

# Magic Wand

Play magically in a scientific way



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# Declaration

We do here by declare that the thesis titled '**Magic Wand: Play magically in a scientific way**' is submitted to the Department of Computer Science and Engineering of BRAC University in fulfillment of the Bachelor of Science in Computer Science and Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

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# Acknowledgement

We thank all who in one way or another contributed in the completion of this thesis.

We are so grateful to the department of Computer Science and Engineering of BRAC University. We also thank to the Professors and Lecturers of the CSE program, the librarians.

Our special and heartily thanks to our supervisor, Dr. Md. Khalilur Rhaman and Co-supervisor Muhammad Abdur Rahman Adnan who encouraged and directed us. We also thankful to our lecturer Risul Karim who helped a lot with our coding and Md. Monir Hasan, head of our workshop who assisted us a lot with the hardware part. It is with their observation that this work came into existence.

# Abstract:

We are working on an automated chess board which is hand free chess board. The type of our chess board is human verses human (H v H). In human vs. human, two players can play through a computer. Chess is a very famous and intellectual game all over the world but the chess board is annihilated because of advance technology. To relate the tradition with the technology, we decided to make an automated chess board. It has also inspired us to give a technical form to an ancient game. We have come up with an efficient solution to preserve our heritage by implementing scientifically. It is not only for fun but it can be very useful too. That is why this project seemed very challenging and purposeful to us. In our project, players will give commands through a computer and the chess pieces will automatically start moving on the board. We have used 30X24 inch wooden board as the chess board. Then we have used drawer channels to create X axis and Y axis. In each axis fault habor motor is attached. An actuator is used along with a powerful magnet which is placed on the top of the actuator to move the chess pieces on board. To control both motors a motor driver was used.

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# **CHAPTER: 1 INTRODUCTION**

## **1.1 Motivation:**

Chess is not only an idle amusement but it also strengthens and sharpens several valuable qualities of human mind. It is taught to the children in the schools and many kinds of tournaments are also held. It is played in the modern popular culture. Chess is a game which has a humble stand in the culture of sub-continent. In ancient times Mughal kings used to play chess. Prehistoric books and travelers stated that we had a strong history of playing chess.(1) In the Middle Ages and during the Renaissance, chess was a part of noble culture and it was used to teach war strategy.(1) Many of the elaborate chess sets which were used by the aristocracy have been lost but some partially survive. So we can see that chess has a strong impact on our culture. But as we are becoming more dependable on electronics, we now prefer playing chess on tablets, pc or play stations rather than playing it on chess board. So day by day playing in boards is being annihilated. So in order to preserve our heritage we have come up with an idea of making an automated chess board. Again this is a good way to connect the tradition with the modern technology. Those who are freak of computer based games especially children can enjoy this game practically. It will help them to practice mental exercise with the help of electronic technology. It is also giving us a glimpse of future condition of electronics technology as the technology is developing fast with the time.

## **1.2 Evolution of chess:**

Chess has been played for centuries through different cultures. The exact origin of chess is a great mystery. There are few ancient books about the



beginning of chess. Most historians think that it started in India, Persia or China.(1)

### **1.2.1 *How chess spread out:***

According to many historians chess was originated in Eastern India in the Gupta Empire. In the 6<sup>th</sup> century its early form was known as “chaturanga”. The four military- infantry, cavalry, elephants and chariotry were later changed into the modern pawn, knight, bishop and rook respectively.(1) Around 600 the evidence of chess was found in the nearby Sassanid Persia. At that time it was known as “chatrang”. When Muslim world conquered Persia the name of this game changed to “shatranj”. The game was very much popular in the Muslim world. The Muslims carried this game across North Africa and eventually in Europe. In Spanish chess is known as “ajedrez”, in Portugese as “xadrez” and in Greece as “ζατρίκιον”.(2) Murray stated that Muslim traders used to bring chess ornaments to European seaports before they brought this game. (2) In the 9<sup>th</sup> century the game reached Western Europe and Russia by at least three routes. By the year 1000 it was spread throughout the Europe. There are many similarities between the modern game and the old one. The regulations of modern shatranj started to change in southern Europe. Around 1475, several changes took place. These changes had been adopted in Italy and Spain.

### **1.2.2 *Changes in chess rules:***

In every area chess reached, it evolved its variation and rules. Though the ancient game is very much similar to the game we play nowadays, it does not have the powerful and strong moves of pawn, bishop and queen.

The old game which was known as '*stantranj*' was played on an 8 by 8 square board but the board was not checkered.(2) The move of king, rook, knight and pawn were the same as today. The king moved one space in any direction. The rook moved any number of squares straight forward, backward, and right or left. The knight could go just two squares forward, backward, left or right, and then one square at a right angle, making an L-shape. And the ancient pawn was always considered being a foot soldier. His forward move and forward-diagonal capture were the same then as they are today. The pawn moved one square forward, and had the option of moving two squares forward on its first move. It captured by moving forward-diagonally.

Bishop and queen have different moves than previous. The bishop was originally named as an elephant, and it had the most unusual move: two spaces diagonally, with the ability to jump over a piece in its way. In this way there are only eight squares on the entire board that the piece can possibly move to. This strange move actually characterizes an actual elephant on the battlefield.

As there were no women on ancient battlefield, so the companion of the king on chess was the king's advisor. This advisor's move was also very feeble: He moved only one square diagonally at a time. It was often useful in guarding the king from attack.

### ***1.3 Evolution of chess throughout the world:***

If we observe the chess boards, we can see that all the chess boards are more or less the same. But there are changes in the chess pieces in different countries in different times across the world.

### 1.3.1 *Chess board of Thailand:*

This is “*makruk*”, the national chess of Thailand, which is still played throughout that country. The earlier chariot is now known as a boat, the elephant is now a nobleman, the king's assistant is a seed and the foot soldier is a cowry shell [1]. The rest of the pieces retain their own properties.



*Figure 1: Makruk, Thailand chessboard*

### 1.3.2 *Chess Board of Burma:*

In *Sittuyin*, the **Burmese** chess, the elephant moves in five directions. (2) The old figures of chessmen represent the characters of their battlefield. The rook is called a chariot or carriage but it is usually portrayed as a small traditional hut. Our modern rook shaped like a castle turret. Some of the Burmese pawns are set up on the 3rd and the 4th rows. So the first move of the game could be one pawn take over another. But the remarkable twist is that under some

restrictions once the pawns are set up, the players can place their pieces according to their wish behind the pawn rows.



*Figure 2: Burmese style sittuyin chessmen*

### **1.3.3 Chess board of China:**

Xiangqi is the chess of China. The board is divided by a big open space in the middle; there are strange X's on each side of the board. In figure 4 we can see that the corner one is the rook which exactly looks like the pieces in ancient and modern chess. Its character is also like the rook from the ancient Persian game. The piece next to it is horse with four little dots that indicates horse's four feet. It also moves like ancient and modern western piece. The only difference is it can be blocked by a piece in its way. The next piece is an elephant on one side and minister on the other. Its character is also like the elephant of the Persian game and this piece can also be blocked. The next one is the advisor which can move diagonally. In the centre there is the general or

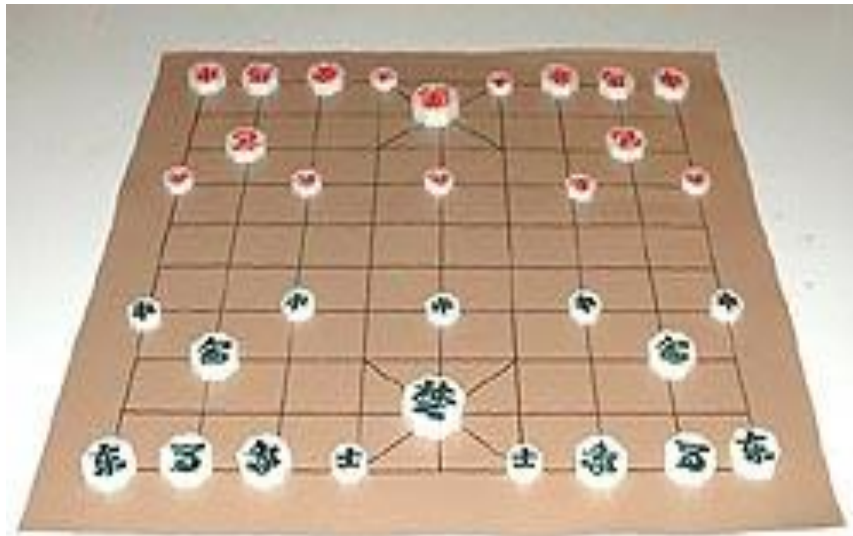
governor and in the front row there are two types of foot soldiers. Another piece is cannon which is a type of rook that leaps to capture.



*Figure 3: Xiangqi, the Chinese chess*

#### **1.3.4 Chess Board of Korea:**

In figure 4, we can see Japanese chess board which is known as “janggi”.(1) If we observe carefully then we can see that the red pieces of the board are similar to the Chinese pieces but the green part is different. The pieces are octagonal and some pieces are larger than the other. The commander starts out on the second row. The Korean elephant always move one space front, back, sideways and two spaces diagonally. The pieces like pawn, rooks, canon advisors and general can move along any line including the diagonal lines.



*Figure 4: Pieces of Korean chess*

### **1.3.5 Chess Board of Japan:**

Shogi, the Japanese chess pieces are flat. There are nine pieces in each row with a commanding general in the centre. The pawn starts on the third row. The pieces are rectangle in shape and the board is wooden. The chariot and horse can move in the forward direction. In the Japanese chess there is no elephant but the silver general has the uniqueness of elephant. The gold general can move four diagonal directions forward, backward or forward diagonal [2]. The pieces are flat and each player can start game with twenty pieces. The king and two gold generals can flip over for promotional value. In total there are forty pieces on the board. Shogi is quite different and never ends up like other chess games.



