Group 12
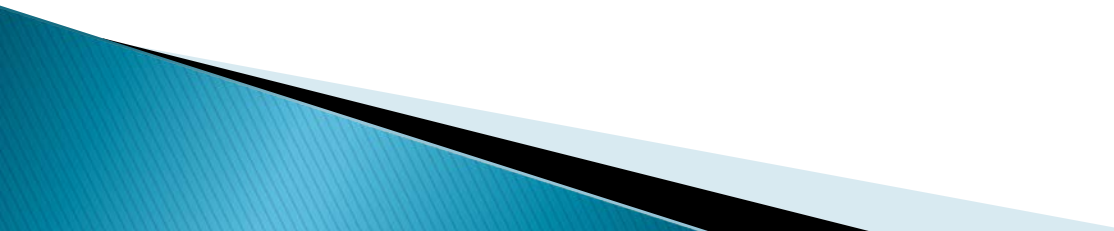Shenmin Lo, EE
Joseph Lunder, CpE
Siarhei Traskouski, EE
Robert Wadsworth II, EE

Motivation

- To allow players separated across great distances to play Chess together
- To streamline the process of practicing Chess against an AI
- To create an elegant physical and virtual environment that is easy to use
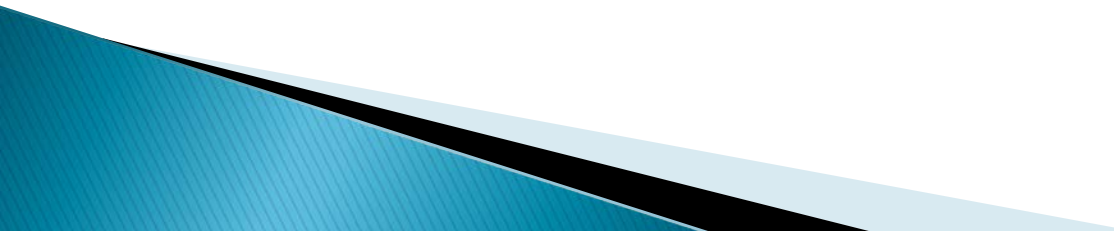- To put a spin on traditional gameplay and create a new way to play a classic game

Deep RGB?

- Automated Chess Board
  - Use magnets to move pieces
  - Take input physically from user
  - Correct user errors
  - Visually assists gameplay
  - Multiple playing modes
  - Sends data wirelessly to off-site server
- Web Interface
  - Allow gameplay from any web-enabled device
  - Allow for environment customization
 - Store saved games and other user data

Goals

- Allow for play between human and computer, human and remote human, or two computers
- Connect to server over any available wireless network
- Detect pieces using a Hall-Effect sensor grid
- Make required moves with under-board magnet
- Show available moves via in-board LEDs
- Play selected sound effects depending on game state

Requirements

- Weight of entire unit no more than 10kg
- Dimensions of playing field no larger than 40cm by 40cm
- Dimensions of whole unit no larger than 70cm by 55cm by 20 cm
- Operates under 110–220V 50/60Hz AC
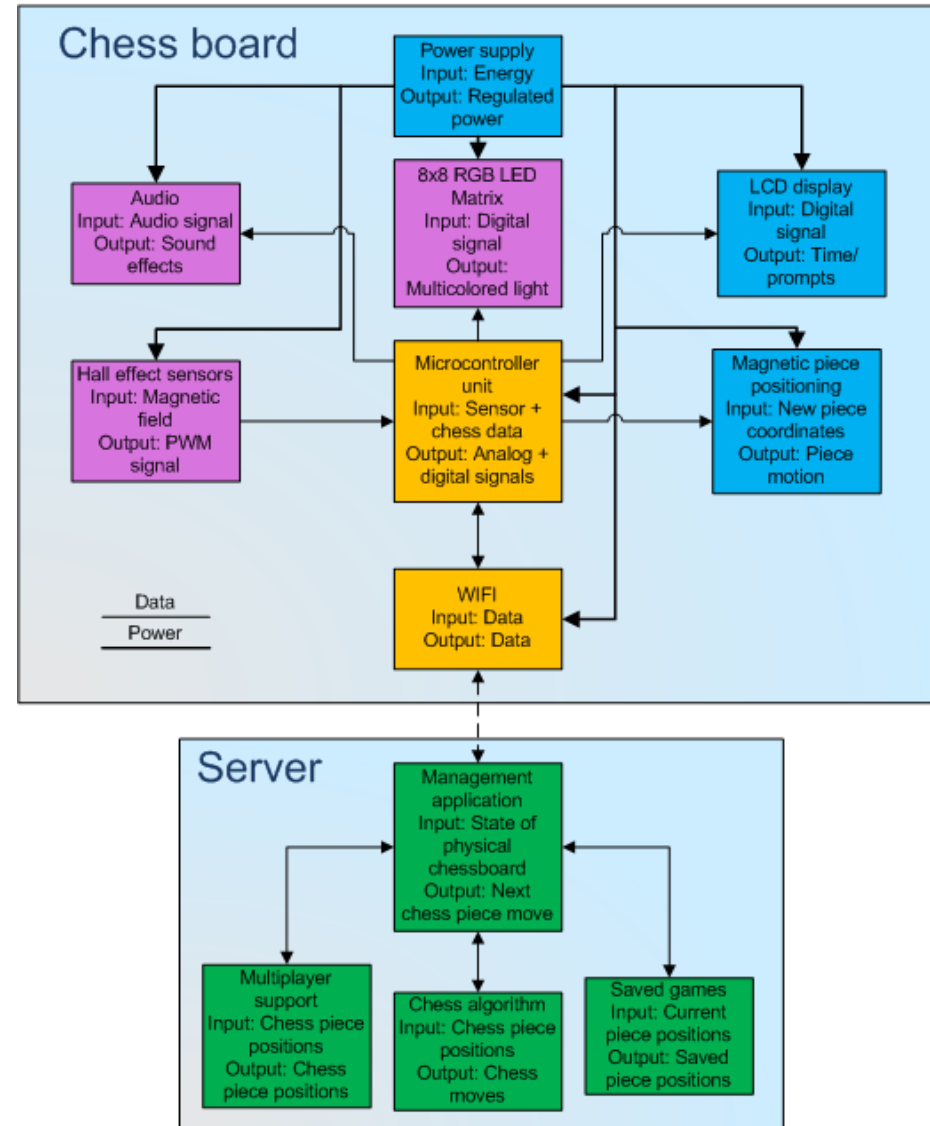- Pieces positioned with less than 10% error

Subsystem Layout
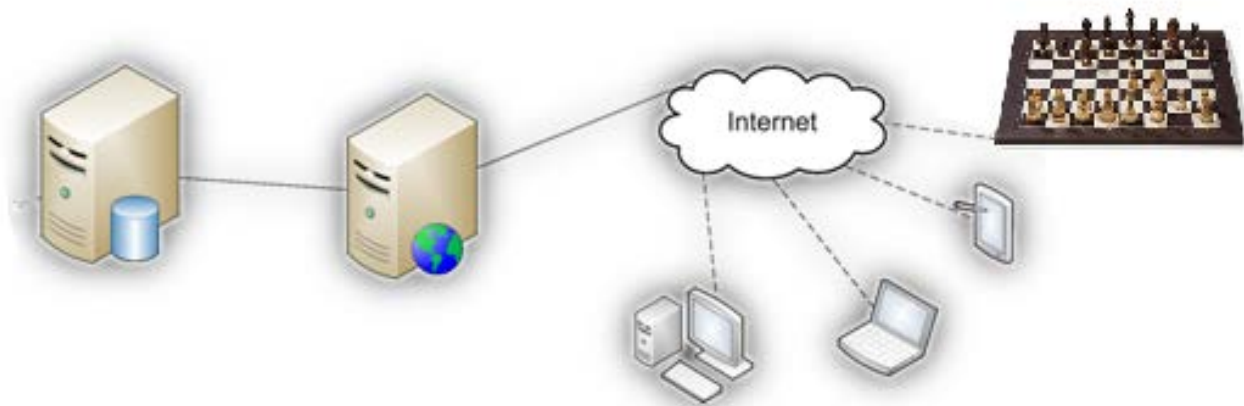
Full System

Labor is divided into hardware and software

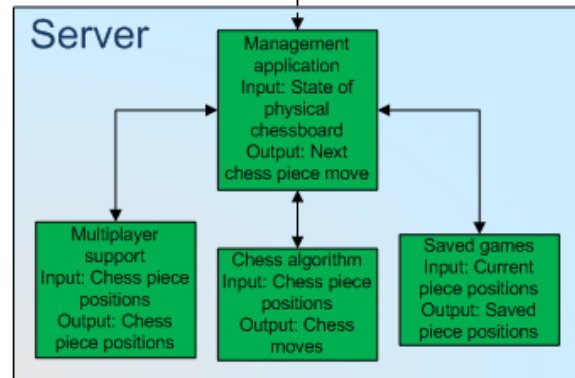▸ Hardware subsystems
  • Shenmin in yellow
  • Robert in pink
  • Siarhei in blue

