COLOR DETECTION FOR VISUALLY IMPAIRED PEOPLE

COE 485: Senior Project - Final Report

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1. INTRODUCTION

Blindness is the condition of poor visual perception, estimation from World Health Organization [1] state that 285 million people are visually impaired worldwide, 39 million are blind and 246 million have low vision.

A Blind person with proper training can function like any person with perfect vision, but there are the small things that can improve the quality of a blind person life, like color detection which is the focus of this project.

Being able to detect color can help in many ways, like identifying colors of clothes or even identifying uniquely colored objects (e.g. paper money) and appreciating art.

The project will help overcome challenges that visually impaired people face in daily basis, by creating a way to detect colors and providing unique biofeedback for each color.

2. PROBLEM STATEMENT

The problem that the project focuses on is the inability to detect or distinguish between colors. This project conducted to help solve the problem by providing an alternative way to detect colors to help visually impaired person in his daily life.

2.1 Positive Impacts:

The tool provided by this project can increase the opportunity for visually impaired person in his life style or career. This will improve the society by increasing Workforce and quality of life, this will lead to better economy and stronger society.

2.2 Possible negative impacts:

A possible negative impact, is wearing the glove for a long period can cause rash.

3. Project Specifications

3.1 Customer Requirements:

The system should be reliable, that is, able to detect all colors with different intensities. It then should be able to translate colors to vibrations that are perceived by the visually impaired as fast as they are scanned by the sensors on the fingertips of the glove, instant comprehension.

3.2 Technical Specifications

The system consists of one right hand glove containing in total:

a) Color sensor chips. The detecting range of which is around 5mm or touching range to detect a color. The sensors are placed on the finger tips. Different colors read will have different values on each of the RGB color format channels red, blue and green.

b) Vibration motors for biofeedback, each channel in RGB will be represented by one vibrator. The vibration motors are able to work with variable voltages between 2 and 3 volts, achieving different vibration intensities. The volt/intensity range is mapped to the RGB channel range where each channel has a range from 0-to-255. All the vibration motors are placed inside the glove and are not visible.

c) A microcontroller, used to process the RGB color feed by the color sensor chips to vibration signals. The signals are generated after the translation and sent to the appropriate vibrators on the finger.

4. System Design

4.1 Architecture

The system consists of two main parts:

i) ***Wearable glove*** and contains:
   (1) ***Color detectors***: Its function is to read the color it's pointed at and send feedback to the processing unit.
   (2) ***Vibration motors***: Its function is to send vibration feedback to the user, with different vibration intensity indicating different colors.

ii) ***Processing unit*** software consist of two main method:
   (1) ***Sensor Translator module***: Its function is to translate the readings from the sensor to specific integers which will be parameters for the vibration generator method.

   (2) ***Vibration generator method***: Its function is to translate the parameters received from the translator method to the appropriate vibration intensity.

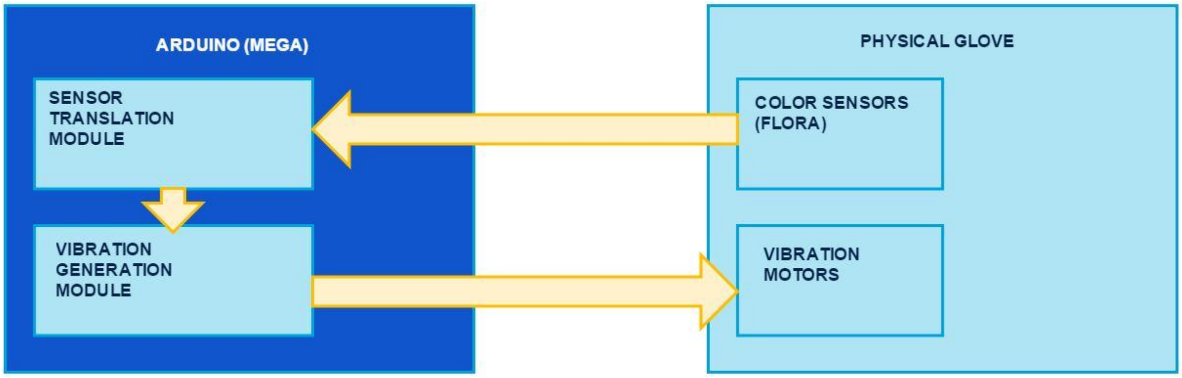

Figure 1 (Design Architecture)