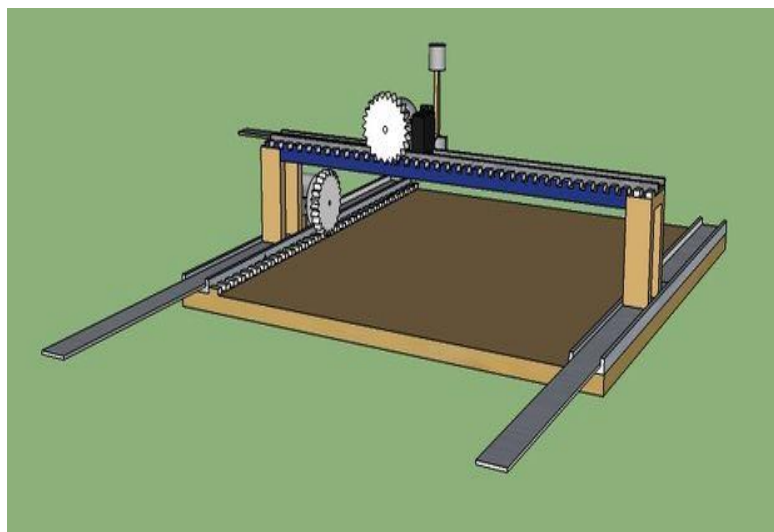
*Figure 5: Japanese Chess Pieces*

Chess has been played for years in different cultures. It went through various changes. Many new moves, pieces have been added. New identities were made and have gone through enormous boards. But the chess that came from Europe haven't been changed for almost a millennium. Though there are many change but most of the rules remain unchanged.

#### **1.4 Introduction:**

Our Automated Chess Board is hand free chess board where people can play chess by using a computer. We all know that chess is played by millions of people around the world as it is one of the most popular games of the world. Again research says that playing chess can develop students' social skills, memory, spatial skills, numerical abilities, creative thinking, problem solving and many more. Chess clearly is a problem-solving tool, an “ideal way to study decision-making and problem-solving because it is a closed system with clearly defined rules” (Horgan, 1988). When faced with a problem, the first

step is to “analyze [it] in a preliminary and impressionistic way: sizing up the problem” (Horgan, 1988, p. 3), possibly looking for patterns or similarity to previous experiences. “Similarity judgements may involve high levels of abstract reasoning” (Horgan, 1988, p. 3). Learning how to solve problem is more effective rather than knowing the solution of a particular problem. For this reason chess act as a tool for problem solving. But there are many people around us cannot play this intellectual game because of their hand problems. So the inspiration to make automated chess board came from those people who are unable to use their hands. It can be very useful for them as they do not need to use hands to play the game. Moreover, chess is a part of our heritage and culture. We wanted to give it a scientific form. Thus it will serve to purpose. Firstly, our heritage will be preserved and secondly, children of this smart generation will be more interested to play this game. This is why we decided to make this board.



*Figure 6: CAD of the partial CHESS BOARD*

In order to move the pieces automatically like the movie an engine board needs to be created and the instruction would be given by the computer. To



make the chess board, a 30 x 24 inches wooden board is taken. On the top of the board there will be two axes. One is X-axis and the Y-axis. The X-Y position needs to be set on the flat wooden board so that everything can be set up on it. Two drawer bearings are taken and placed parallel to each other on the two sides. They need to place perfectly parallel to each other or else it will not move exactly the way it needs to move. The drawers are mounted on the board with the help of screw and glue. On the top of the drawer two small wooden pieces are attached with glue so that it can hold the Y axis. A hole is made in one of the wooden pieces and inside that FAULHABER DC 12V Motor is attached with the help of glue. To control the motors L298N motor controlling driver is used. Two motors are connected with the outputs of L298N. To control these outputs there are four inputs which are connected with Arduino pin no 8, 9, 11, and 12. There are also 3 inputs in L298N which provides 5 volt, GND, 12 volt. On the DC motor, a pinion was set so that it could move smoothly on the gear. Then linear gear was glued onto a long piece of wood in a perfectly straight line and the wood was attached next to the motor in such a way so that the motor can move smoothly on the gears. The next step is to mount the Y-axis. At the top of the X-axis a wooden bar is set. The wooden piece is mounted on the X - axis with screws and this must be long enough to support the Y axis. A drawer was attached on the wooden bar just like the X axis. Just like the X - axis we take a motor along with a pinion set on it and a wooden piece where a gear was attached and the motor is set in a way so that it can move over the wooden piece. To grab the pieces, a magnet is taken. The magnet grabs the chess piece and takes it to the destination. An actuator is needed to move towards the destination and lift the magnet in the upward direction. Then the magnet will hold the piece and take it to the desired position. The pieces that will move by the actuator that is placed underneath the board will be operated by the X-Y axes. When the work of the magnet is done the actuator will move downwards. And will come back to its position. So an actuator was attached on a wooden piece on the Y-axis. In

addition, there will be a relay to control the actuator. The gap between the chess pieces will be 1.5 inches so that whenever the magnet tries to grab one piece, the other pieces don't get magnetized. The player will place his move through a laptop or a computer. At first he will be asked to give 4 inputs. Then a message will appear whether he wants to capture, move or quit. Then according to the decisions he will be treated. If he wants to place a random move then the X and Y axis will go to that place with the help of the motors. After that the actuator will be activated and the magnet will grab the chess piece and move it to the destination and then it will be retracted. Thus we can place a piece to a new position. If we want to eat a piece then firstly the piece will be removed from the board and then again the move method will be activated. A non-magnetic sheet was placed on four pillars. The four pillars are attached on the board. All chess pieces were put on this plastic material. To hold the chess pieces from above is difficult as it works against gravitational force. After moving to any place we need to clear all data. If the player wants to stop the game the clear method will be called and all data will be cleared. In hands free chess, software needs to perform some task. It should recognize the input and gives the appropriate output. The software needs to check the input from both the sides and according to the input it needs to run the system and activate the magnet. The software is mainly important to control the flow of the overall system.

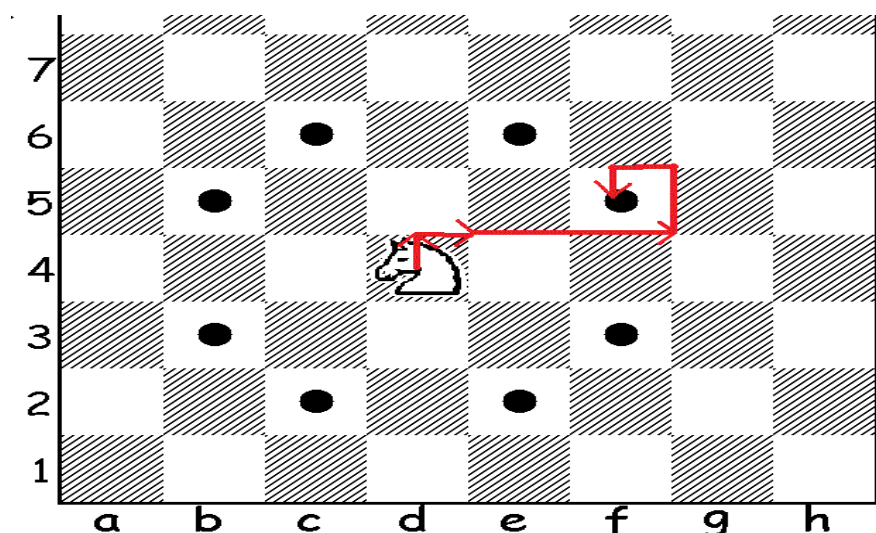
## CHAPTER: 2 SYSTEM OVERVIEW

### 2.1 System architecture:

The whole system has been organized in such a manner that all moves are happening between the chess pieces. There will be spaces between the chess in such a way that they do not get attracted with each other. Therefore, the pieces are not colliding with each other. The magnet does not attract others because it is very small in size. As it moves along the middle line between two pieces so the clash doesn't come about. The main concept of this game is consists of three main methods. They are:

- Move
- Capture
- Clear

#### 2.1.1 Move:



*Figure 7: Knight Movement*

We are going to consider the movement of knight here. In above picture the knight is at 4D position. It can go to 8 different places- 3B, 2C, 2E, 3F, 5F, 6E, 6C and 5B. Let us assume that the player wanted to move the knight from 4D to 5F. So the X axis will firstly take position on top of 4D. Then X will move  $(6-4) = 2$  square forward and  $(5-4) = 1$  so Y will move 1 square forward. Next, it will go half Y backward and half X forward and thus reach its destination.

### 2.1.2 Capture:

To capture a chess piece it needs to remove the captured piece first. After that the required movement will be done. That is exactly what was done in this project. Firstly, the user will state whether he wants to capture a chess piece or not. If he wants to capture the chess piece he will have to state and that piece will be detached first. Then, the chess piece will be placed in that very position.



*Figure 8: Capturing a soldier*

For example, in above picture the soldier of 4D wants to capture 5E. So, this chess board will remove the 5E first. To do that it will do a small calculation. It will subtract 5 from 8. Here 8 is the number of square and 5 is the moved placed by player. Same thing will happen for the Y axis also. So the result will be 3 for both X and Y. After that, X axis will move 3 square and Y axis will move 3 square and the chess piece will be removed from board. Right after removing the captured piece, the whole method will be cleared and X and Y axis will be moving back to 0, 0 position. Then the piece of 4D will move to 5E. To do so it will first subtract X and Y coordinates accordingly. The result will be 1, 1. After that X will move 1 square and then y will move 1 square. To go to exact destination a half movement is needed. Half movement is half rotation of both Y and X axis. Firstly Y axis will go hah rotation back and then X will go half rotation back. And thus the chess piece will reach its destination.

### ***2.1.3 Clear:***

After every movement a clear method is needed to be called. In this method, both X and Y axis will return to the starting position.



*Figure 9: Clearing the position*

In above figure, the position of X and Y axis is demonstrated with a red dot. This is the 0, 0 or starting position. After calling the clear method the XY axis will return to this position.

## **CHAPTER: 3 Implementation**

### **3.1 Hardware:**

The descriptions of the hardware that are implemented in the project are given below:

#### ***Hardware and Parts List:***

- Arduino for implementing the code on the board.
- Laptop or pc for giving the command.
- Motor driver for controlling the motors.
- Voltage source for power supply.
- Relay for controlling the voltage source of the actuator.
- 1 USB cable
- Wire
- Super Glue
- 1 chess set

#### ***Parts for the XY Table:***

- 1 flat and heavy plane wood board to mount everything
- 3 Drawer Tracks
- PVC Board
- Screws
- 2 Faul haber motors for moving the X-Y plane.
- 1 Actuator
- 1 pair of linear gears
- One small magnet

## Implementation of hardware:

In this project there are mainly three axes. These are X axis, Y axis and Z axis. The above hardware have been used in these axes. The descriptions of the hardware that have been used in the automated chess have been given in the following.