▸ Software subsystems
  • Joseph in green
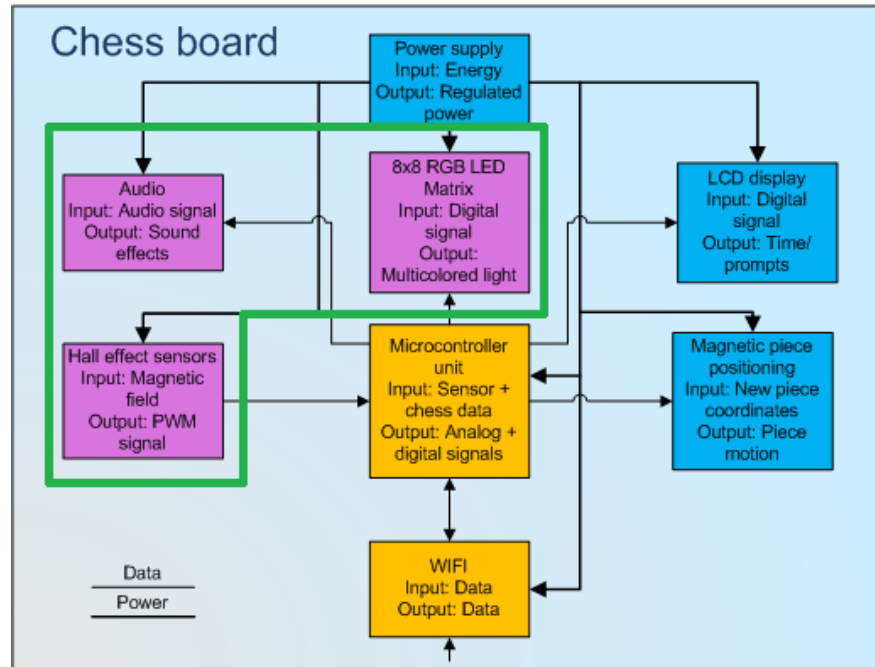
RGB Light Emitting Diodes
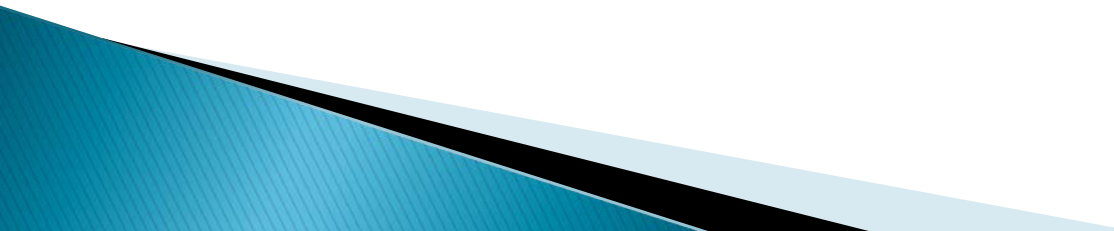
	RL5-RGB-C-2	R596CR3G4B5C-C10	R596CR3G4B5W-F12
Operating Voltage (R,G,B)	2.4, 3.5, 3.5 V	2.2, 3.4, 3.4 V	2.2,3.4,3.4 V
I(Peak)	50mA	30mA	30mA
Viewing Angle	60°	40°	40°
Luminosity	1K-5K mcd	800-4000 mcd	1200-6500 mcd
Diameter	5mm	5mm	5mm
Package	SIP	SIP	SIP
Pins	4	4	4
Price per Unit	$0.79	$0.60	$0.60

RL5-RGB-C-2
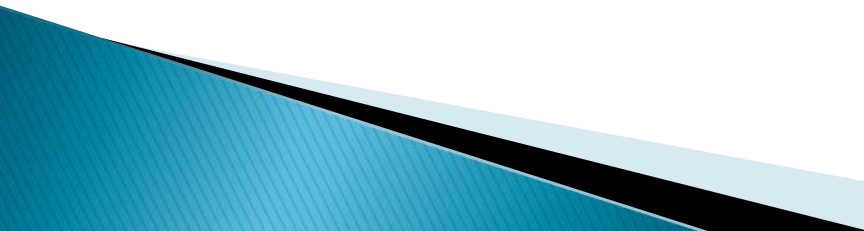
- Substituted for the R596CR3G4B5W-F12
- Super bright RGB LED
- Highest Viewing angle
- Capable of creating a wide array of colors
- Compact design
- Low cost
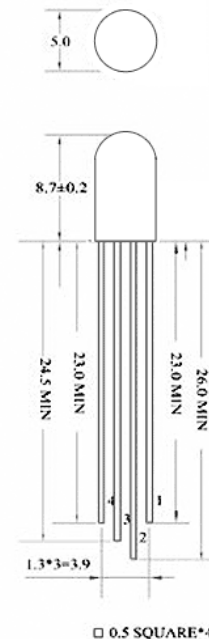
LED Array Functionality

- Display available moves when a piece is picked up
- Visual queues for errors
- Helps distinguish between player's pieces
- Personalization and user customization

LED Array Implementation

- Each pin is connected to a specific rail running horizontally and vertically
- Each LED is activated one at a time by activating two or more rails
- Rails are controlled using four shift registers connected in series
- Each register controls one group of rails; red, green, blue and cathode
- Implementation caused massive traffic on SPI bus

LED Array Schematic
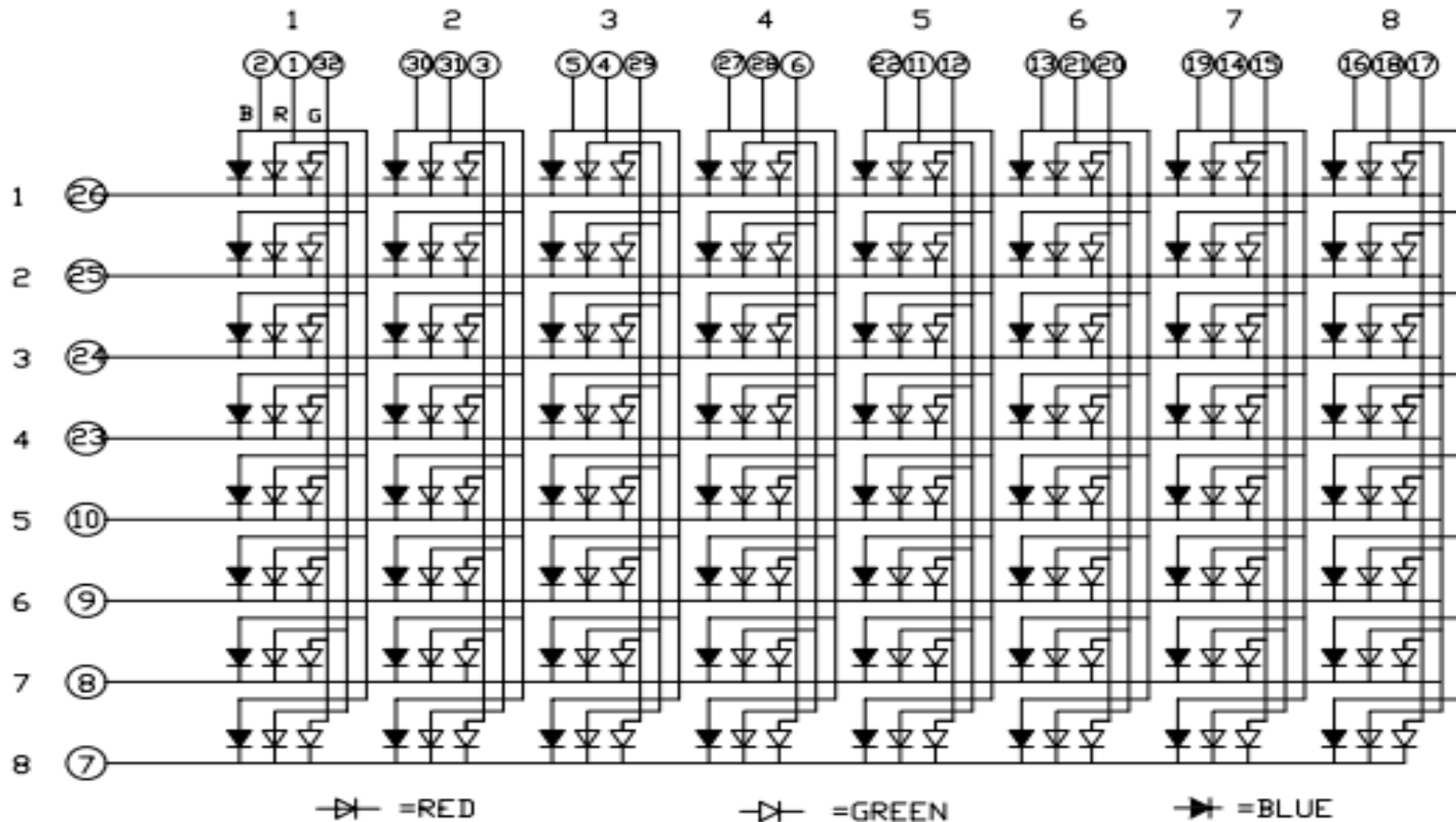
Shift Register Configuration
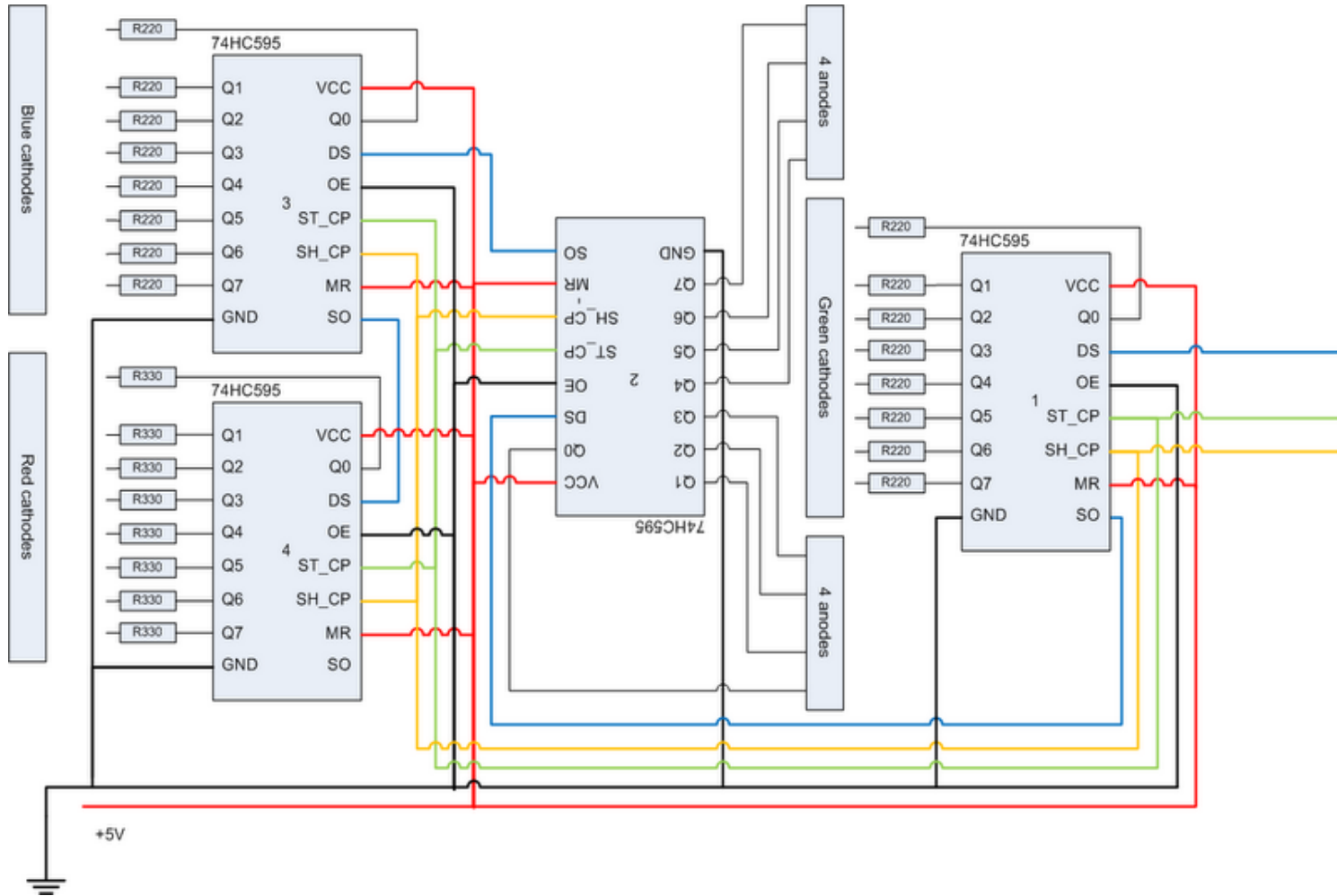
Hall-Effect Sensor

