location or not. And will display message on LCD if kept at wrong position. If kept properly will go to step 3.
Step 6. Simultaneously, while calculating the moves, controller will check if any capture is possible or not, will blink the LED on the square that can be captured.
Step 7. Will note the piece that has been captured.
Step 8. Keep the track on the current pieces.
Step 9. Declare the game.

In the *Competition mode*, Software just checks the moves as per rule, if something wrong, will be displayed on the LCD, and keeps the track on the time.

VII. EVALUATION / RESULTS

Each system is evaluated with regard to the initial specifications. RFID based chess board is so far a prototype 8x8 square chessboard. This is by no means a failure of the project as many goals of this thesis have been achieved.

A. *Sensing and Feedback Performance:*

On system resume, initial placement of the chessmen with RFID tags is very well achieved using Reader and the feedback obtained from key matrix.

After game starts, sensing chessmen are a success! A modified chess piece (with alfoil) causes closing of a switch below it. The microcontroller software detects this change easily. This sensing of course cannot tell one piece from another, but this is not necessary as the software keeps track of piece position.The ATmega32 microcontroller takes on this role easily. With the use of LED matrix, feedback to the user is provided for their moves and indicates where the opponent has moved. Sixty Four bright LEDs around a square leave no doubt where to move the opponent's pieces. Corresponding message is also displayed on the LCD. The board uses In-Systems Programming (ISP) socket.

The board is a little larger than it needs to be due to the position of the components around the edge of the board. The cost of the prototype chessboard is in the order of including components, alfoil, RFID tags and reader is around Rs. 5000/- which is needed to be reduced.

B. *Personal Evaluation:*

The undertaking of this project has been a great learning opportunity. RFID based *Chessboard* was a significant project, which required many different skills. The project involved both hardware and software development. The author gained a lot of experience from this project. By the end of the project, the Atmel microcontroller was well studied. Protel schematic drawing and PCB design was one area the author greatly expanded his knowledge and skills. Some areas that need improvement in future projects are:

- PCB layout and routing
- Recording of results
- Project planning

VIII. FUTURE WORK

Electronic Chessboard provides a great platform on which further study can be carried out. It has been a worthwhile project in the area of sensor chessboards and RFID.

A. *Hardware:*

There are a few main areas in which future projects could proceed. The first is to completely implement the original specifications of this project using RFID technology completely instead of using switches to detect position of the pieces. The aim should be to turn the prototype board into a

marketable product. The wireless communication that was originally intended for this project could be implemented. The design could be true low power, and shutdown almost completely when not in use. The board could be packaged into hard case and quality pieces could be made. A speech module could be built that speaks aloud the opponent's moves.

B. Software:

Software for the microcontroller could be improved in future projects. The board could be given the ability to save and remember games. This thesis did not develop PC software. The interfacing of the chessboard to a PC game engine or an online chess server would make an excellent future project.

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CONCLUSION

The goal of the project was to build a useful chessboard and develop interesting sensing of chessmen. Although not all of the original specifications were completely implemented, significant progress was made toward them. The prototype board has all the original specifications intended with the exception of wireless communication and size. The Keypad logic detects the pieces and a LED array clearly indicates squares. From a personal point of view, the project has been an excellent educational and fulfilling experience. RFID based chessboard, provides an excellent foundation for future work.

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