### 3.1.1 X-axis:



*Figure 10: X-axis*

The X-axis is the first and one of the most important stages of this project because the whole system will be running based on this stage. Even this axis has to take the whole weight of Y-axis too. The X position needs to be set on a



flat and heavy board so that it can hold everything on it. A 30x24 inches wooden board lies beneath X axis. This wooden board is heavy enough to carry the whole weight. The X axis is made of PVC board, therefore it weighs lighter. It was set with the help of super glue and screw. Super glue was applied to strengthen the X axis. Length of X axis is 21 inch. On top of it a gear rail is placed. With super glue it was attached very carefully. This gear rail is made of plastic. It is necessary for moving of the motor. As there is a pinion in motor so it needs rail to roll over. Therefore, a rail gear is placed perfectly straight on X axis. The pinion and rail gear was removed from old printers. Old printers have pinions and rail gear inside. After that two drawer bearings parallel to each other were set up on the wooden board with the screw and super glue. These two bearings must be parallel to each other. Otherwise the movement of motors will not be perfect and thus it will create problem in time of playing chess. On top of drawer rails two small PVC pieces were attached with the help of the screw and glue. On this 4x4 inches PVC piece of the first drawer rail, there is a half circle hole where the DC motor is attached inside the hole. To attach the DC motor strongly, hot glue gun is used because the super glue cannot take the weight of the motor to attach. Another 4x4 PVC piece is plain standing on the other drawer rail with help of glue. The motor which was used is Faulhaber motor. It is consisted of two parts- DC motor and encoder. At first we used stepper motor to move both directions. It is easy to control stepper motor in both directions. The main problem with it was the weight of our project and stepper motor couldn't carry that much weight. So we decided to move on with servo motor. Servo motor can carry heavy objects easily. But again, linear movement of servo motor is not convenient and we needed a motor which can tell us how many steps it takes to make a revolution. Every chess piece has a specific move. For instance, a horse moves two and half square in each direction. So each step is needed to be calculated precisely. Faulhaber motor has this feedback system. In this motor we can

control the movement of motor by calculating encoder movement. It takes 12 rotations for one revolution.

### 3.1.2 Y-axis:



*Figure 14: Y Axis*

The Y-axis is the next and another important stage of this project because the actuator depends on this stage. The whole Y-axis is lying on the X-axis. At the top of the X-axis, a long PVC bar is set up to hold the Y-axis. This PVC bar which is 21 inches long and 4 inches wide is attached with the help of screw and glue to support Y-axis. Another drawer is mounted on the PVC bar just like the X axis. This drawer rail is also attached with the screw and glue. On the PVC board a drawer rail is attached with screw. Just like the X-axis, a 21 inches long PVC piece is attached by using glue. On this long PVC piece a linear gear rail is attached. This linear gear rail is made of plastic and with the

help of super glue it was attached very carefully in a perfectly straight line. It is necessary for moving of the motor as there is a pinion in motor so it needs rail to roll over. The pinion and rail gear was removed from old printers. Old printers have pinions and rail gear inside. There is a 4x3 PVC piece on the drawer rail for the DC motor. On the PVC piece, there is a hole where the motor is attached inside the hole with the help of hot glue gun to make it strong because the super glue cannot take the weight of the motor to attach. The motor is set in a way so that it can move over the PVC piece with the pinion set. The description of the motor has already been discussed above. This PVC piece of Y-axis is carrying the weight of an actuator to support the Z-axis.

### **3.1.3 Z-Axis:**



*Figure 15: Z-axis*

A pseudo Z axis is created when an actuator is placed on Y axis. A linear 12 volt actuator is put on top of Y axis with the hot glue gun. A small magnet was attached on it in a very simple way using scotch tape. In order to hold chess pieces and move them from one place to another it was necessary to hold them from beneath. A non-magnetic sheet was placed on four pillars. All chess pieces were put on this plastic material. To hold the chess pieces from above is difficult as it works against gravitational force. A robotic arm was needed for that. Moreover, to place the chess piece properly with robotic arm is more complicated. Keeping all these in mind we took the opportunity to move them from beneath. To do this, a piece of iron is attached under every chess piece. Therefore, when the actuator is activated it moves upward, hold the chess piece and then move them to destination. The actuator moves downward to remove the magnet from the chess piece after reaching the given destination. An actuator is a type of motor that is responsible for moving or controlling a mechanism or system. It is operated by a source of energy, typically electric current, hydraulic fluid pressure, or pneumatic pressure, and converts that energy into motion. An actuator is the mechanism by which a control system acts upon an environment. The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), a human, or any other input.

The hardware that have been used in Z axis are-

- Chess board
- Magnet
- Chess pieces
- Actuator

A brief discussion of these parts is given below:

*Chess piece:*



*Figure 16: Chess piece*

There will be 32 chess pieces on the board. Underneath the pieces there will be a magnet attached to it. The chess pieces can also be electromagnetic so that the magnet used in this project can magnetize the pieces. The size of the chess pieces is around 3.5 – 4 cm. The pieces should be small so that they do not collide with each other.

### ***Chess board:***



*Figure 17: Chess board*

Over the Z-axis a board has been attached where the game will be played. On the 30x24 inches wooden board four pillars have been attached with glue. These four pillars have been attached so that it can support the chess board. Above the pillars a transparent plastic board has been attached. As the chess piece is magnetic and beneath the board there is also a magnet so a non magnetic field has been chosen. On the board 64 small square size boxes have been drawn. The size of each box is 4.5 cm. More spaces can be kept to avoid collision. In the figure it is seen there are two types of colored boxes. One is black and the other one is white. The alternative boxes are black and white.

### ***Magnet:***

A magnet is used on the actuator in order to grab the chess pieces. The work of the magnet is to go to the desired position with the help of XY axis and the actuator will lift it upward and the magnet

will hold the pieces and will keep holding until it comes to its destination. The magnet should also be small so that it does not attract the other pieces. If the size is big it will attract the other pieces will get magnetized towards it.

***Actuator:***



***Fig18: Actuator***

An actuator is a type of motor that is responsible for moving or controlling a mechanism or system. It is operated by a source of energy, typically electric current, hydraulic fluid pressure, or pneumatic pressure, and converts that energy into motion. An actuator is the mechanism by which a control system acts upon an environment. The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), a human, or any other input. [6]

***PA-14 model Actuator:[7]***

Stroke sizes (in inches)		
	Fully Retracted (in inches)	Fully Extended (in inches)
0	4.13	4.13
1	5.13	6.13
2	6.13	8.13
3	7.13	10.13
4	8.13	12.13
6	10.13	16.13
8	12.13	20.13
9	13.13	22.13
10	14.13	24.13
12	16.13	28.13
14	18.13	32.13
16	20.13	36.13
18	22.13	40.13
20	24.13	44.13
22	26.13	48.13
24	28.13	52.13
30	34.13	64.13
40	44.13	84.13



***Performance metrics:***

Performance metrics of an actuator includes:

- Speed
- Acceleration
- Force
- Energy efficiency
- Mass
- Volume
- Operating conditions
- Durability

***Force:***

When considering force in actuators for applications, two main metrics should be considered. These two are static and dynamic loads. Static load is the force capability of the actuator while not in motion. Conversely, the dynamic load of the actuator is the force capability while in motion. The two aspects rarely have the same weight capability and must be considered separately.

***Speed:***

Speed should be considered primarily at a no-load pace, since the speed will invariably decrease as the load amount increases. The rate the speed will decrease will directly correlate with the amount of force and the initial speed.

***Operating conditions:***

Actuators are commonly rated using the standard IP Code rating system. Those that are rated for dangerous environments will have a higher IP rating than those for personal or common industrial use.[6]

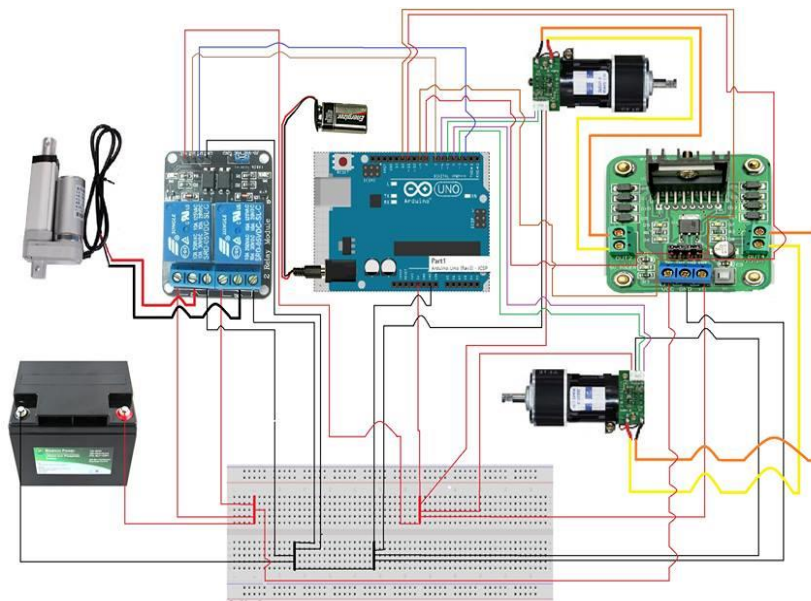
***Durability:***

This will be determined by each individual manufacturer, depending on usage and quality. [7]

## CHAPTER: 4 Control circuit

### 4.1 Control Circuit

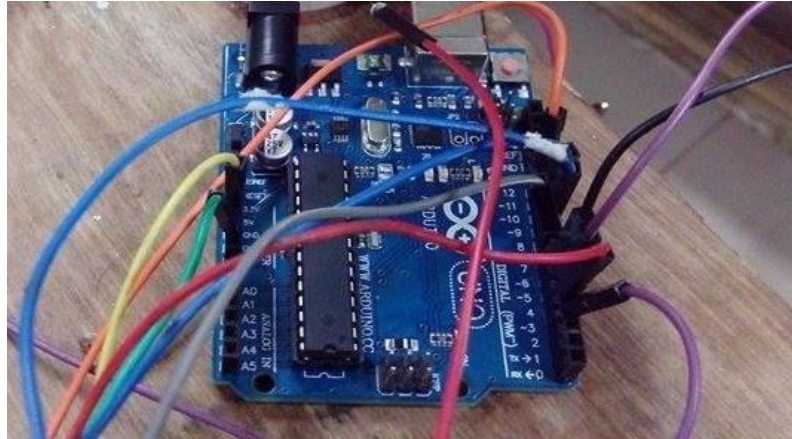
A control circuit of the overall system is described below:



*Figure 19: Connection diagram of the Automated Chess*

All the devices that include motor driver, motors, relay, actuator, voltage source are connected with arduino. Brief discussions of all the parts that have been used in the hardware part are described below:

### 4.1.1 Arduino:



*Figure 20: Arduino*

Arduino is an open source prototyping platform based on easy-to-use hardware and software [8]. It consists of both a physical programmable circuit board and a piece of software or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board [8]. Arduino was invented by Massimo Banzi a school teacher. He wanted to create a board which is cheap, simple and will work on Windows, Mac and Linus. So Banzi along with his student Hernando Barragan and their team developed the first Arduino Board in 2005. Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. This microcontroller is easy to use not only for technical people but also for students, hobbyists, artists, designers and so on. It is a microchip, like a little computer where people can write code in it to create electronic projects. People can control its several inputs and outputs by giving commands into program they write.