	MLX 90215	A1325	A1302
VCC(recommended)	5V	5V	4.5 – 6V
VCC(max)	5.5V	5.5V	8V
I(max)	6.5mA	9mA	11mA
Package	SIP	SIP	SIP
Pins	4	3	3
Sensitivity	5–140 mV/G	3.125 mV/G	0.85 – 1.75 mV/G
Price per Unit	$2.38	$1.35	$1.54

Allegro A1325

- Linear ratiometric Hall-effect sensor
- Capable of determining range and polarity
- Simple, small and reliable
- Low cost per unit
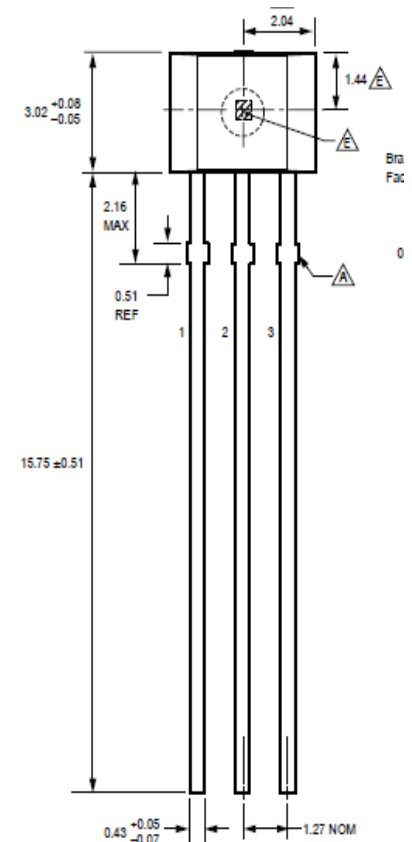
Hall–effect Grid

- 2D 8X12 array (96 sensors)
- One sensor in the center of each tile
- Powered simultaneously
- 6 MUXs channel output into MCU
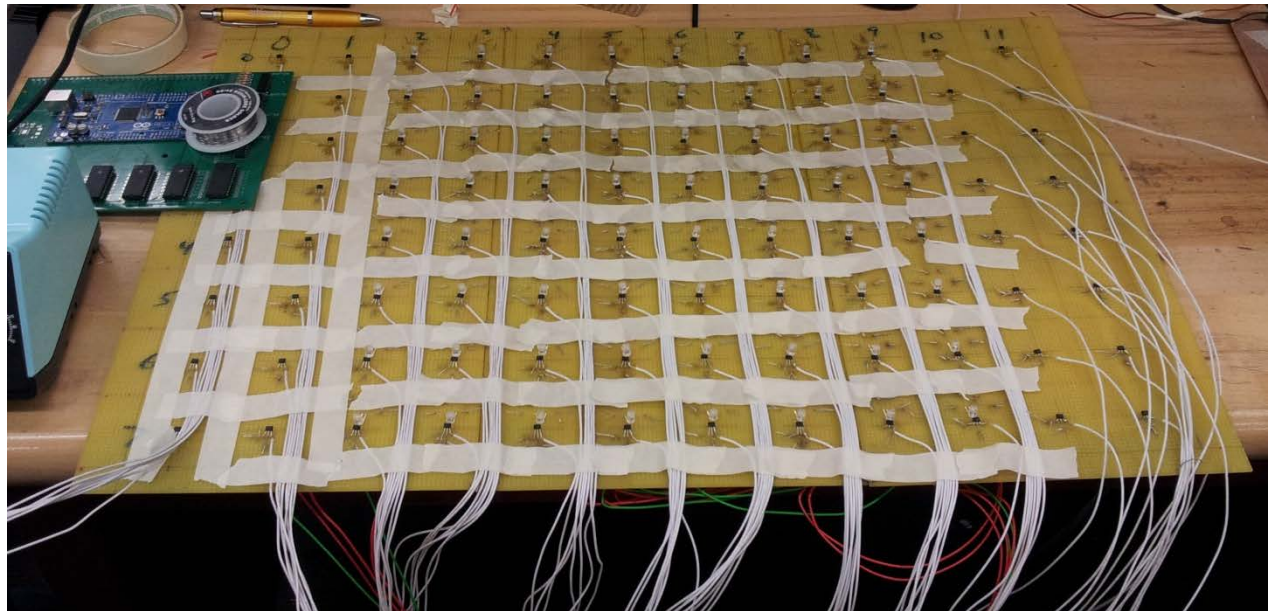
Audio Module

	Arduino–019	rMP3	DEV–10628
Operating voltage	5V	5V	5V
Current	Unspecified	60mA	Unspecified
Input	SPI	SPI	SPI
Outputs	3.5mm jack, line out	3.5mm jack	3.5mm jack , line out
Data Storage	Micro SD up to 2GB	Micro SD up to 32GB	Micro SD
Interrupt Capable	Unspecified	Yes	Yes
Decoding Capabilities	Mp3, Ogg Vorbis	Mp3	Mp3, Ogg Vorbis
Price	$27.50	$64.99	$39.95

DEV-10628

- Low cost audio shield
- Designed for use with Arduino boards
- Capable of decoding most popular audio formats
- Onboard data storage
- Interrupt capable through buffer
- Multiple outputs

Chess board

Power supply
Input: Energy
Output: Regulated power

Audio
Input: Audio signal
Output: Sound effects

8x8 RGB LED Matrix
Input: Digital signal
Output: Multicolored light

LCD display
Input: Digital signal
Output: Time/ prompts

Hall effect sensors
Input: Magnetic field
Output: PWM signal

Microcontroller unit
Input: Sensor + chess data
Output: Analog + digital signals

Magnetic piece positioning
Input: New piece coordinates
Output: Piece motion

Data
Power

WIFI
Input: Data
Output: Data

Server

Management application
Input: State of physical chessboard
Output: Next chess piece move

