ECE 445 - Spring 2026

Paint Color and Gloss Classification Device

Design Document

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Project No. 69

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1) INTRODUCTION

1a) Problem

The home maintenance and renovation industry faces significant challenges stemming from inefficiencies in accurately matching existing wall paint for touch-ups and repairs. Homeowners, renters, and college students frequently need to seamlessly patch wall damage, yet they rarely have access to the original paint cans or exact color codes. While the traditional method involves destructively peeling a physical paint chip off the wall to scan at a hardware store, this process is highly inconvenient, damages the property, and is often forbidden for renters.

Furthermore, current digital alternatives fall short of consumer needs. While mobile color-matching applications exist, they rely heavily on standard smartphone cameras. These cameras utilize automatic white-balancing algorithms and are highly susceptible to variations in ambient lighting, leading to inaccurate color readings and mismatched product recommendations.

Most critically, these existing solutions completely fail to account for the paint's sheen. Paints come in various finishes from lat/matte to eggshell, satin, and semi-gloss. Even a perfect color match will look like a glaring error if the sheen is incorrect. This systemic lack of accuracy results in high volumes of wasted paint, wasted time, an economic loss for the consumer, and a deeply frustrating user experience that yields a poor final result.

1b) Solution

To address these challenges, we propose the development of a non-destructive Paint/Surface Analysis Device **Prototype** that accurately identifies precise wall color and gloss directly on the wall. Our device integrates a high-precision spectral color sensor housed within a custom, light-isolating enclosure. This design eliminates the negative variables of ambient lighting and automatic camera corrections, providing a true and reliable measurement of the wall's exact color composition.

To overcome the limitations of color-only matching, our device integrates a secondary optical subsystem utilizing an angled light. This specific illumination technique allows our system to accurately analyze light reflectance and classify the specific paint finish (e.g., flat, eggshell, or semi-gloss).

By combining the spectral color data and the gloss classification, our device processes the readings through an onboard microcontroller to output a highly accurate color match and finish type. This comprehensive approach ensures a more accurate "first-time" match, empowering users to confidently repair their walls without removing physical chips, while significantly reducing the environmental and economic impact of wasted, mismatched paint.