### ***Hardware description of Arduino:***

Arduino can operate on computer, electronic devices and controller chips, independently or other Arduinos. It can interact with buttons, motors, LED, speaker, camera, internet, smart phones and TV. It is more like a brain to any electronic project.

There are many Arduino Boards are available which are designed differently for using different purposes but most Arduinos have some common components. These are – Power (USB/ Barrel Jack), Pins, Reset Button, Power LED Incator, TX RX LEDs, Main IC, and Voltage Regulator. **(8)**

- ***Power ( USB/ Barrel Jack):***

Arduino board will have a power source. The Arduino UNO can be powered from a USB cable coming from computer or a wall power supply, terminated in a barrel jack. USB connection is also for loading code onto Arduino Board. The limitation of the voltage for Arduino is maximum 20 volt otherwise it can cause damage for the Arduino. The recommended voltage for most of the models of Arduino is 6 to 12 volts.

- ***Pins:***

Arduino has several different kinds of pins to connect wires to construct a circuit. Different pins are used for different functions. For example –

- ***GND:***

There are several GND pins on the Arduino, which can be used to ground the circuit.

- **5V & 3.3V:**

5V pin supplies 5 volts and 3.3V pin supplies 3.3 volts. Most of the simple components used with Arduino run easily off 5 or 3.3 volts.

- **Analog:**

In area of 'Analog In', there are some analog pins. They can read signals from an analog sensor and can convert it into digital value so that people can read.

- **Digital:**

As analog pins are digital pins so they are used for both digital input and digital output.

- **PWM:**

The tilde (~) next to the digital pins, acts as digital pins but can also be used for something called Pulse-Width Modulation (PWM).

- **AREF:**

AREF stands for analog Reference. It is sometimes used to set an external reference voltage (between 0 to 5 volts) as the upper limit for the analog input pins.

- **Reset Button:**

Arduino has a reset button which will temporarily connect the reset pin to ground and restart any code that is loaded on the Arduino. It is very useful the user to test their code multiple times if their code does not repeat. [9]

- **Power LED Indicator:**

A tiny LED light, next to the word 'ON'. Whenever the board is powered up, this LED should light up. If light does not turn on properly then there is something wrong with the circuit.

- ***TX RX LEDs:***

TX is short for transmit, RX is short for receive. There are two places on the Arduino UNO where TX and RX appear once by digital pins 0 and 1, and a second time next to the TX and RX indicator LEDs.

- ***Main IC:***

The black thing with all the metal legs is an IC. It is the brain of Arduino which can be slightly different or vary from Arduino board to board but usually from the ATmega line of IC's from the ATMEL Company. The type of IC can be written on the top of the IC.

- ***Voltage Regulator:***

It controls the voltage of Arduino. It turns away the extra voltage to protect the circuit. It has a limited voltage which is 20 volts [11].

There are two pins in arduino, one is input and another one is output pin. Input is for putting information inside and output is for taking out from Arduino [12].

### **Software part of Arduino:**

The Board Manager makes a request to the arduino .cc servers for a file called package\_list.json every time you load the Board Manager. This works very similar to the Arduino Library Manager, but unlike the Library Manager, there is currently no support for adding third party board packages. This is where our proxy server comes in. There is no need to download the proxy server unless you wish to server your own custom board packages.

At the proxy server, pointing the Arduino IDE allows us to intercept any requests to the `package_list.json` file, and inject new boards into the JSON before serving it back to the IDE. This is known as a man-in-the-middle attack. Generally man-in-the-middle attacks are used for malicious purposes, so let's refer this as "Adafruit-in-the-middle" since we are using it for friendly purpose [9].

### **Reasons for using:**

For the project 'Automated Chess Board', a microcontroller is needed which can take several logical inputs and calculate different logical calculation on those logical inputs. The results of these logical calculations are obtained from the outputs. There are various microcontrollers available but raspberry pie and arduino are well known amongst all. Though we are not using raspberry pie as it is hard to handle and we do not need that higher level controller for our project. This is why we have chosen Arduino as it is easy to control.

If you connect a push-button to an input, you can check if the button is pushed or not by writing `digitalRead()` in the Arduino.

If you connect a Light-Emitting Diode to an output, you can turn the light on and off by writing `digitalWrite()` in your program code.

### **4.1.2 L298N:**

L298N is a dual full-bridge driver or dual motor controller which is an integrated monolithic circuit in a 15-lead Multi watt and PowerSO20 packages. It is a high voltage, high current dual bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors [10].



**Specifications:**

- The power supply voltage of L298N is started from 5V, up to 46V.
- It has low saturation voltage.
- It protects over temperature
- Controlling level: Low- 0.3 – 1.5V, high- 2.3 – V<sub>ss</sub>
- Logic power output V<sub>ss</sub>: +5 - +7V
- Total DC current of up to 4A
- Max power: 25W
- Working temperature: -25C - + 130C [15]

**Usage:**

It is used to control the two DC motors speed and direction or control one bipolar stepper motor. It can also be used for driving the brightness of certain lighting project. For example, high power LED arrays. The motors that have a voltage of between 5 and 35V DC, this driver controller can be used there [11].

## Hardware:

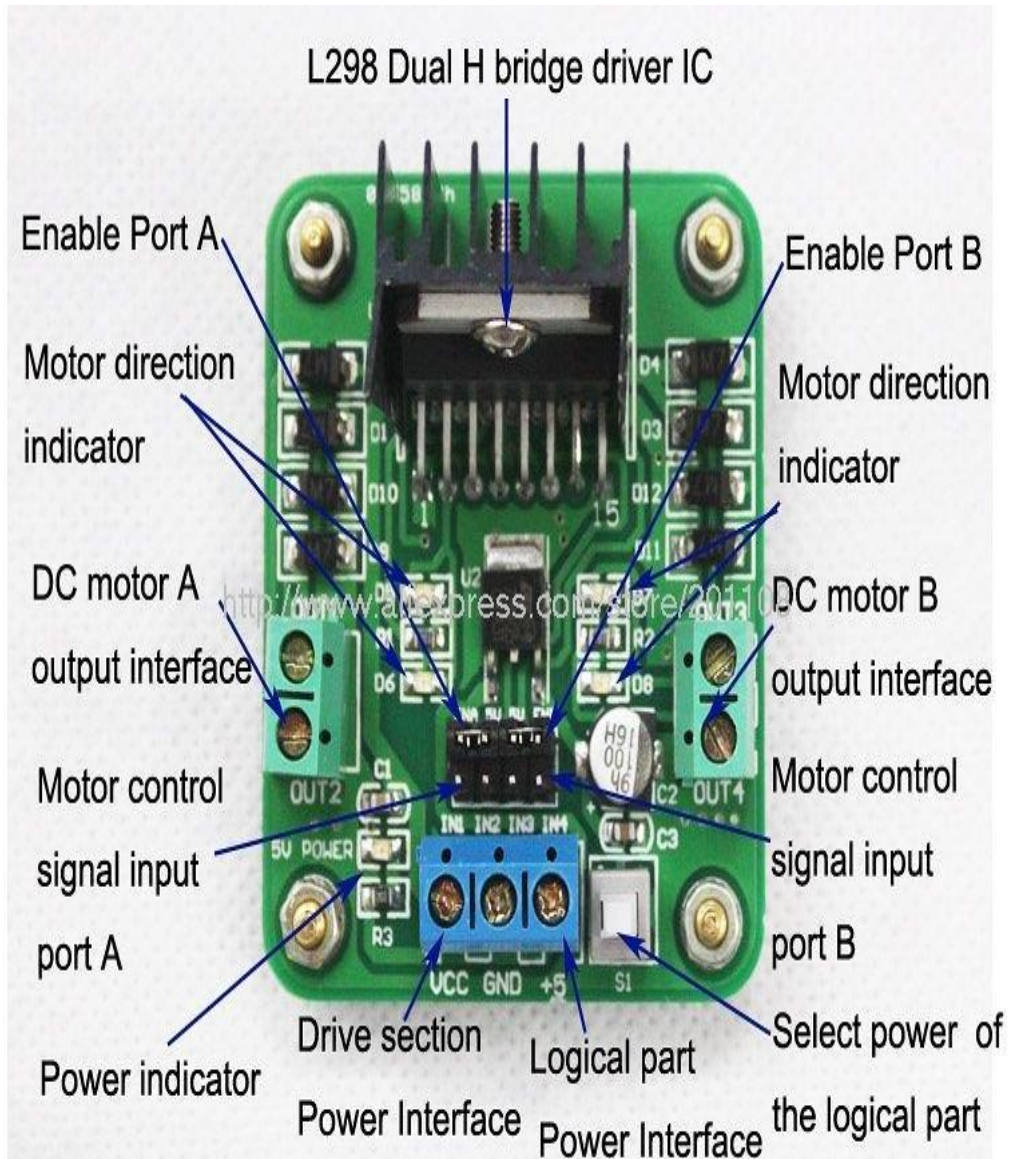


Figure 21: L298N

### Features:

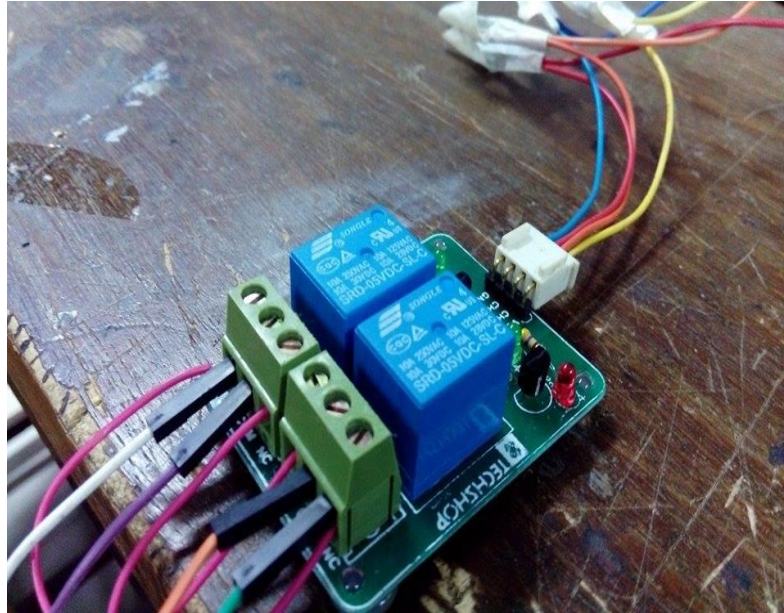
- Drive terminal power supply : +5v to \_35V