Multiplayer support
Input: Chess piece positions
Output: Chess piece positions

Chess algorithm
Input: Chess piece positions
Output: Chess moves

Saved games
Input: Current piece positions
Output: Saved piece positions

Moving System Block Diagram
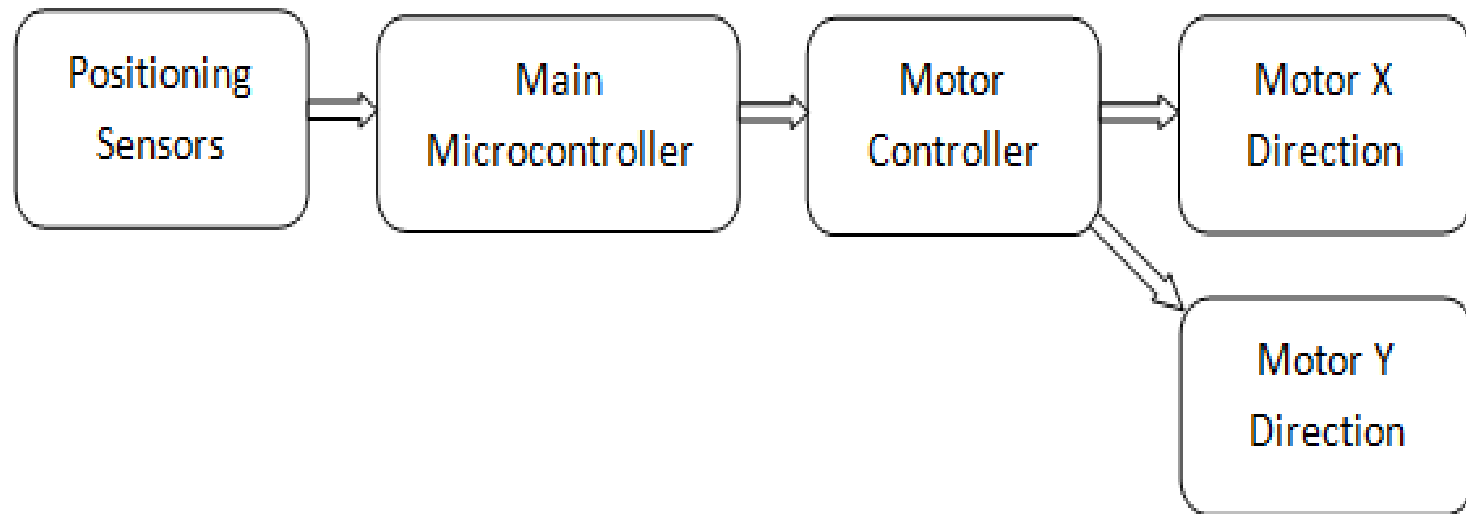
Magnetic Piece Moving System

- Main parts of the moving system are the X and Y positioning tables.
- The XY rails will be located underneath the chess board
- It will be capable of moving from one X-Y coordinate to another in order to move certain chess pieces
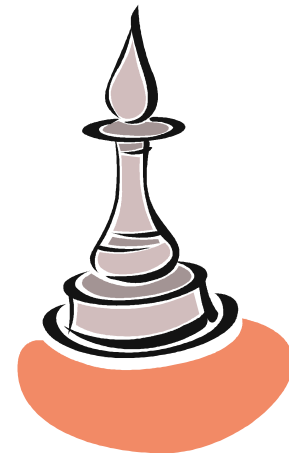
Moving system

	Noise level	Difficulty of installation	Reliability	Cost of the system
Internal gear	High	Medium	Low	Medium
Worm gear	Low	High	High	High
Rack and gear	Medium	Low	Medium	Low
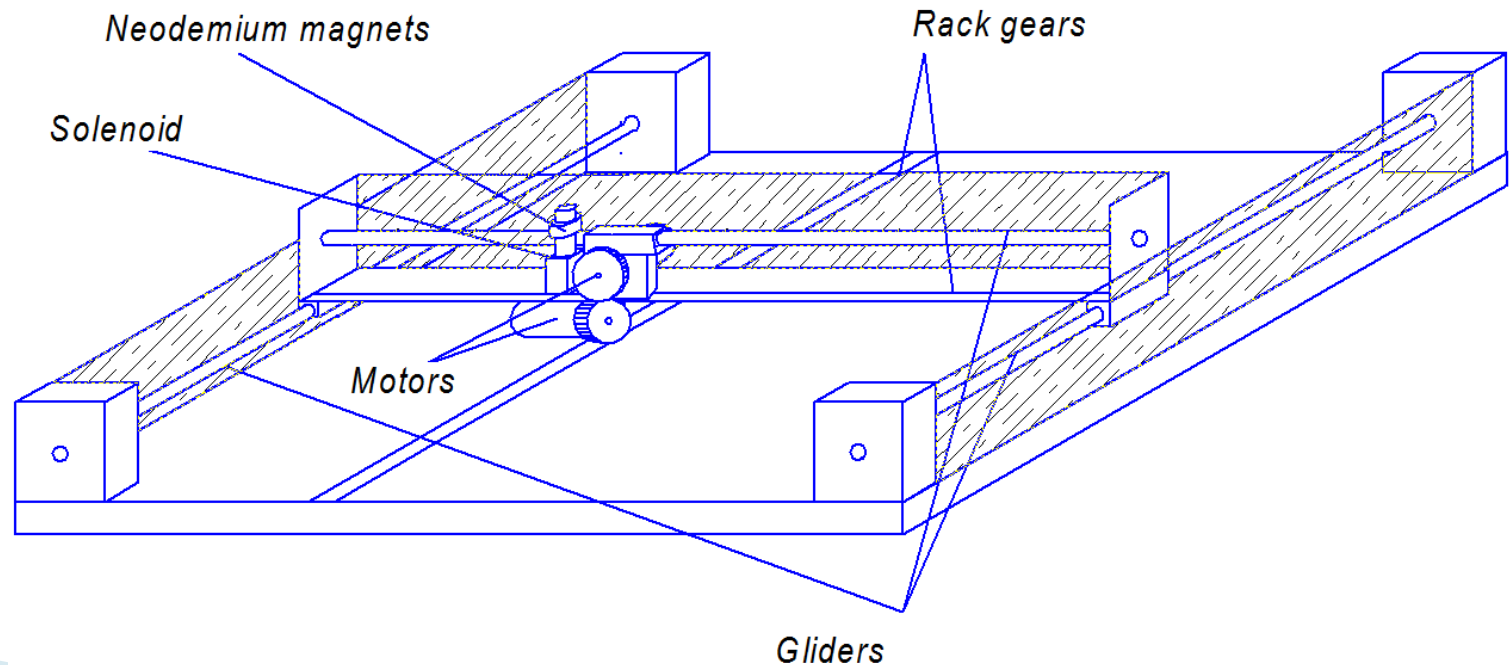
Magnets

- Each chess piece has a magnet attached to the bottom of it
- Under the board we have one strong magnet installed on the moving positioning system

Chess figures' neodymium magnets

▸ Disk 1/2" x 1/16"
▸ N42-class
▸ Over 6.6 lbs pulling force

Electromagnet

Model of electromagnet	R-1207-12	EM 137	ER2-103
Voltage, V	12	12	24
Duty	Continuous	Continuous	Continuous
Watts	3.3	5	4.2
Amps	0.28	0.41	n/a
Holding Force, Lbs	45	33	22
Weight, Lbs	0.24	0.24	0.4
Diameter, cm	3.175	3.493	3.175
Height, cm	1.905	2.06	n/a
Price, $	40	29.24	76.06

Electromagnet & Solenoid

- EM 137
  - Inexpensive and lightweight
  - Could not reach through the playing surface
- Solenoid equipped with magnets used for replacement
- Uses an electromagnet to push a rod up and down allowing the magnets to grab pieces

Activation Circuit Decision

- We used NPN-transistor as a switch
- Diode used to protect the transistor from back voltage
- Capacitors reduced signal noise from solenoid.
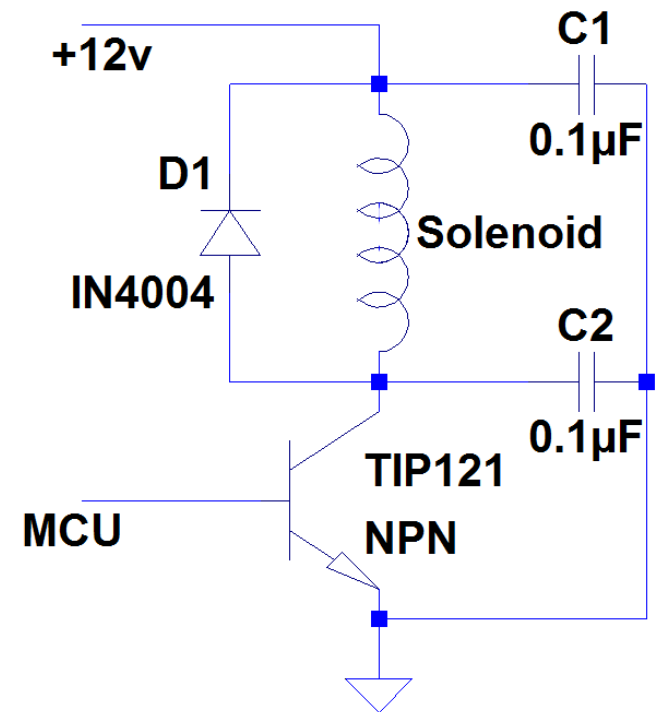
Stepper motors

| Motor Model #	Stepper Motor -200 steps/rev	Unipolar/Bipolar, 200 steps/rev	Applied Motion – 5017–009 Bipolar Stepper Motor	Mercury ROB-09238 Bipolar Stepper Motor
Motor type	Bipolar	Unipolar/Bipolar	Unipolar/Bipolar	Bipolar
Step Angle, degree	1.8	1.8	1.8	1.8
# of Wire Leads	4	6	6	4
Leads length, mm	230	300	305	1200
Drive Shaft Diameter, mm	5	5	5	5
Rated Voltage, V	12	4	6	12
Rated Current, mA	350	1200	570	330
Holding Torque, oz-in	28	44	31.4	31.9
Winding Resistance, Ohm	34	3.3	15	34
Frame Size, mm	42.3 x 42.3	42.3 x 42.3	42.3 x 42.3	42.3 x 42.3
Weights, g	200	350	n/a	200
Price, $	14.00	19.95	12.95	14.95