4.2 Component Design and Implementation

a) Ready-made component:

i) Color Sensor (Flora TCS34725): The sensor has RGB and Clear sensing elements, each element is connected to its own ADC to get a digital signal. The output from the sensor is Red-Channel data, Green-Channel data, Blue-Channel data and Clear-Channel data. Each channel is represented by 16 bit integer.

ii) Vibration Motors.

iii) Arduino mega Microcontroller.

b) Custom Component:

i) Gloves as Wearable device:

The gloves was designed per the system requirement, the size of the gloves was selected to hold one sensor and three vibrators on each finger. Moreover, the layer between the vibrators and human skin is thin to allow a better sensing of the vibrations.

ii) Software Component:

The code was written to meet the system requirement, in the code we used the RGBC conversion method to convert the data we get from the sensor into RGB format, the component mainly consist of three parts:

a) ***Sensor translator Module***: Detecting the Sensor, requesting and receiving raw data from the sensor, and converting raw data to RGB format.

b) ***Vibration generator module***: Taking RGB data and sending it to the appropriate vibrators using PWM algorithm.

c) **Design and implementation:**

i) **Gloves**

The gloves are built to hold three vibrators and one sensor on each finger. Moreover, the vibrators and wiring are placed and stitched on the first layer that is topped with a second thin fabric layer to cover the wires and separate them from the user skin .The second layer will cover the vibrators and wiring. Finally the sensor will be placed on the outer layer of the glove.

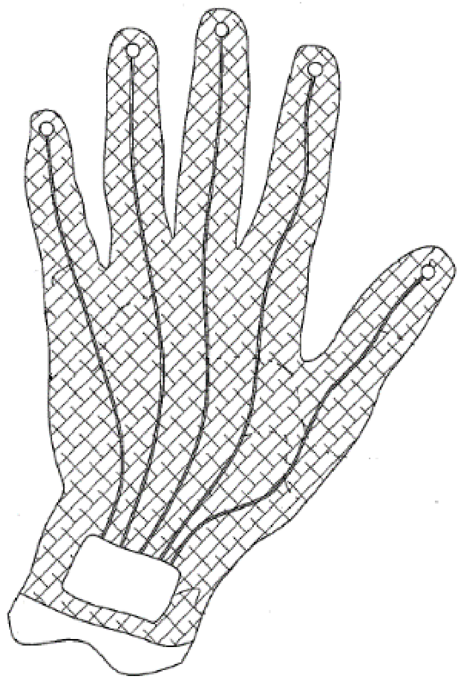

Figure 2 (Glove concept design)

Figure 3 (Glove making 1)

Figure 4 (Glove making 2 done)

ii) Software component

(a) ***Sensor translator module***, for this module we used the TCS34725 library, the functions we used from the library is as follow:

1. ***Begin*** function, to initialize and detect the color sensor.
2. ***SetInterrupt*** function, to turn on/off the sensor.
3. ***GetRawData*** function, to obtain the data from the sensor. The function will return Four 16 bit integer representing each color channel (R, G, B, and C).

(b) ***Vibration generator Module***, the goal of this module is to take the translated RGB data and generate appropriate vibration signals.