- Peak current in Drive part : 2A
- Power supply of logic terminal: +5v to +7v
- Operating current in the logic part: 0 to 36mA
- Input voltage range(control signal): low :0.3V Vin 1.5V;High :2.3V Vin Vss
- Input voltage range(enable signal): low :-0.3V Vin 1.5V (control signal inactive); High :2.3V Vin Vss (control signal active)
- Power consumption(MAX): 20W
- Temperature of storage : -25 to +130.
- Other features: power supply interface logic unit, control indicators.
- Size: 55 x 49 x 33 mm

**Reason:**

As we need to control the motors rotation, direction and speed this is why we are using this motor controller to control our RC motor.

### 4.1.3 2-Channel 5V Relay Module:



*Figure 22: 2-Channel 5V Relay Module*

A relay is an electrically operated switch which is used to control circuits by a low power signal or when need only one signal to control several circuits. It was first used in long distance telegraph circuits as amplifiers. It was also used in telephone exchanges and early computers to perform logical operations [13]. It can be controlled by wide range of microcontrollers such as Arduino, AVR, PIC, ARM, and MSP430 with digital outputs to control larger loads and devices like AC or DC motors, actuators, electromagnets, solenoids, and incandescent light bulbs. The 2-Channel 5V Relay is designed with 2 relays on the board with “NC” ports mean “Normally connected to COM” and “NO” ports mean “Normally open to COM”. The output of relay states by a light-emitting diode [14].

#### ***Specification:***

- There are two mechanical relays

- “NC” and “NO” ports for each relay
- Control signal: TTL levels
- Maximum switching voltage: 250VAC 30VDC
- Rated Load: 7A/240VAC 10A/125VAC 10A/28VDC [15]

***Pins:***

- COM: Common pin
- NC: Normally closed
- NO: Normally open
- Vcc: 5V(+)
- GND: Ground(-)
- INT 1: Relay 1 control port
- INT 2: Relay 2 control port

***How it works:***

Relay is a series of switches. When the power is on, the NC switch would open and close. We can see a visual representation of what is happening by attaching two LEDs. We can easily code through the Arduino Software and when the relay receives power, it works just like an LED [15].

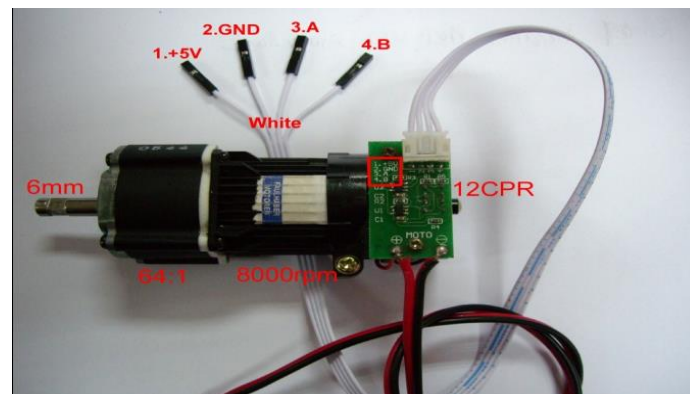
***Reason for using:***

As we are using actuator which is 12V and we know that Arduino cannot provide more than 5V so we are using this 2-channel 5V relay module to control the voltage. We have used total two relay modules, one is for moving the actuator up and another one is for

moving the actuator down. The two digital inputs of the relay module are connected with the Arduino board. One Vcc port is attached to the Arduino's 5V. One GND port is connected to the ground. The outputs of the relay module are connected with the actuators.

#### ***4.1.4 Faul Haber Motor:***

We have used FAULHABER DC 12V Motor 2342L012CR motor for our project.



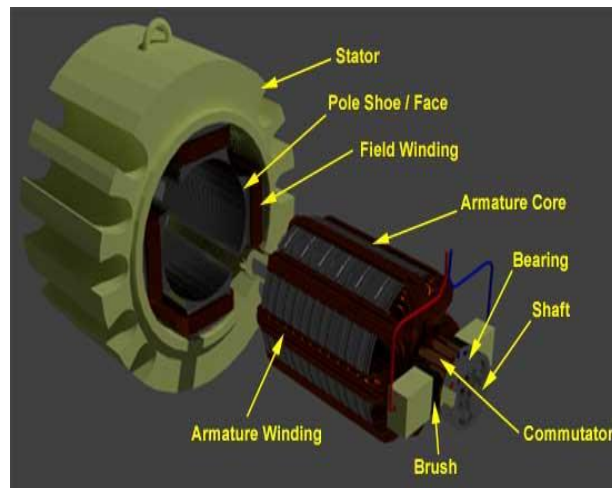
*Figure 11: Faulhaber 12V DC Coreless Motor*

This is a DC motor with an optical encoder. At first we used stepper motor to move both directions. It is easy to control stepper motor. The main problem with it was the weight of our project and stepper motor couldn't carry that much weight. So we decided to move on with this motor.

This motor has two main parts. One is DC Motor and another is Optical Encoder

We will be discussing about this two parts below:

### 1. DC motor:



*Figure 12: Parts of a DC motor*

The 12V 8100 RPM DC Motor has six basic parts (3) –

- Axle
- Rotor (a.k.a., armature)
- Stator
- Commutator
- Field magnet(s)
- Brushes

#### *Axle:*

An axle is a central shaft for a rotating wheel or gear.

***Rotor:***

It is also known as armature. The rotor is a moving component of an electromagnetic system in the electric motor.(3)Its rotation is due to the interaction between the windings and magnetic fields which produces a torque about the rotor's axis.

***Stator:***

The static part houses the field windings and receives the supply.

***Commutator:***

It is a cylindrical structure. It is made up of copper pieces attached together. Its main function as far as the dc motor is concerned is to commute or relay the supply current from the mains to the armature over a rotating structure. It goes through the brushes of dc motor. (3)

***Field magnets:***

The field winding of dc motor are made with field coils (copper wire) wound over the slots of the pole shoes in such a manner that when field current flows through it, then nearby poles have opposite polarity are formed. The field winding basically forms an electromagnet that produces field flux within which the rotor armature of the dc motor rotates.

***Brushes:***

The brushes of dc motor are made with carbon or graphite structures, making sliding contact over the rotating commutator. The brushes are used to relay the current from external circuit to the rotating commutator from where it flows into the armature winding. So, the commutator and brush unit of the dc motor is concerned with transmitting the power from the static electrical circuit to the mechanically rotating region or the rotor. [3]



DC motors are used for a variety of purposes, such as robot kits, boats, sometimes planes and individuals wishing to develop their own electric vehicle. The simple design and reliability of a DC motor makes it a good choice for many different uses, as well as a fascinating way to study the effects of magnetic fields.

## 2. **Optical encoder:**

A sensor attached to any rotating object known as encoder. To measure rotation, displacement, velocity, acceleration or rotating angle we use encoder. We have used an optical encoder. It has a moving mechanical component and a reflector to provide a series of electrical pulses to the arduino. A LED source and lens system transmits collimated light through a low inertia metal disc to give two channels with ninety degree phase shift. The index pulse is synchronized with the channel B [4]. Index pulse is a pulse that occurs once per rotation. Each encoder channel gives opposite output signals. The single 5 volt supply and the digital output signals are interfaced with a connector. When the encoder is used in noisy environments line driver is used. Motor with ball bearings are recommended for continuous operation at low and high speeds and for elevated radial shaft load. From these pulses we can determine distance, rotational velocity and rotating angle. This is known as the PID feedback system. We needed to work on this feedback system. Because we are giving a particular rotating number and the chess piece should move up to that position. The output of an encoder is a square wave and when the result comes in arduino we can easily measure the distance and angle it has covered.