Mercury ROB-09238 Bipolar Stepper Motor

- Bipolar Motor
- 5mm shaft diameter
- 12V at 330 mA
- 0.166 foot pounds of torque
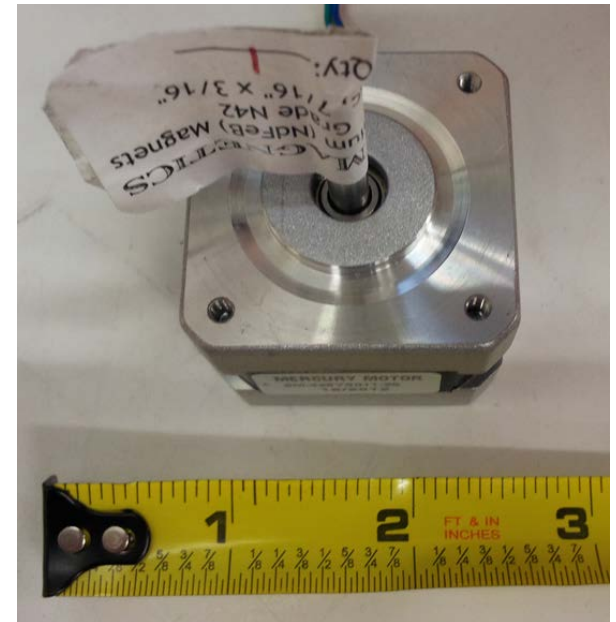
Motor Driver

	Easy Driver	Big Easy Driver	A4988 Stepper Motor Driver
Power supply range, V	From 7 to 30	From 8 to 35	From 8 to 35
Output power, V	3.3/5	3.3/5	3.3/5
Microsteps	1/2; 1/4; 1/8	1/2; 1/4; 1/8; 1/16	1/2; 1/4; 1/8; 1/16
Chip	A3967	A4983	A4988
Current control per phase, mA	Up to 750	Up to 2000	Up to 2000
Board size, in	0.6 x 1.9	1.25 x 1.75	0.7 x 1.4
Source	Open	Open	n/a
Price, $	14.95	22.95	14.95

A4988 Stepper Motor Driver

- 8 to 35V stepper voltage range
- Capable of 1/2; 1/4; 1/8; 1/16 steps
- Tiny board size
- Inexpensive
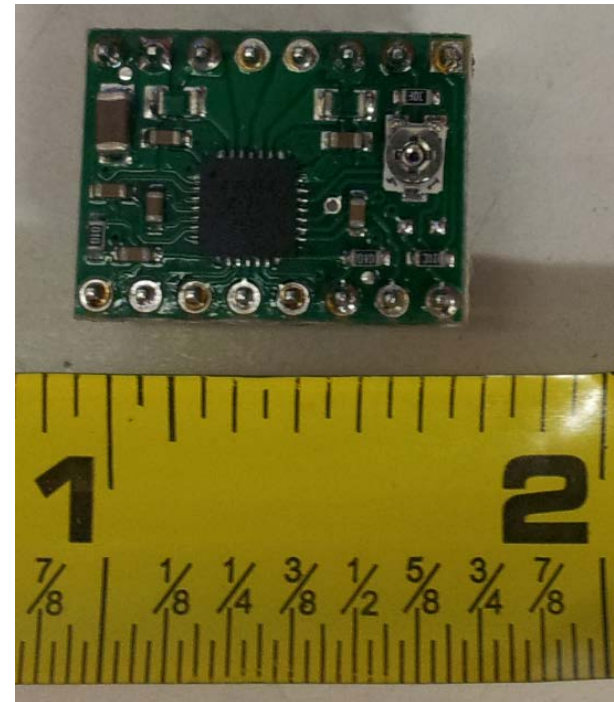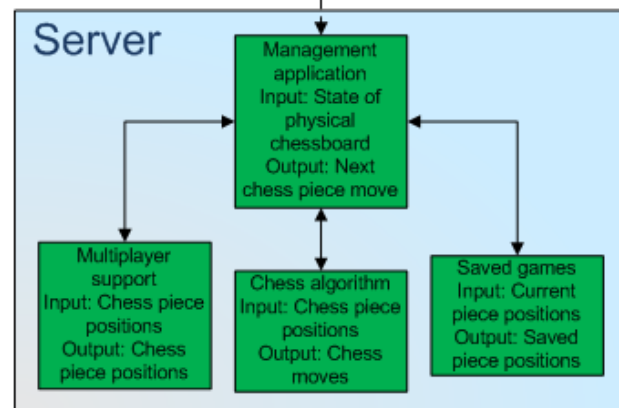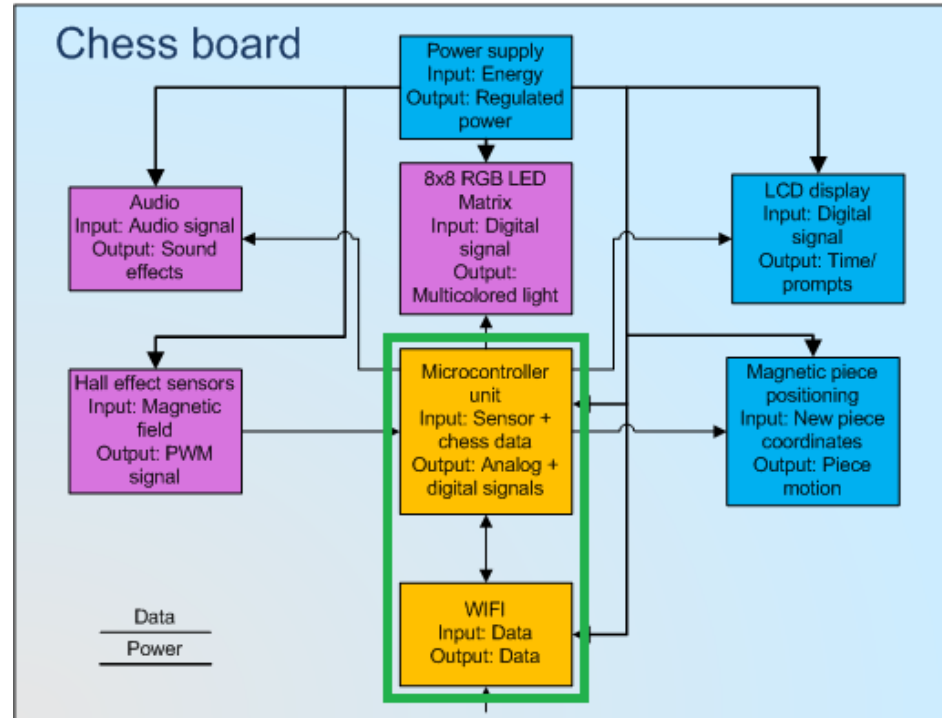
Microcontroller Unit (MCU)

	PIC18F46K80	MSP430FR5739	Atmel Corporation ATmega 2560
Operating voltage	1.8 – 5.5 V	2 – 3.6 V	2.7 – 5.5 V
Digital I/O pins	35	33	54
Analog input pins	11	14	16
UART & SPI busses	3	3	4
Program memory	64 KB	16 KB	256KB
Clock speed	64 MHz	24 MHz	16 MHz
Experience with product	None	None	Very experienced
Price per microcontroller	$4.30	$6.35	$17.97
Price per development board	$165.00	$29.00	$58.95

Atmel ATMega 2560

- Low power 8-bit microcontroller
- Clock Rate of 16MHz
- 4 serial I/O
- Has analog to digital converter
- 70 General Purpose I/O

16mm

RESET
XTAL2
XTAL1
AREF
GND
Y1
CSTCE16M0V53R0 / STARD 16MHZ
AREF
C3
100n
C4   C5   C6
100n 100n 100n
GND
+5V

RESET   30
XTAL2   33
XTAL1   34
AREF   98
AVCC   100
AGND   99
VCC   10
VCC   31
VCC   61
VCC   80
GND   11
GND   32
GND   62
GND   91

PL7   42   PL7
PL6   41   PL6
PL5   40   PL5(OC5C)
PL4   39   PL4(OC5B)
PL3   38   PL3(OC5A)
PL2   37   PL2(T5)
PL1   36   PL1(ICP5)
PL0   35   PL0(ICP4)

ADC15   82   PK7(ADC15/PCINT23)
ADC14   83   PK6(ADC14/PCINT22)
ADC13   84   PK5(ADC13/PCINT21)
ADC12   85   PK4(ADC12/PCINT20)
ADC11   86   PK3(ADC11/PCINT19)
ADC10   87   PK2(ADC10/PCINT18)
ADC9   88   PK1(ADC9/PCINT17)
ADC8   89   PK0(ADC8/PCINT16)

         79   PJ7
         69   PJ6(PCINT15)
         68   PJ5(PCINT14)
         67   PJ4(PCINT13)
         66   PJ3(PCINT12)
         65   PJ2(XCK3/PCINT11)
TXD3   64   PJ1(TXD3/PCINT10)
RXD3   63   PJ0(RXD3/PCINT9)

PH6   27   PH7(T4)
PH5   19   PH6(OC2B)
PH4   17   PH5(OC4C)
PH3   16   PH4(OC4B)
         15   PH3(OC4A)
         14   PH2(XCK2)
TXD2   13   PH1(TXD2)
RXD2   12   PH0(RXD2)

71   (AD7)PA7   PA7
72   (AD6)PA6   PA6
73   (AD5)PA5   PA5
74   (AD4)PA4   PA4
75   (AD3)PA3   PA3
76   (AD2)PA2   PA2
77   (AD1)PA1   PA1
78   (AD0)PA0   PA0