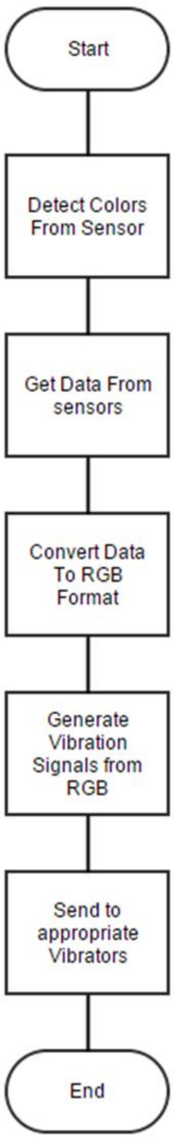

Figure 5 (System flow chart)

4.3 System Integration

Flora color detectors are compatible with the Arduino. It will be connected to the Arduino SDA/SCL pins directly using the I2C protocol. After processing the data in the Arduino, signals will be generated to the vibration motors. This will drive the vibration motors to act according to the specific color that has been read.

4.4 Design Decisions

a) Components Decisions:

Part required	**Targeted Criteria**	**Option1**	**Option2**	**Option 3**	**Preferred one**	**Main reasons**
processor	Ability to handle data and generates appropriate signal after processing for the output	Arduino uno	raspberry PI	Arduino Mega	Arduino Mega	Provides enough in/out pins. Easy to program (in C), efficient in meeting the needs.
Color Sensor	Size limited by the average finger size, ability to recognize the colors immediately and uses RGB module.	Flora color Sensor s	Color Sensor/TCS3200D/RGB Module	TCS3200 Color Sensor RGB Module	Flora Color Sensor	It meets the targeted criteria perfectly. Others are not arduino compatible
Vibration motors	Smaller than a finger tip and has a vibration intensity range.	Grove vibration motor	Aslong A1234 Flat Vibration Motor	vibration motor module 310-101	vibration motor module 310-101	Perfectly meets the targeted criteria and easier to purchase.
Programming language	A language that works with our processor and efficient for the processing task	C	java	python	C	Arduino's language, easier to use by the team members than python.

Table 1: Components Decisions

b) ***System Design decisions*** :

We have made many Designs and we chose the one that primarily comfortable to the user. The following are two of the designs we thought of as options to choose from:

In the following Fig. shown a front and palm view of an embodiment of a color detection system. Consisting of a color sensor (204).three vibration motors (206,207,208)

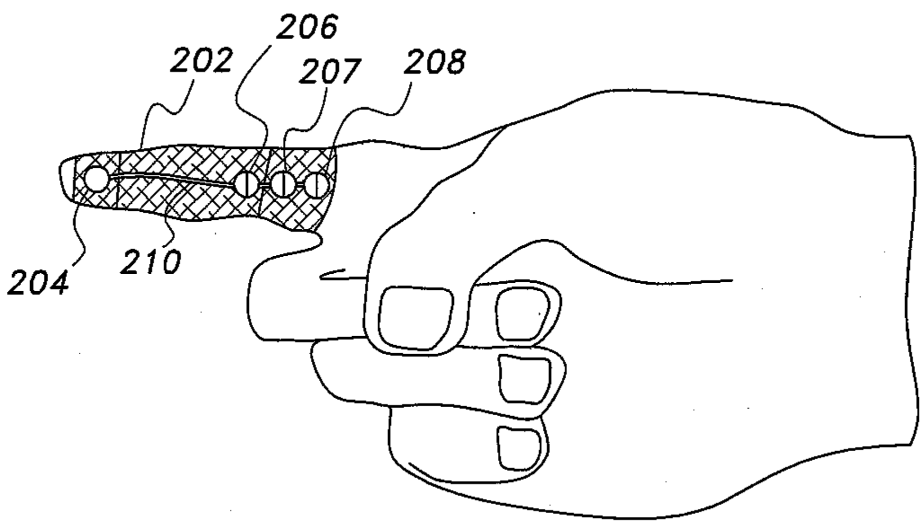

Figure 6 (Design concept 1)

In the following Fig. 2B is a back view of an embodiment of a color detection system of Fig. 2A illustrating the finger cover containing the number of color sensors attached by a wire connected to the control unit.