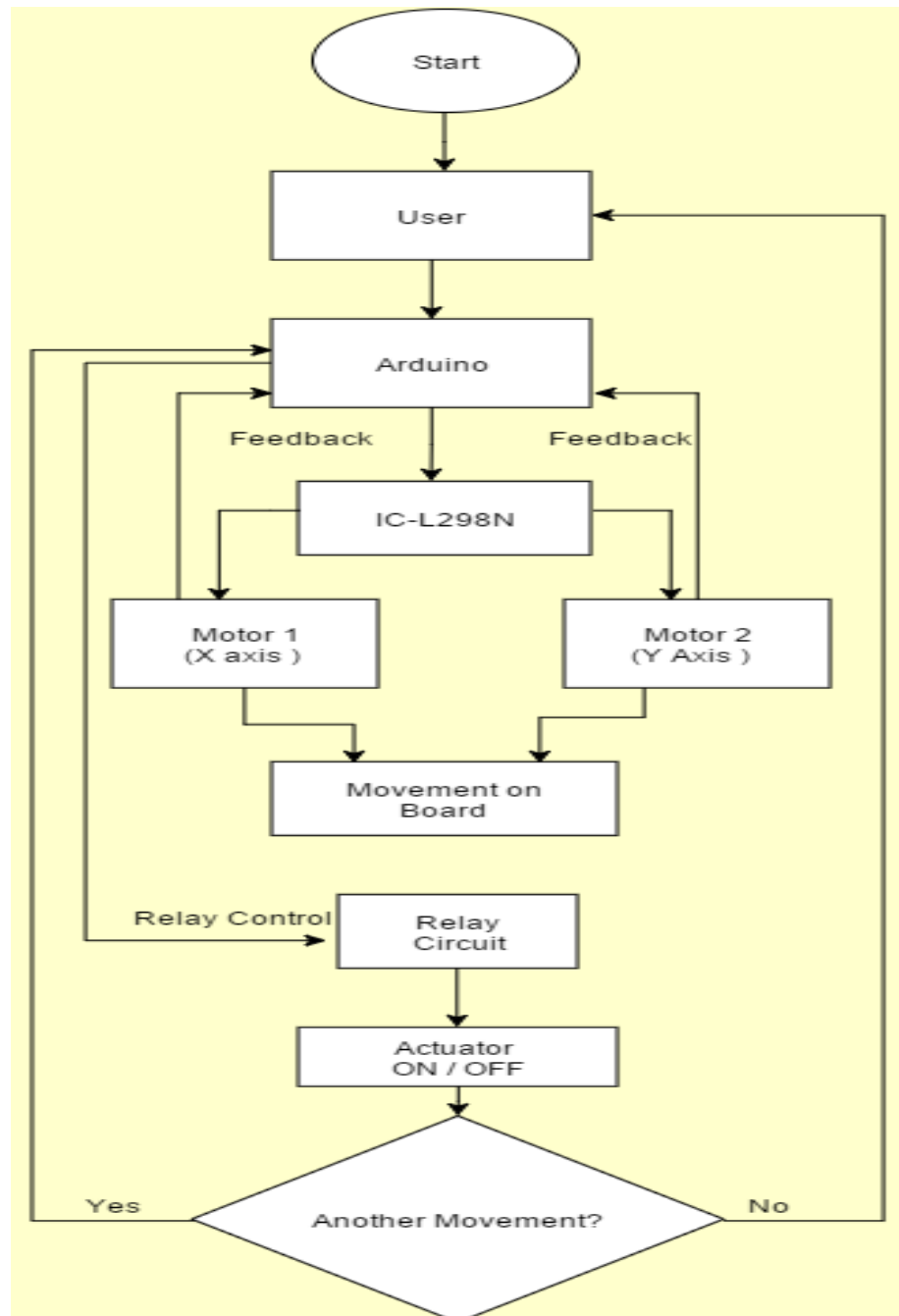
The Faulhaber motor uses optical encoder with line driver. The data sheet of this encoder is given below: [5]

HEDL 5540			
Pulses per revolution	N	500	
Signal output, (quadrature)		2+1 index and complementary outputs	channels
Supply voltage	$V_{CC}$	4.5 to 5.5	V DC
Current consumption, typical ( $V_{CC} = 5$ V DC)	$I_{CC}$	57	mA
Pulse width	P	$180 \pm 35$	$^{\circ}$ e
Index pulse width	$P_0$	$90 \pm 35$	$^{\circ}$ e
Phase shift, channel A to B	$\Phi$	$90 \pm 15$	$^{\circ}$ e
Logic state width	S	$90 \pm 35$	$^{\circ}$ e
Cycle	C	$360 \pm 5.5$	$^{\circ}$ e
Signal rise/fall time, typical	tr/ff	0.25 / 0.25	$\mu$ s
Frequency range <sup>1)</sup>	f	up to 100	kHz
Inertia of code disc	J	$8.497 \cdot 10^{-6}$	oz-in-sec <sup>2</sup>
Operating temperature range		0 to 70 (32 to 158)	$^{\circ}$ C ( $^{\circ}$ F)
<sup>1)</sup> Velocity (rpm) = f (Hz) x 60/N			

*Figure 13: Data sheet of optical encoder Series 5540*

## CHAPTER: 5 Control Software

### 5.1 Control Software



*Figure 23: Control Circuit*

At first, the user sends values to arduino. Arduino sends signals to motor driver L298N. Motor moves forward or backward accordingly. Each time the encoder sends the feedback. When the feedback meets the requirements then the motor doesn't move anymore. That is the main concept of using this FaulHabor motor. Its feedback system is the most important part.

```

1 if(motorActivate)
2   { if(rotateCount>rotateTime)
3     {
4       stopMotor();
5       motorActivate = false;
6       rotateCount =0;
7     }else
8     {
9       forward();
10    }
11  n = digitalRead(encoder0PinA);
12  if ((encoder0PinALast == LOW) && (n == HIGH)) {
13    if (digitalRead(encoder0PinB) == LOW) {
14      encoder0Pos--;
15    } else {
16      encoder0Pos++;
17    }
18    if(encoder0Pos==24)
19    {
20      Serial.println("One Rotation");
21      encoder0Pos=0;
22      rotateCount++;
23    }
24    if(encoder0Pos==24)
25    {
26      Serial.println("One Rev Rotation");
27      encoder0Pos=0;
28    }
29    encoder0PinB=0;

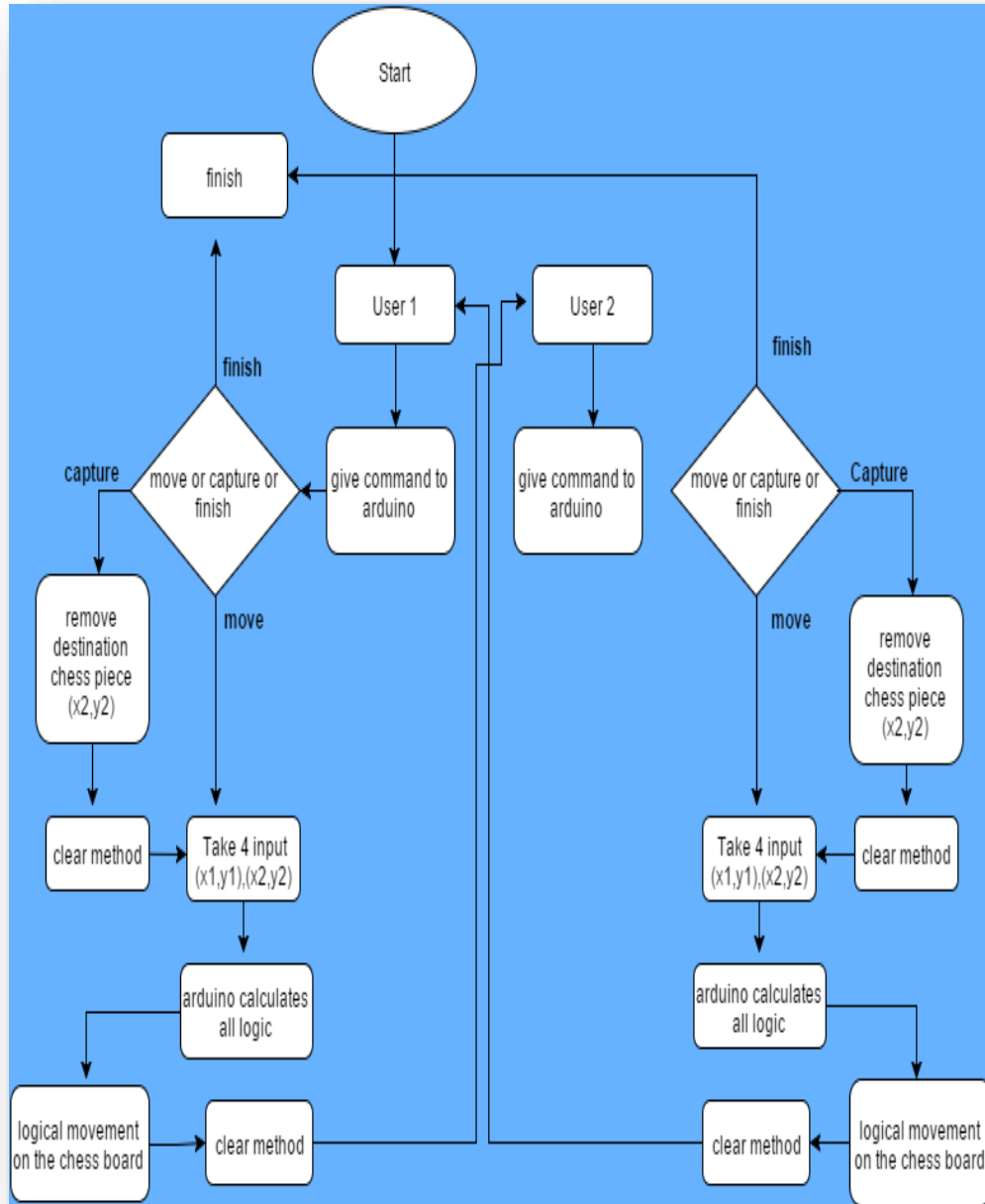
```

*Figure 14: Encoder Code Parts*

There are two signals A and B. When the code finds a low-to-high changeover on the A channel, it checks to see if the B channel is high or low and then

increments or decrements the variable to account for the direction that the encoder must be turning. For crossing one square these very motor needs 24 steps at a fixed 6V. When the counter exceeds 24 it stops immediately. Two motors are being controlled by L298N. Thus the motor reached to the destination and activated the actuator. The actuator is controlled with the help of a relay. By turning pins low and high we activate and deactivates relay. After getting into the position the actuator turns of, it slowly goes down and the contact between chess piece and magnet detached. And thus the whole game is being played.

## CHAPTER6: Chess playing algorithm:



*Figure25: Chess Playing Algorithm*

The game has many methods but it mainly has three methods:

- Move

- Capture
- Clear

These elements will maintain and manage the whole game. From starting till end with the assistance of these methods the game will be dealt with.