26   (OC0A/OC1C/PCINT7)PB7   PB7
25   (OC1B/PCINT6)PB6   PB6
24   (OC1A/PCINT5)PB5   PB5
23   (OC2A/PCINT4)PB4   PB4
22   (MISO/PCINT3)PB3   PB3   (MISO)
21   (MOSI/PCINT2)PB2   PB2   (MOSI)
20   (SCK/PCINT1)PB1   PB1   (SCK)
19   (SS/PCINT0)PB0   PB0

60   (A15)PC7   PC7
59   (A14)PC6   PC6
58   (A13)PC5   PC5
57   (A12)PC4   PC4
56   (A11)PC3   PC3
55   (A10)PC2   PC2
54   (A9)PC1   PC1
53   (A8)PC0   PC0

50   (T0)PD7   PD7
49   (T1)PD6
48   (XCK1)PD5
47   (ICP1)PD4
46   (TXD1/INT3)PD3
45   (RXD1/INT2)PD2
44   (SDA/INT1)PD1   SDA
43   (SCL/INT0)PD0   SCL

9   (CLKO/ICP3/INT7)PE7
8   (T3/INT6)PE6
7   (OC3C/INT5)PE5   PE5
6   (OC3B/INT4)PE4   PE4
5   (OC3A/AIN1)PE3   PE3
4   (XCK0/AIN0)PE2
3   (TXD0)PE1   PE1
2   (RXD0/PCINT8)PE0   PE0

90   (ADC7/TDI)PF7
91   (ADC6/TDO)PF6
92   (ADC5/TMS)PF5
93   (ADC4/TCK)PF4
94   (ADC3)PF3
95   (ADC2)PF2
96   (ADC1)PF1
97   (ADC0)PF0

1   (OC0B)PG5   PG5
29   (TOSC1)PG4
28   (TOSC2)PG3
70   (ALE)PG2   PG2
52   (RD)PG1   PG1
51   (WR)PG0   PG0

SCL
SDA
AREF
GND

PH6
PH5

TXD3
RXD3
TXD2
RXD2
TXD1
RXD1

PH4
PH3
PE3
PG5
PE5
PE4

ADC7
ADC6
ADC5
ADC4
ADC3
ADC2
ADC1
ADC0

ATMEGA2560-16AU

Development Environment

- Hardware
  - Arduino Mega 2560 R3
    - Open source schematic
    - Low cost

- Software
  - Multiplatform capability
  - Community supported
  - C-esque programming language


```
#define stepPin 3
#define dirPin 2
#define enablePin 7
#define MicroStep1Pin 6
#define MicroStep2Pin 5
#define MicroStep3Pin 4

#define numMsInOneSec 1000
#define numMicroSecInOneMs 10000
#define stepPulseWidthInMicroSec 2
#define setupTimeInMicroSec 1

#define inputBufferSize 128

int   serialCharIn;
char  serialInString[inputBufferSize];
int   serialInIndex  = 0;
```
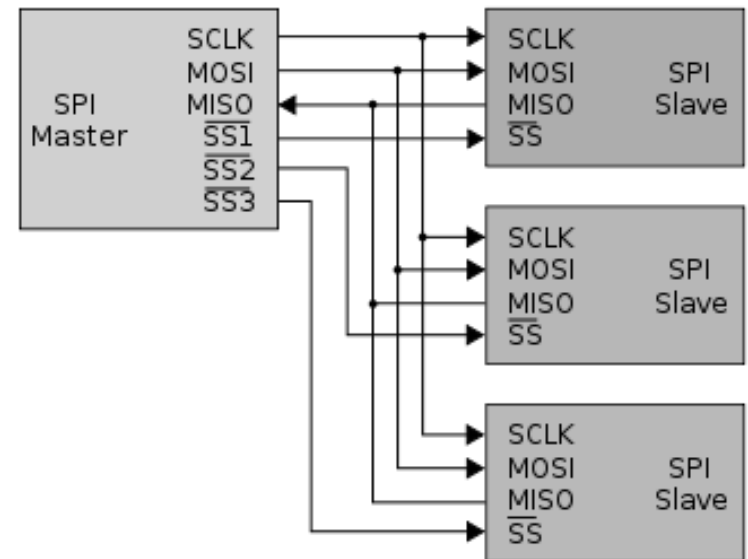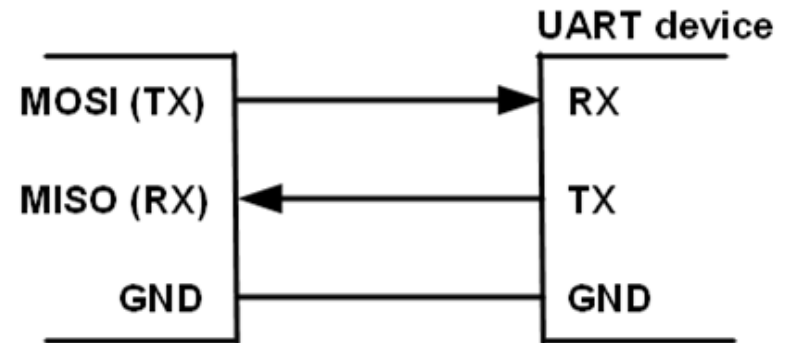
Distribution of I/O

- Wireless networking
  - UART bus
- LCD/Stepper motors/ Solenoid/ Sensors
  - General purpose I/O pins
- LED
  - SPI Bus

Wireless Networking

Device Name	WiFly GSX	XBee Series 1	BlueSMiRf Silver
Data transfer rate	1Mbps	0.24Mbps	0.1Mbps
Range	100m	100m	18m
Required input voltage	3.3V	3.3V	3.3V
Required input current	210mA	50mA	45mA
Microcontroller interface	UART	UART	UART
Price	$84.95	$22.95	$39.95

WiFly GSX

- 2.4GHz IEEE 802.11b/g transceiver
- 1Mbps data rate with TCP/IP and WPA2
- Up to 100m range
- UART hardware interface
- WEP-128, WPA-PSK (TKIP), WPA2-PSK (AES)
- FCC / CE/ ICS certified
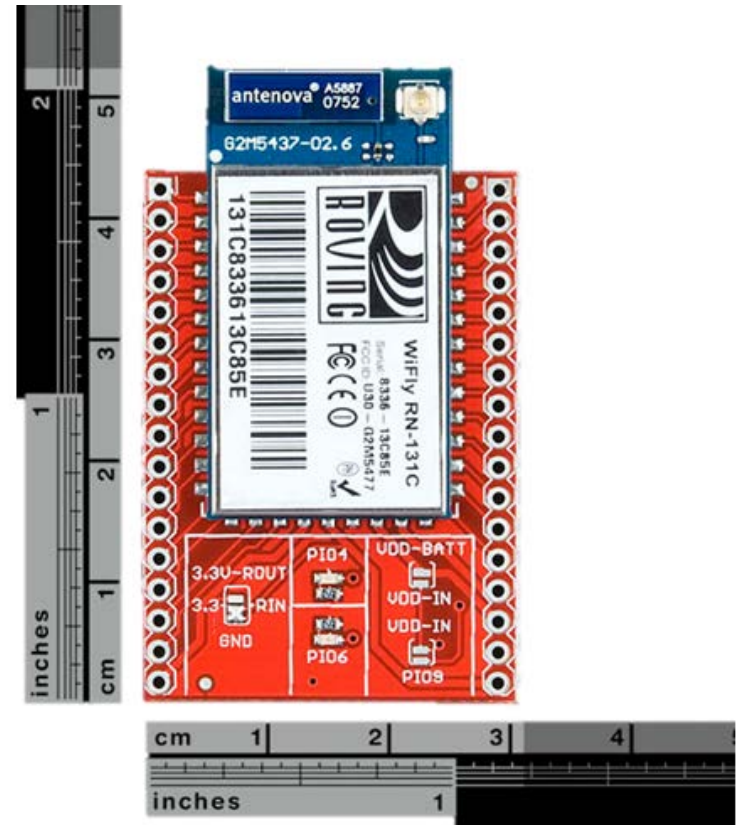
BLUELCD16x2BL LCD Display