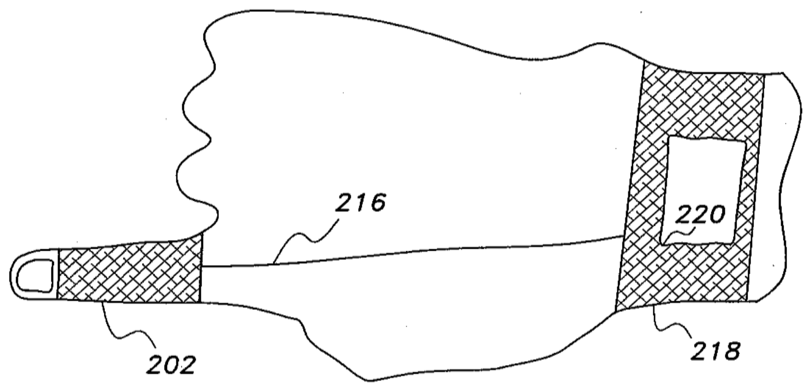

Figure 7 (Design concept 2)

In the following Fig. 3 shown a front, palm view of an embodiment of a color detection system in the form a glove containing color sensors connected by wires to a control unit (312). Containing five color sensors at the tip of each finger (302, 304, 306, 308 and 310) and three vibrators on each finger.

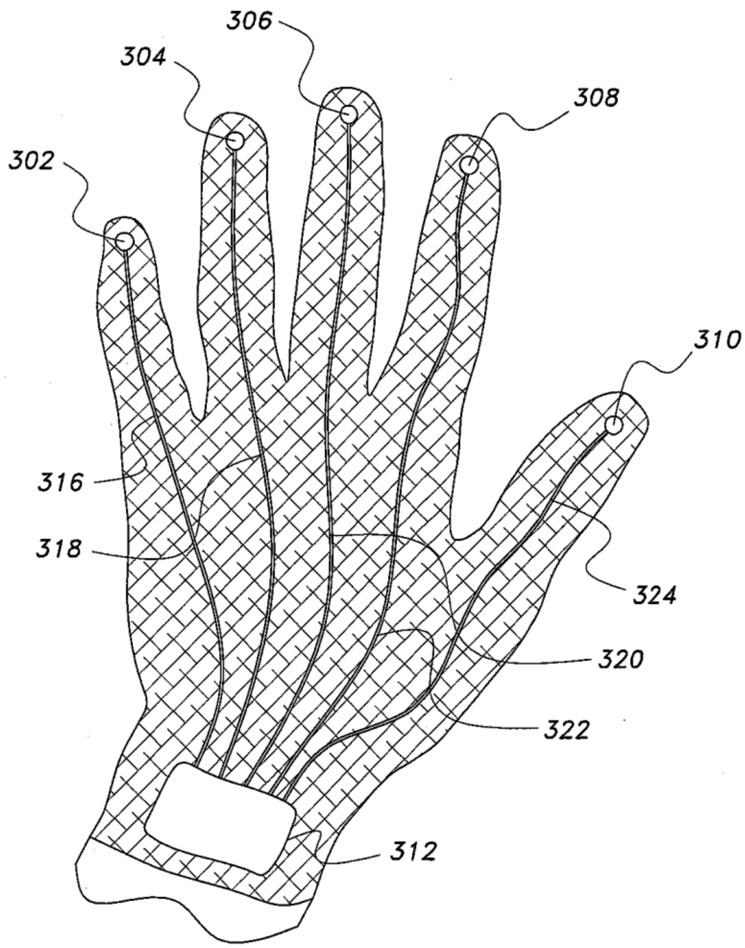

Figure 8 (design concept 3)

The chosen Design:

We choose the glove design illustrated in Fig 3. It is the most comfortable design to the user. We added to the design three vibrators. They will represent the detected color through certain vibration intensity.