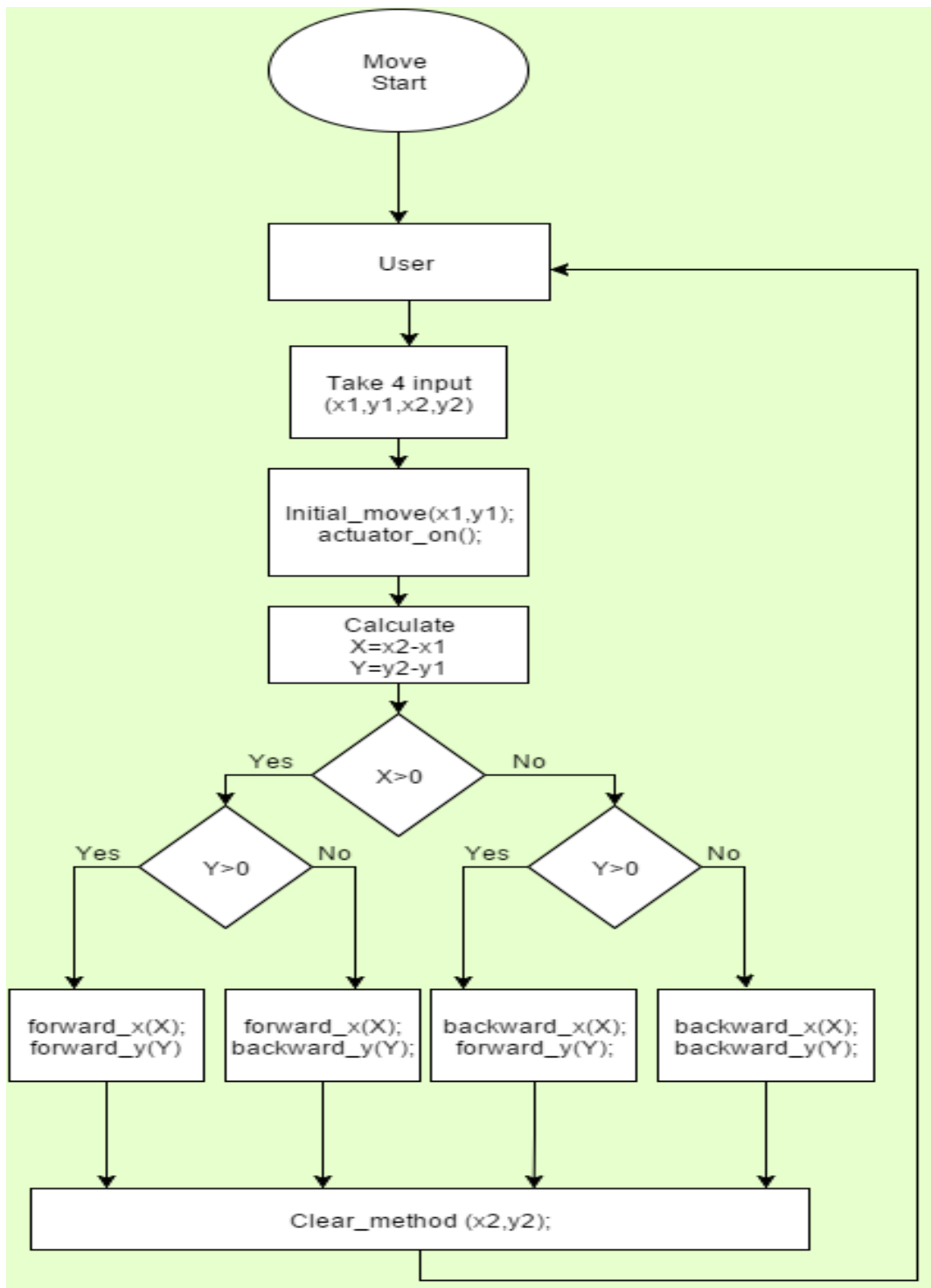
Firstly, the player will be taking decision on the move he wants to play and will give his command through laptop or pc. He can choose any one from these three types of methods. He can place a normal move call or capture a chess piece or can quit the program. Then according to his command the game will start. The arduino will take the command of the user. After placing his move the second player can give his command in the same way. The three types of methods are elaborated below:

### ***6.1 Move:***

A player after selecting the move option, He needs to give four inputs (x1, y1, x2, y2) or co-ordinates. Here, x1,y1 are source and x2,y2 are destination pointers. Move is divided into 2 special branches. First the X and Y axis needs to go to source square from 0,0 co-ordinates and after that they go half Y and half X backward, turn on the actuator. After actuator is activated it holds chess piece and then again both X and Y axis go half forward to the corner of source square. As all of the chess pieces moves between lines it is necessary to go to the corner of a box. Thus a chess piece takes its initial position to start to move towards destination. After it is done with initial movement, it begins to calculate the move it needs to take to go to destination.

$$X = X2 - X1$$

$$Y = Y2 - Y1$$



*Figure 26: Move Method*



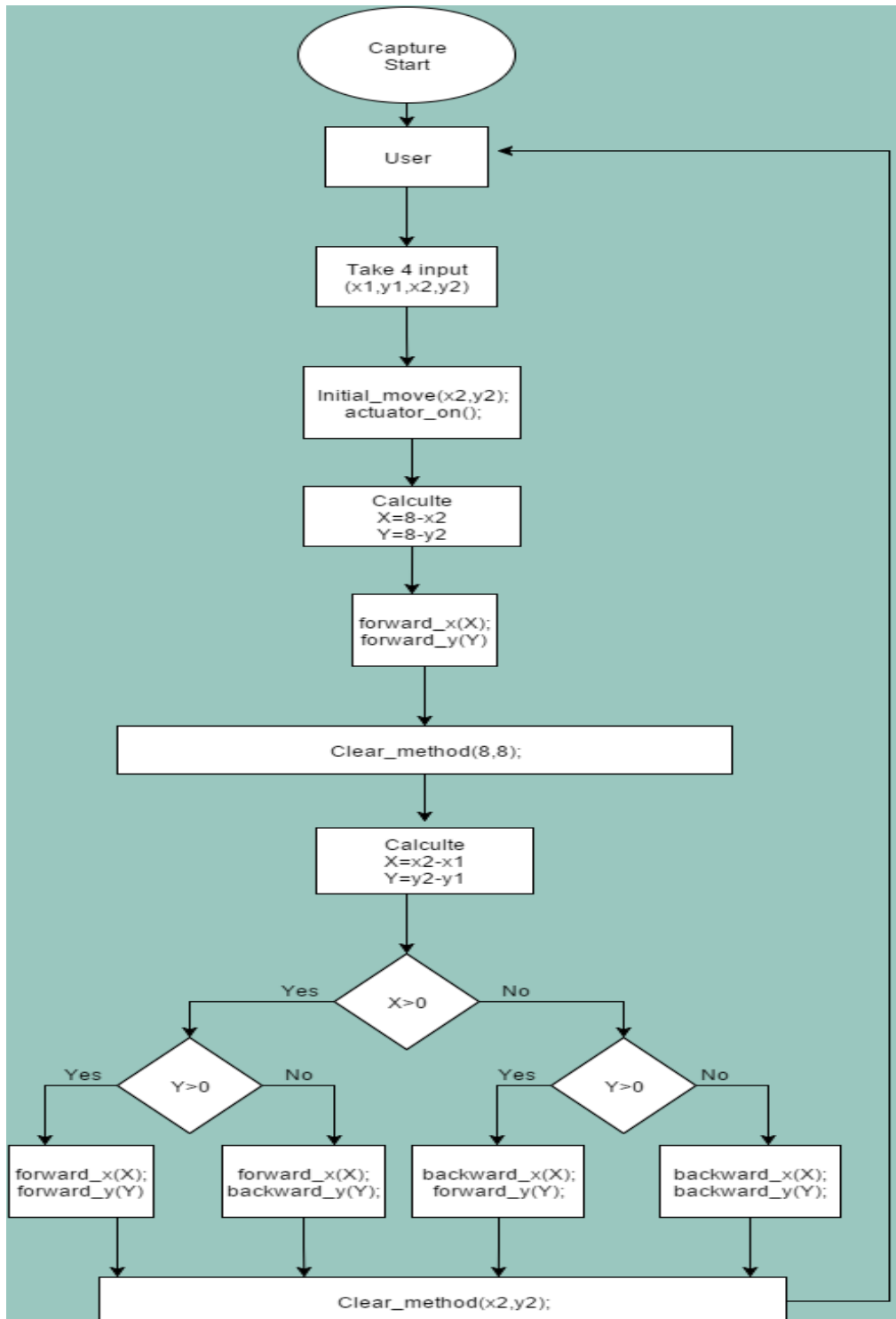
Depending on result there can be four different movements. Just like the Cartesian co-ordinate system the chess board was divided into 4 parts. This is very important because depending in this the arduino sends signal to motor that whether it should move forward or backward. It is shown clearly in the table below:

<b>Co-ordinate of X</b>	<b>Co-ordinate of Y</b>	<b>Movement of motor X</b>	<b>Movement of motor Y</b>
Positive	Positive	Forward	Forward
Positive	Negative	Forward	Backward
Negative	Positive	Backward	Forward
Negative	Negative	Backward	Backward

When both X and Y are positives that depicts that they are in first co-ordinate and so motors of X and Y axis will move forward. When X is positive and Y is negative that implies that the result is on second co-ordinate. Therefore, X goes forward and Y goes opposite. Vice versa happens when the results lies on third co-ordinate. And lastly, when both of the results are negative, the motors move to backward direction. According to this the move method is performed.