1	Vss
2	VDD
3	Vo
4	RS
5	R/W
6	E
7	DB0
8	DB1
9	DB2
10	DB3
11	DB4
12	DB5
13	DB6
14	DB7
15	A
16	K

BLUELCD16x2BL
Display 16x2

(+)Power Supply

Digital Pins

MCU

(-)Ground

80 mm
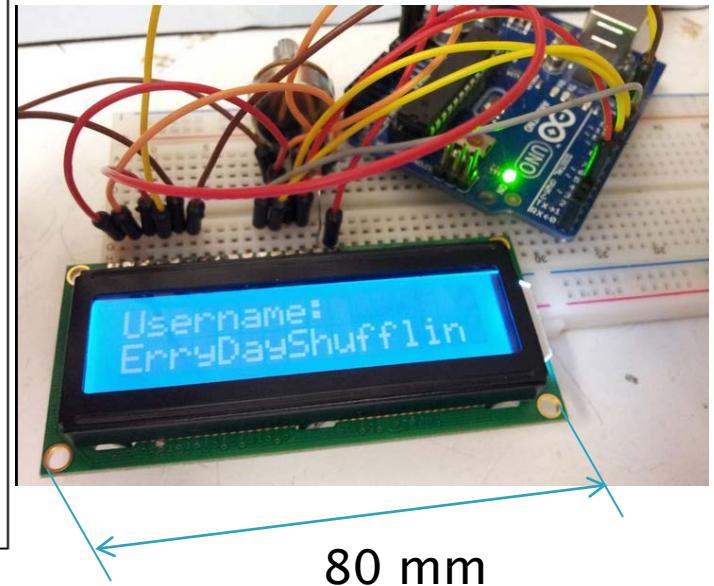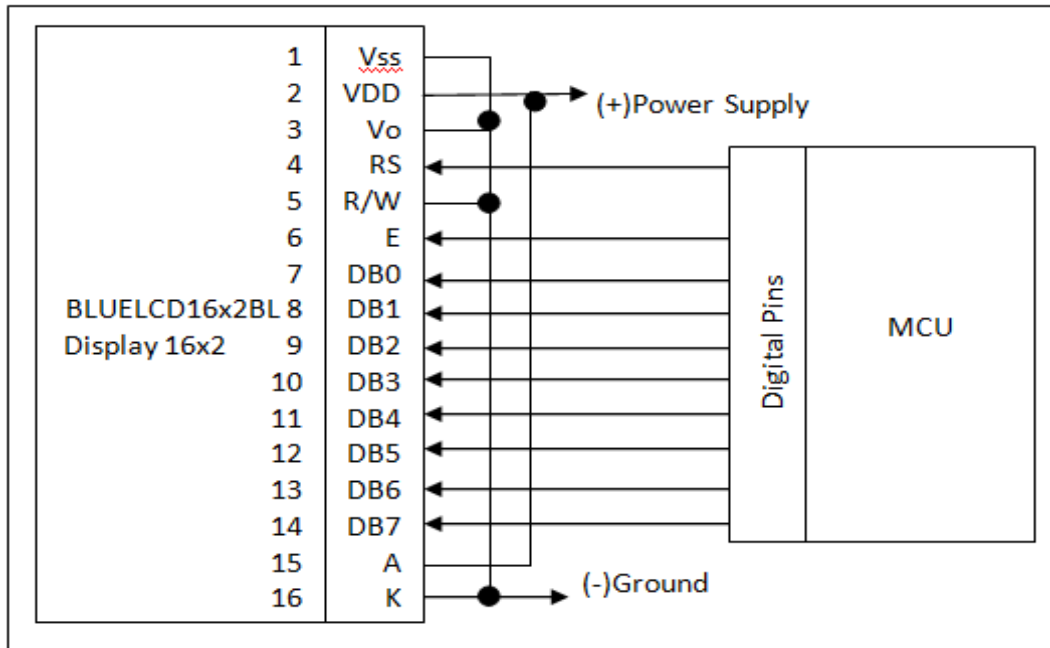
- 5V DC supply voltage
- Hitachi HD 44780 display driver
- Temperature range from 5 C to 40 C

Power supply

N82E16817103064

- Flex ATX /TX12VSingle/
- Power150W
- Output Current+3.3V@10A, +5V@13A, +12V1@10A, – 12V@0.5A, +5Vsb@2A
- Cost: $30

6"

Power AC Adapter from laptop

- Power 72W
- Output Voltage 12 V
- Output Current 6A
- Cost: $10

3"

Power Supply Cont.

- picoPSU-160-XT
- 160 Watt normal operation (200W peak)
- Low component impedence 4mOhm
- Supplies multiple voltage levels (12V, 5V,3V)

3"
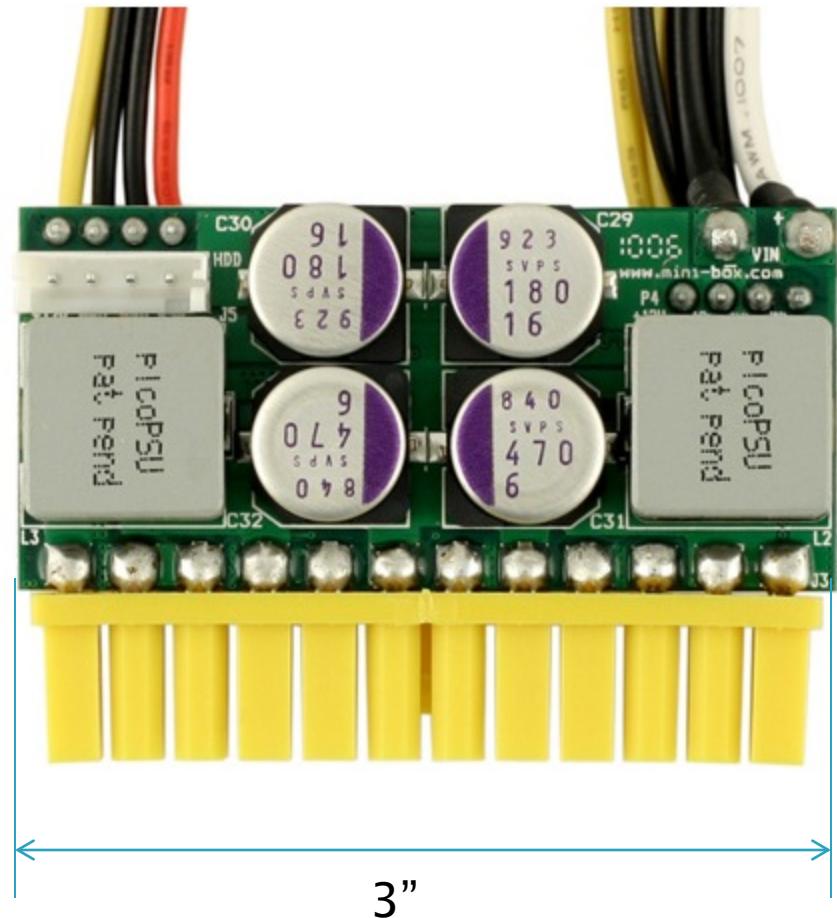
Arduino Code

- Wifi
  - Utilize the WiFly library to connect to a secure hotspot and transmit and receive piece positions to and from the website
- Sensor matrix
  - Loop through the matrix of sensors and obtain the positions as they arise
- Piece positioning
  - Position the solenoid to the correct location
  - Turn the solenoid on and travel a clear path to the new location
- LED matrix
  - Assign an 8 bit number to control the color of the LED
- Audio
  - Intended to use an interrupt and only request new data when necessary
- LCD
  - Utilizes the LiquidCrystal library to write to the LCD
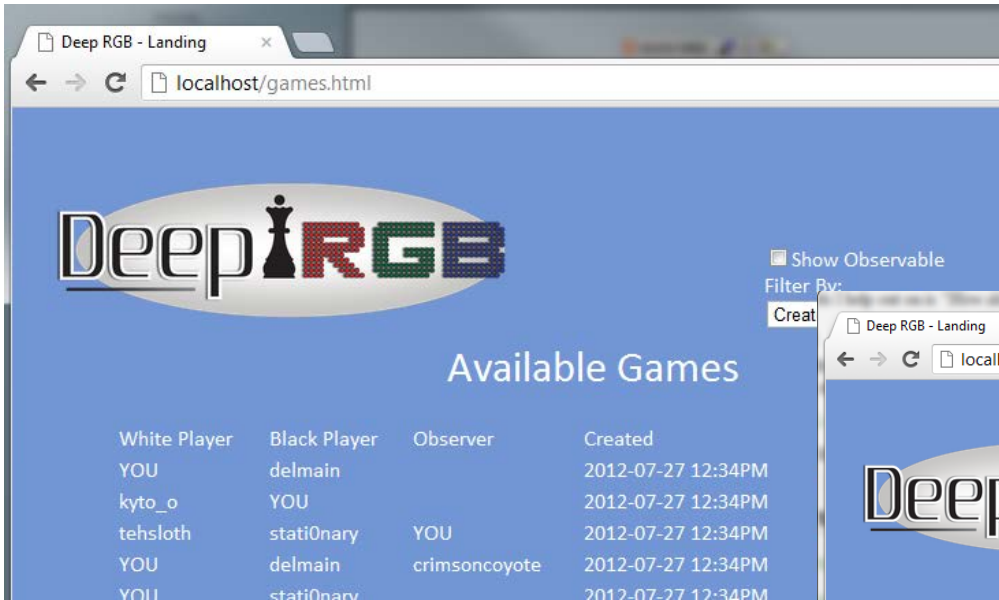
Management Pages

Page Name	Required Input	Optional Input	Output	Description
Log In	• Username • Password (SHA-1 hashed)		• Authentication Key • User ID	Logs in a user and creates a session on the server
User Info	• Authentication Key • User ID		• Username • LED Color • Audio Theme	Get information about the currently logged in user.
Games List	• Authentication Key • User ID	• *showObserver* • *page_count* • *page_number*	• Games IDs • Player usernames	Get a list of all games the user can interact with.
Game Info	• Authentication Key • User ID • Game ID	• *moves* • *move_limit*	• Game ID • Players • Board State • Turn Number • Active Player • Turns (Optional)	Get the full state of a game, given its ID.
Create Game	• Authentication Key • User ID • Opponent Username	• *allowObserver*	• (Success) o Game ID o Players o Board State o Turn Number o Active Player	Make a new game, given a logged in user and an opponent.