4.5 Design Evolution

Blind or visually impaired persons are incapable of experiencing color richness of the world. This does not mean that they cannot imaging paintings or be acquainted with color names. Example applications could include them identifying their cloth articles, color walls or simply art appreciation.

In this project we propose a method of decoding color into a few parameters like:

1. HSB (Hue, Saturation and Brightness),
2. HSL (Hue, Saturation and Lightness),
3. RGB (Red, Green and Blue) or
4. CMY (Cyan, Magenta and Yellow)
5. CMYK (Cyan, Magenta, Yellow and Black)

The parameters are sent to the blind person as three analog signals simultaneously. The analog signal could be in form of:

1. Vibration of varying intensity
2. Vibration of varying frequency
3. Auditory pitches of varying intensity
4. Height of pins above a surface (optional to touch)
5. Rotational position of a tip (on a ring)

As illustrated in section 4.4, this method could take several formats. We choose the following format:

Glove System Format

The blind person could wear a glove that equips his/her fingertip with a photo detector that detects the color and decode it into 3 or 4 parameters. The parameter values are fed into the analog actuators. The actuators are three vibrators that change their vibration intensity. The vibrators and the reading end are all in one finger wear.

5. Testing, Analysis and Evaluation

5.1 Testing

A set of tests have been done for each component, to confirm it meet the requirements and confirm it is operational. After verifying each component we started integrating and testing the system as a whole.

Component level testing:

Each component requires a custom test code, for color sensor we used external library from Adafruit (Adafruit_TCS34725) to write the test code.

a) Color Detector:

ACCEPTANCE TESTING, the test focus was to verify that the component meets the requirement specified in the project, we focused on timing, compatibility and physical shape.

In timing, the test was done to confirm that the sensor can accommodate the movement of the user hand. The color sensor can read and output the raw data in less than 20 ms which is fast enough to meet the requirement.

In Compatibility, the test was done to confirm it works with the Arduino board. The component uses the I2C protocol for communication, which is supported by the Arduino mega.

In physical shape, the test was done to confirm the component can be sewed in the finger tip of the gloves with no effect on the reading. The result did not change and there are no signs of heat increase after one hour of use.

FUNCTIONAL TESTING, the test was done to verify the reading from the sensor, we used a color spectrum shown in Fig (), and took the result after converting raw data to RGB format into a Color picker (ex: http://www.colorpicker.com/) to compare the result.

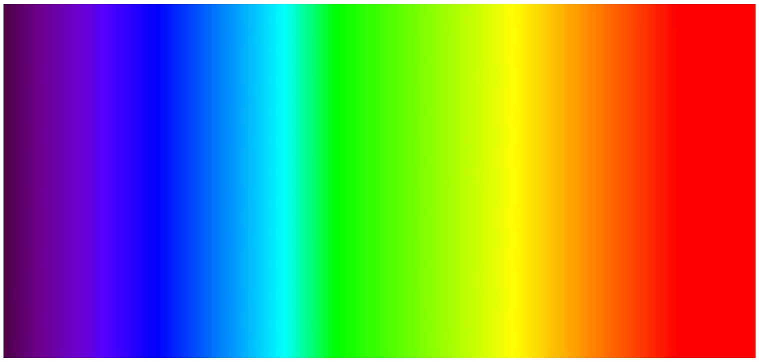

Figure 9 (color spectrum)

System level testing:

The system integration started after testing each component on its own. The first thing we did is confirming the connections after integration, before starting the testing process.

FUNCTIONAL TESTING, We tested the system after integration and it worked with no problems. The color data was correct. It was translated correctly to vibration signal. The vibration sensation was clear to the user.

5.2 Debugging

When a problem arises we try to reduce it to its simplest form by breaking it down. We try to locate the source of the error, by checking the output of each component. After finding the source of the problem we try to understand it and fix it accordingly.