### ***6.2 Capture:***

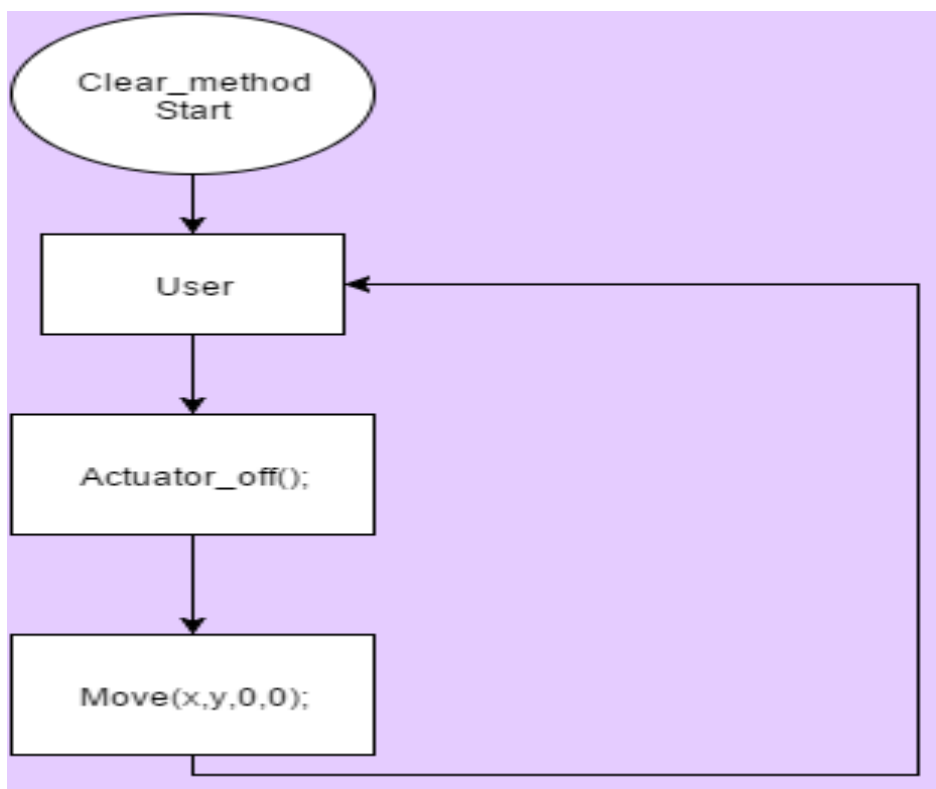
To capture chess piece the player needs to move the captured piece first. In order to do so the X and Y axis go to  $x_2, y_2$  position and make the initial movement by going to half y and half x backward. Then the actuator activates and holds the chess piece and drags it towards the corner of source co-ordinate. Next, it does a small calculation by subtracts  $x_2$  and  $y_2$  from 8. After that,



*Figure 27: Capture Movement*

X and Y axis go to forward up to that number and move the captured piece out. Subsequently, clear method is called and all the values return to default point. Then the move method is called and the whole work of move method repeats. After moving the pieces, clear method is called again in order to set the values to default.

### 6.3 Clear:



*Figure 28: Clear Movement*

Clear method is a very important part of the whole algorithm. Whenever a player calls this method every value reached towards default values. At first the actuator turns off. Next, X and Y axis move back to its initial position.

## CHAPTER: 7 DATA ANALYSIS

### 7.1 Theoretical Study:

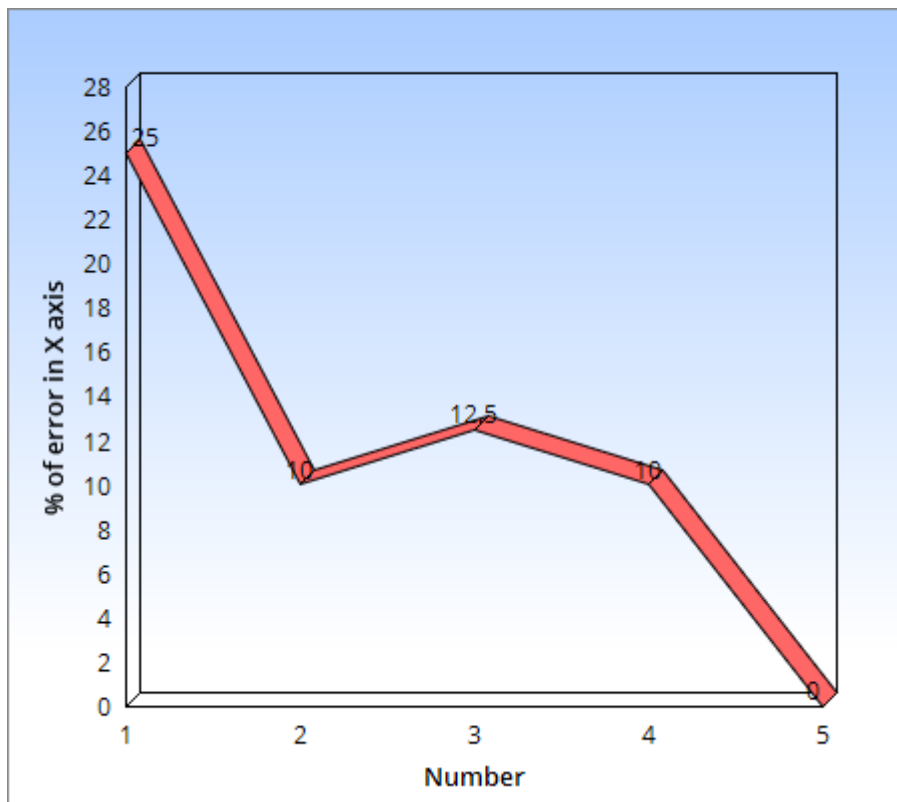
The lower part of our project (X axis) will be bearing the weight of its upper part (y axis). Moreover, we need to move on both forward and backward, so we needed a motor which we can move both ways easily. The length of our X and Y axis is 21 inch. The higher part is almost 10kg. To move this motors linearly pinions were used. Rail gears were also attached. To place a movement our board should not draw current more than 2 Amp. 12 volt is needed to power up the chess board. As the motor moves along X and Y axis it will have to face some frictions. We need to keep in mind that the less the friction the better the solution. To lessen friction, grease was applied.

Each method was tested several times and necessary audits were done to improve its performance. 6 different positions were chose to test the system. Here is the table below:

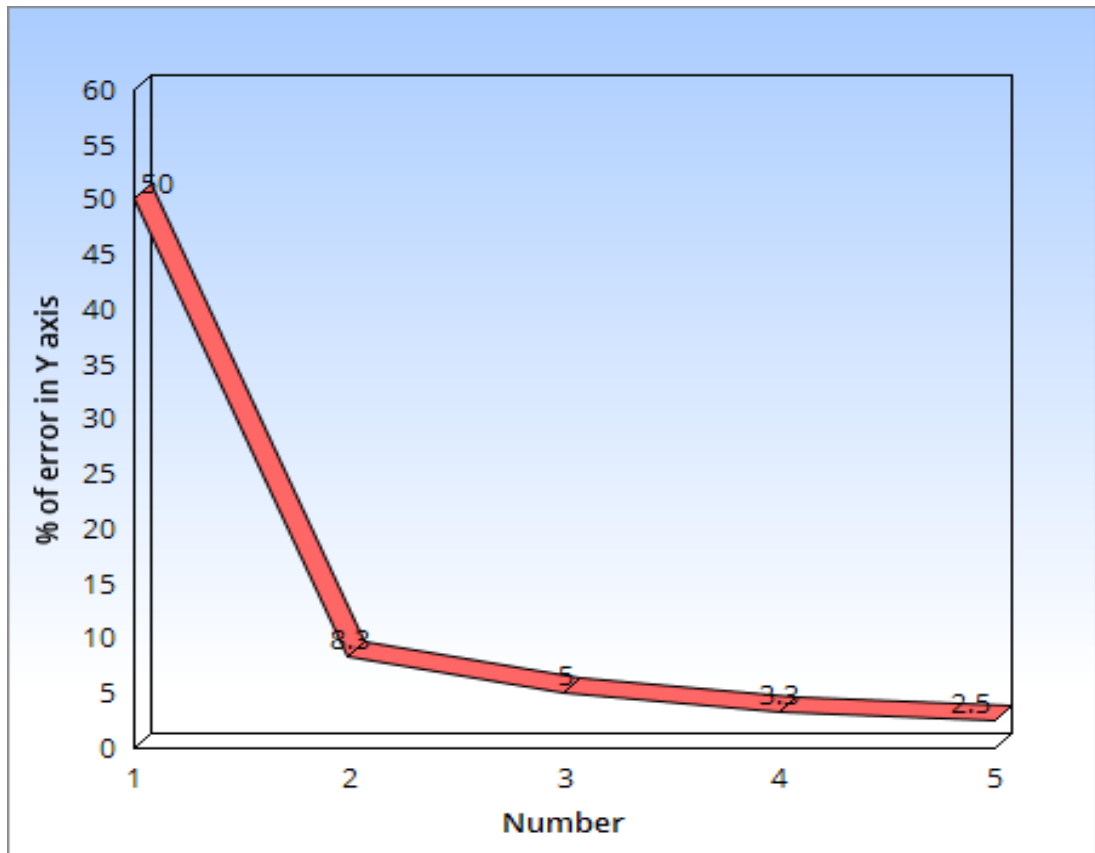
num ber	Theorit ical X	Practi cal X	Differ ence	error % in X	Theoriti cal Y	Pract ical Y	Differ ence	error % in Y
1	2	1.5	0.5	25%	2	1	1	50%
2	2	1.8	0.2	10%	6	5.5	0.5	8.30 %
3	4	3.5	0.5	12.50%	4	3.8	0.2	5%
4	3	2.7	0.3	10%	6	5.8	0.2	3.30 %
5	-4	4	0	0%	4	3.9	0.1	2.50 %

At the beginning, for backward method the percentage of error was high. It was mainly occurred due to the fluctuation of voltage. Again the steps per revolution may vary in times of taking measurements. After maintain all these things error rate started to decline. Here are two graph chart for X and Y axis.

The last percent of error for X axis is .05% which is negligible and it doesn't effect in the game.



Again the percentage of error in Y axis is 1% which is also negligible.



## **CHAPTER: 8 Discussion**

Throughout the project we had planned to add many more features. As the time was limited and we had faced many problems so we could not implement all our plans. But there are many possibilities of adding more features.

### ***8.1 Future Investigation:***

In order to make our project more efficient we have some future plans. We will add the following features:

- ***Attaching reed switches to our chess board:*** we will attach the reed switches.
- ***Implementing AI based system:*** We will implement AI based system so that the computer can take decisions and humans can play with the computers.
- ***Controlling the chess board via Bluetooth device:*** We will control the chess board by Bluetooth device so that two players can give their move through mobile phone instead of using laptop.
- ***Adding voice recognizer:*** if we add voice recognizer the user do not need to use any device rather they can give their command.

### ***8.2 Difficulties and solutions:***

We have failed to make our desired projects as we faced many problems. The problems are:

**Firstly**, we have used stepper motor in this project. But this motor cannot take the load so later on we used RC motor.

**Secondly**, with the magnet. As the size of the square boxes was small we faced problems working with the magnet as it was pulling the chess pieces of the other boxes.

**Thirdly**, it was difficult to match the DC motor perfectly with the rack gears.

**Finally**, we faced a huge problem with the battery source. Then we used voltage circuit of power supply.



## **CHAPTER: 9 CONCLUSION**

We want to express gratitude towards Almighty Allah that we have finished our thesis effectively. Still we have many more features to add. We believe that this project will increase children's enthusiasm to play chess. This hand free chess board will hopefully also encourage young people to make robots. Though we still needs to add more features but we think this project will serve the purpose of entertaining people.

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