Management Pages

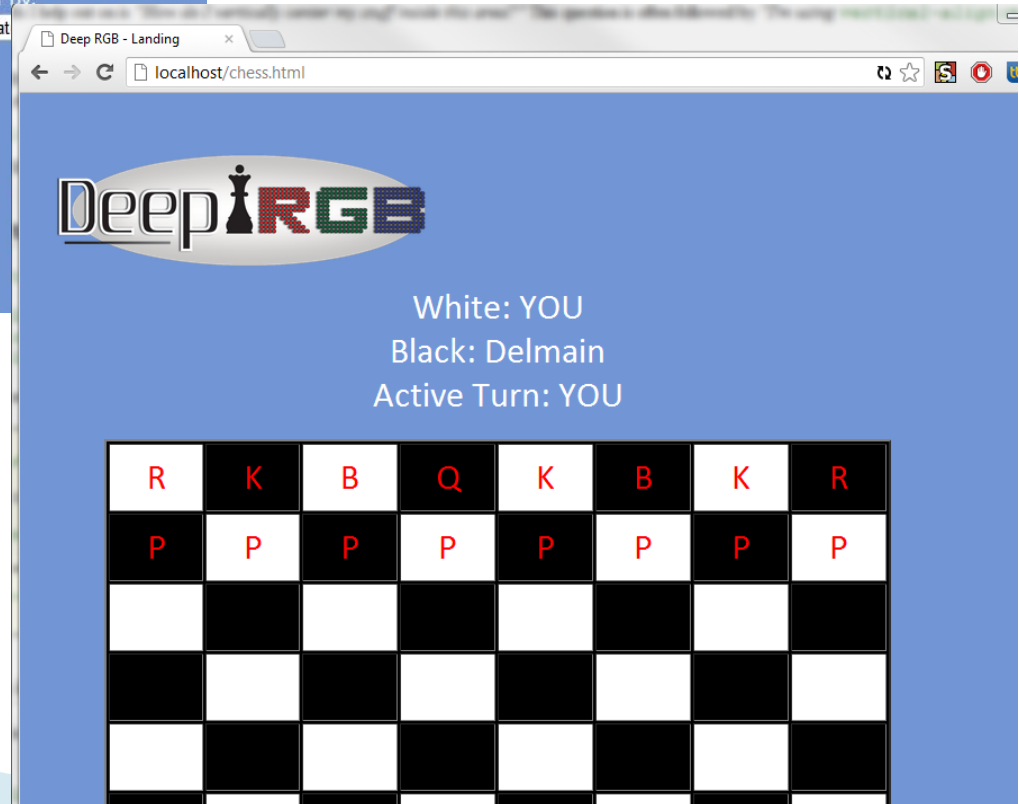| Page Name	Required Input	Optional Input	Output	Description

Update Move	• Authentication Key
	• User ID
	• Game ID
	• Board State
	• Move Made
			• (Success)
			  o Game ID
			  o Players
			  o Board State
			  o Turn Number
			  o Active Player
				Submit a move in an ongoing game.

New Account	• Username • Real Name • Email Address	• LED Color • Audio Theme	• (Success) o Success Code	Create a new account using the information provided.
Pass Lost	• Username		• Email containing reset key	Request a reset key for a user who has lost their password
Pass Reset	• UserID • Reset Key		• (Success) o Success Code	Choose a new password for the user
Add Observer	• UserID • Authentication Key • GameID		• (Success) o Success Code	Add a user to a game as an observer.

Web Interface

Bill of Materials
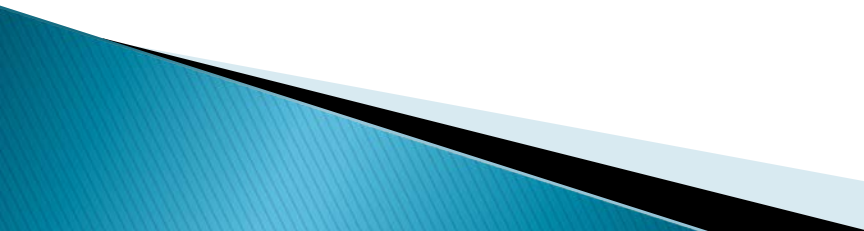
Item	Distributor	Part Num.	Quantity	Projected Cost	Total Price
PCB	4PCB	None	1	$60.00	$33.00
ATmega 2560	Digikey	ATMEGA2560V-8AU	1	$30.00	$19.97
ATmega16-U2	Digikey	ATMEGA16U2-AU-ND	1	$5.00	$3.71
Various main board components(USB socket, headers, etc)	Digikey Sparkfun Ebay	None	N/A	$50.00	$33.46
Rover RN131C	Digikey	WRL-10050	1	$40.15	$84.95
Stepper motor driver IC	Digikey	620-1140-2-ND	2	$39.90	$27.90
Motors	Sparkfun	ROB-09238	2	$29.90	37.68
Audio Shield	Sparkfun	DEV-10628	1	$30.00	$19.95
Racks and Gears	SDP-SI	none	N/A	$30.00	$47.77
Neodymium Magnets	ebay	None	N/A	$4.95	$65.25
Solenoid	Skycraft	None	1	$20.00	$5.00
Hall Effect Sensors	Newark	89T7955	100	$281.43	$135.00
RGB LEDs	Superbright LEDs	RL5-RGB-C-2	70	$70.00	$49.70
Construction Materials	None	None	None	$250.00	$160.82
Custom PC functioning as server	Donated by team member	None	1	$300.00	$0.00
Server OS	Donated by team member	None	1	$0.00	$0.00
Visual Studio 10	Donated by team member	None	1	$180.00	$0.00
SQL Server Browser	Donated by team member	None	1	$200.00	$0.00
Chrome Developer Toold	Google Inc.	None	1	$0.00	$0.00
Total price without tax or shipping				$1601.03	$745.37

Distribution of Labor
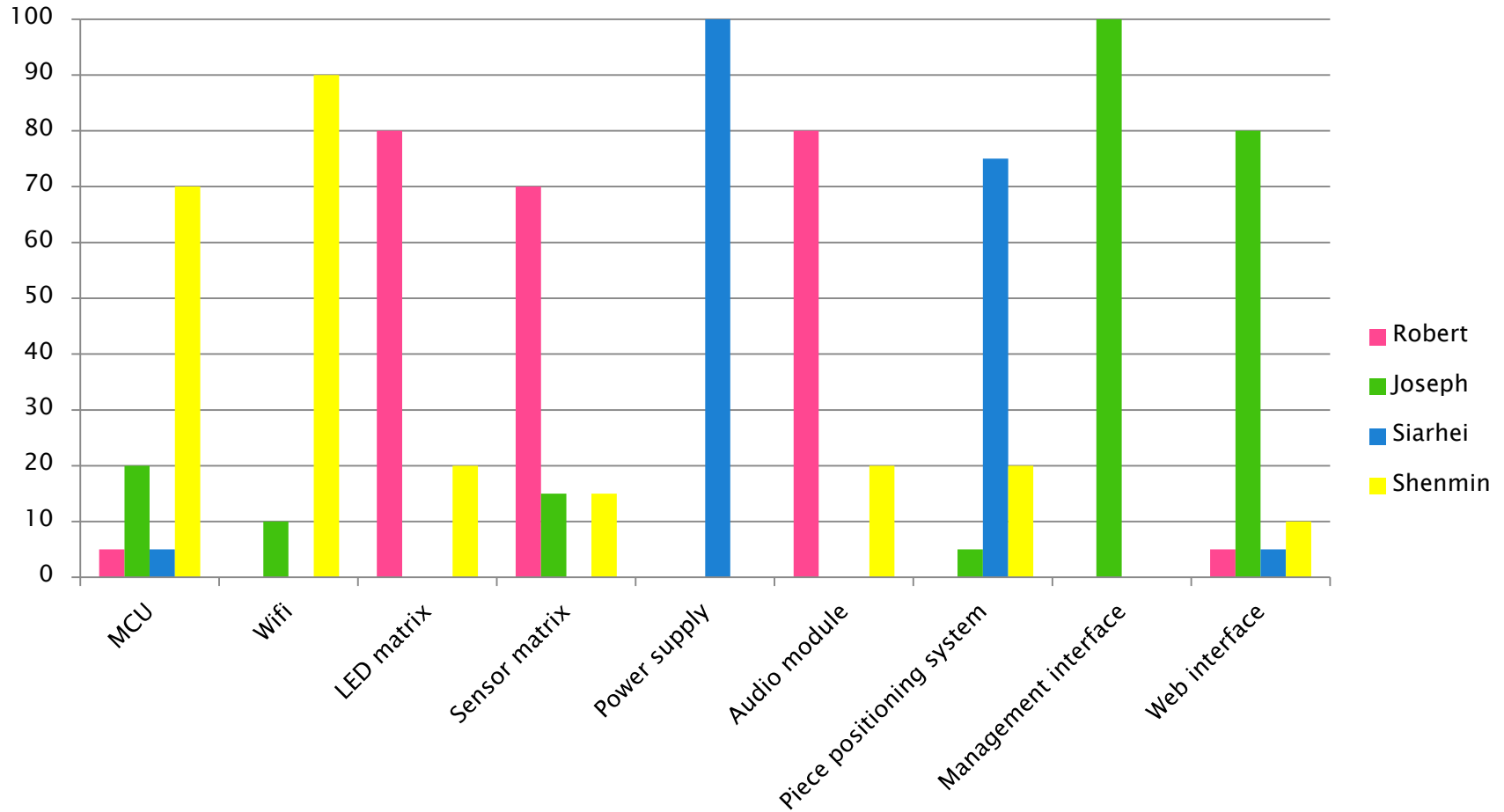
Problems

- Low Hall-Effect sensor sensitivity
  - Resulted in the replacement of the original sensors with the A1325
- Stable power for the electromagnet
  - Purchase of a third party reliable power source
- SPI bus traffic
  - Removal of audio
- Electromagnet Impotency
  - Replaced with solenoid and neodymium magnets
- Wi-Fi Module not connecting
  - No solution was found before presentation

Questions?