5.3 System analysis and Evaluation

The system was evaluated according to the following criteria, Performance and Reliability.

Criteria	Score (1-5)	Reason
Performance	5	All requirements are met .
Reliability	5	All requirements are met.
Efficiency	4	The prototype has some limitations in mobility.
Security	NA	NA

Table 2: System analysis and Evaluation

6. Engineering Tools and Standards

The main tools used in this project are micro controllers and color detector chips. The available microcontrollers were:

- The **Arduino Uno** based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller can simply be connected to a computer with a USB cable to upload code.

- The **Arduino Mega** based on the ATmega2560. It has a USB host interface to connect with Android based phones, based on the MAX3421e IC. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

- **Raspberry pi** Being a minicomputer, it can be used for running considerably more complex things than Arduino and can use high-level programming languages such as Python, C++ and Java.

The **Adriano Mega** was chosen. The extra input/output pins for the digital and analog were needed in our project for the high number of devices to control and read from (sensors and vibrators). In addition to satisfying our needs and requirements for the project as a microcontroller, the team is familiar to using Arduino boards having taken courses using it. Plus the board itself is the most popular prototyping tool in its field and it was available in our labs here in KFUPM. The Raspberry pi was discarded knowing there will be no use for the extra complexity and the multi programming languages. The Arduino IDE was used to program the Arduino Mega.

The color sensors choices:

The **Flora color** sensor by Adafruit. Adafruit has a family of different sensors accompanied with ready to use libraries and code providing a very user friendly environment using their tools. The chip works by reading the reflected light frequency value bouncing off a colored surface.

The **TCS3200** can detect and measure a nearly limitless range of visible colors. Applications include test strip reading, sorting by color, ambient light sensing and calibration, and color matching.

The **Flora sensor** was chosen In addition to the Flora sensor being compatible with Arduino, the tool is very simple to use and satisfies our need for a color detector. The **TDC3200** was discarded for having more complexity to operate and being more expansive than the Flora.

Available relevant standards:

I2C a multi-master, multi-slave, single-ended, serial computer bus.Used to control all the sensor chipson the glove. no licensing fees are required to implement the I2C protocol.

Pulse-width modulation (PWM), is a technique used to encode a message into a pulsing signal. It is a type of modulation. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. It’s used to send the volt to the vibration motors.

SPI: the Serial Peripheral Interface or SPI bus is a synchronous serial data link,that operates in full duplex mode. It is used for single master communication, for example in embedded systems and sensors.

http://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus

UART, A universal asynchronous receiver/transmitter, is a piece of computer hardware that translates data between parallel and serial forms.

The protocol and standards chosen:

The sensor supports the **I2C** protocol .the Pulse-width modulation (PWM) is used in transferring the generated vibration signals to the vibration motors, it was used to support all color ranges (255^3 colors).

7. Issues

1) Providing required components

Issue: finding and purchasing the Essential components. After choosing the appropriate design and specifying the needed parts. We didn't find the needed parts in the local market nor in the university's supplies.

Attempted: We started looking for an international provider to order the components. The components are color detectors and vibration motors. We needed these components to fit specific criteria, such as an appropriate size. Another problem we had was the recipient name. We needed to buy with our own visa's but with the university's name to get compensated.

Final Resolution: we found a provider for the specified parts. We ordered all the parts and received them in excellent statues. It cost us time and effort to find alternatives in order to meet the university purchasing regulations.

2) Making the glove

Issue: in order to meet our design we needed to make a costumed glove. We needed a tailor to stitch our glove in a specific way. Since the work wasn't profitable enough for them, they refused to do it.

Attempted: we tried to do it but the result wasn't efficient. The vibrators were tearing the stitches.

Final resolution: special thanks to Faris's grandmother, she helped us in stitching the glove. The result is perfect and the stitches adhere strongly.

3) Programming the control unit components.

Issue: translating the readings from the sensors to the vibration motors.

Attempt: the sensors detect and translate the colors in RGBC model. We tried to specify each vibrator of the three vibrators on the finger for a specific value. For instance vibrator 1 represents the R value, vibrator 2 represents the G value and vibrator 3 represents the B value. Each color's value will differ from 0 to 255. While the vibration intensity have only two levels, high or low. We had to implement it on the hardware by having two lines for each vibrator. One passes a resistor and the other doesn't. This method limited the colors we could represent to 27 colors. Which were a big limitation and a failure in the system's output.

Final Resolution: We found a better way to translate the colors. We decided to use P.W.M. (pulse width modulation) in translating the colors from integer values between 0 and 255 to a vibration with a specific intensity. P.W.M. allows us to represent all colors, each in specific vibration intensity.

4) Working with multiple Flora color sensors

Issue: flora sensors use I2C protocol. The issue happens at the control unit. Flora's color sensors have a manufacturer fabricated address and the addresses are the same for all flora color sensors, we couldn't issue a correct connection to multiple sensors. The control unit will not be able to distinguish between the color sensors. So the communication will be impossible.

Attempt: the solution is to have a switch or a multiplexer to help the Arduino in addressing the sensors. This way the sensors won't interfere with each other. We tried to order them but we couldn't. The order would take at least two weeks up to three weeks to arrive, unfortunately this occurred during week 11. Thus the team didn't have enough time to test and implement the new part.

Final resolution: since the multiple reading is just a replication for the same system working on single finger. We decided to work on one finger only to demonstrate the prototype. Missing a replication shouldn't affect the system's function. But it will limit us to work only on one finger or we could replicate the work on multiple Arduino.

8. Teamwork

Team Members:

Ibrahim Al-turkestani 200923810

Responsibilities:

- Communications.
- Purchasing Components.
- Programming

Contributions:

- Project plan
- Design document
- Design presentation
- Final report
- Identify the engineering and marketing requirements
- Formulate specifications identify different solutions and choose one
- Identify hardware and software needed
- Identify the engineering tools needed
- Purchasing needed parts
- Programming the system
- Physical integration
- System analysis and Output measurements
- System Final tests and solves any issues

Expertise:

- Arduino Programming.

Faris Albaitouni 200825340

Responsibilities:

- Physical Integration
- Documenting

Contributions:

- Project plan
- Design document
- Design presentation
- Final report
- Identify the engineering and marketing requirements
- Formulate specifications identify different solutions and choose one
- Identify hardware and software needed
- Identify the engineering tools needed
- Physical integration
- System analysis and Output measurements
- System Final tests and solves any issues

Expertise:

- Physical design implementation.

Mohannad Hakami 200816800

Responsibilities:

- Programming.
- Physical Integration.
- Documenting

Contributions:

- Project plan
- Design document
- Design presentation
- Final report
- Final presentation
- Final demonstration
- Identify the engineering and marketing requirements
- Formulate specifications identify different solutions and choose one
- Identify hardware and software needed
- Identify the engineering tools needed
- Purchasing needed parts
- Programming the system
- Physical integration
- System analysis and Output measurements
- System Final tests and solves any issues

Expertise:

- Arduino Programming

9. Conclusion

The main goal of the project is to help the visually impaired people to recognize the colors. We created a glove with an embedded system to detect and indicate different colors. We applied different skills in order to accomplish the project such as Team work, problem solving and using the technical information. We learned about different communication protocols between different electronic components. We learned about different possible biofeedback. We worked on a water flow plan and gained experience in working with non-familiar electronic parts such as the color sensors. The only real issue we couldn’t solve is the addressing problem as explained in the issues section. In a similar project we will make sure to implement the whole system and test them all at once as early as possible.

Hopefully, our project will serve a lot of visually impaired people and it will help them to recognize colors and appreciate art greatly.

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