1c) Visual Aid

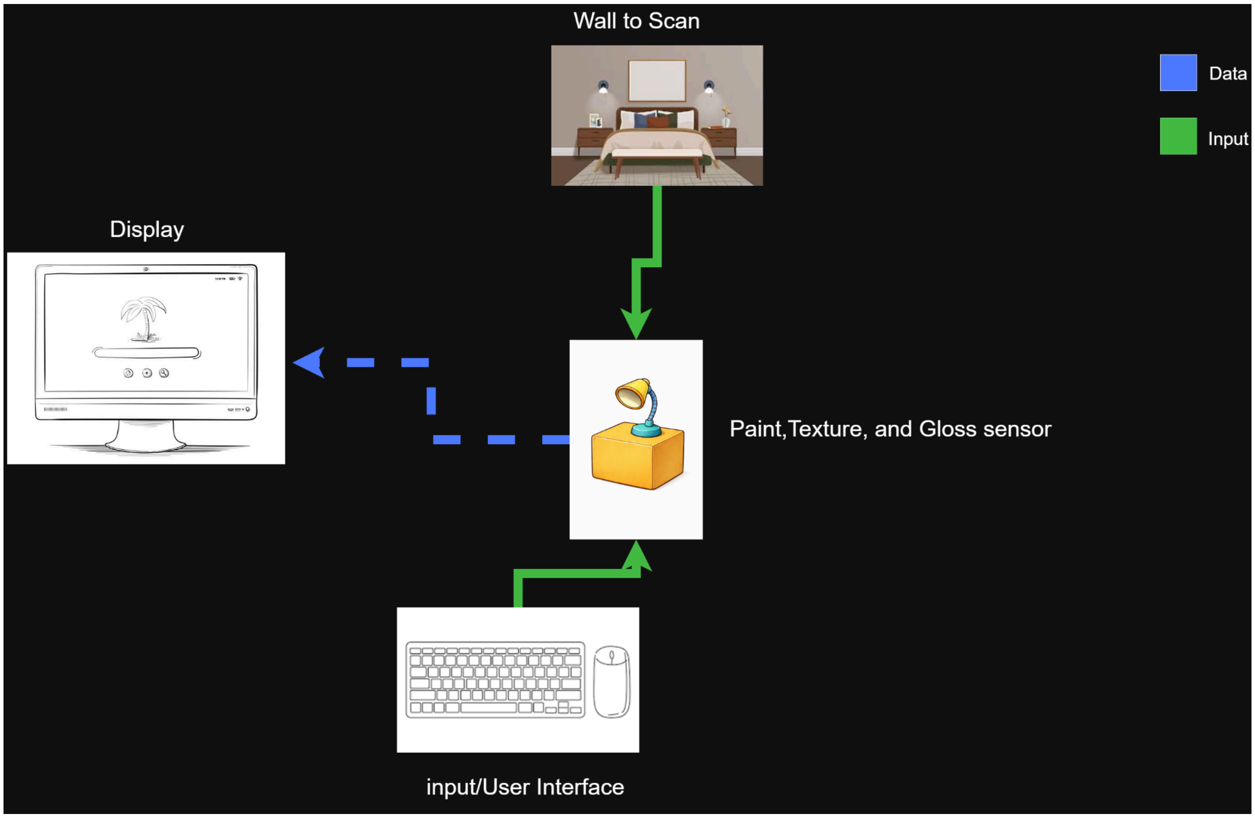

Figure 1: Visual Aid

1d) High-Level Requirements

Color accuracy within Delta E < 5

- Delta E (or ΔE) is the distance between two colors in the color space. We will be using the CIELAB space, which is the standard color space used for Delta E [1]
- Delta E is further discussed in section 2f

Sheen Classification

- Sheen classification of (Matte vs Gloss vs Semi-Gloss) within 80% accuracy across 10 different test samples

Figure 2: Example images of sheen [4]

- We will use three photodiodes to measure the gloss. One at the specular angle, and two at angle of specular angle ± 30.

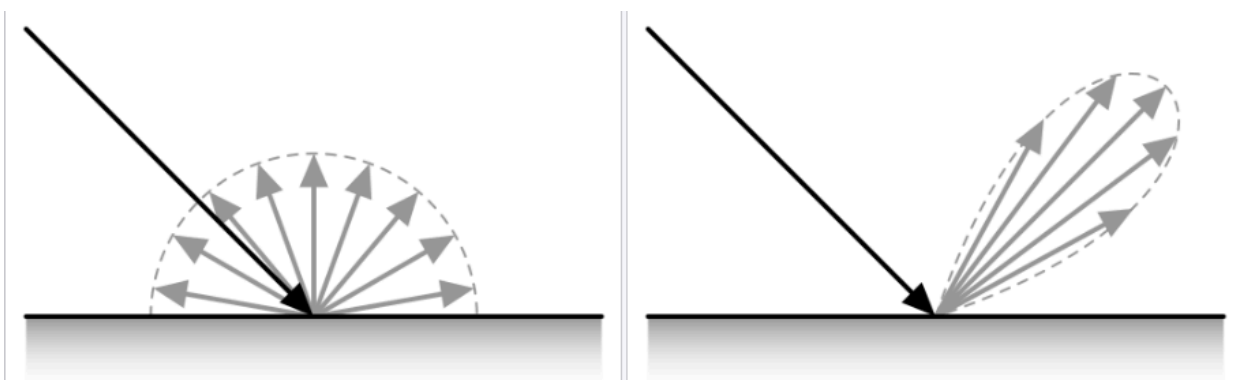

Figure 3 Light Diffraction of Matte vs Glossy Surfaces

- From Figure 3, we can see that matte surfaces don't necessarily reflect less light, it simply diffuses it more. By comparing the light reflected when measured from the specular angle and comparing it to side angles, we can measure how well the light is being diffracted. Using the specular angle light measurement as a baseline, we can measure diffraction regardless of the intensity of light or color of the wall.

$$Gloss\ Index\ =\ \frac{Light\ Intensity\ at\ Specular\ Angle}{\Sigma Light\ Intensity\ across\ photodiodes}$$

Figure 4: Formula for Gloss Index

- We are using a simplified calculation inspired by the Bidirectional Reflectance Distribution Function(BRDF), as shown in Figure 4. [6]We will calculate this index between glossy and matte surfaces across multiple color samples to set our ranges for each gloss type. A glossier surface should have a higher gloss index, and a matte surface should have a lower one.

Environmental Isolation

- The enclosure must provide light isolation such that the spectral sensor reading varies less than 10% when external ambient light changes from dark (0 lux) to bright lighting (500 lux).
    - This is further discussed in section 2b: Physical Design

2a) Block Diagram

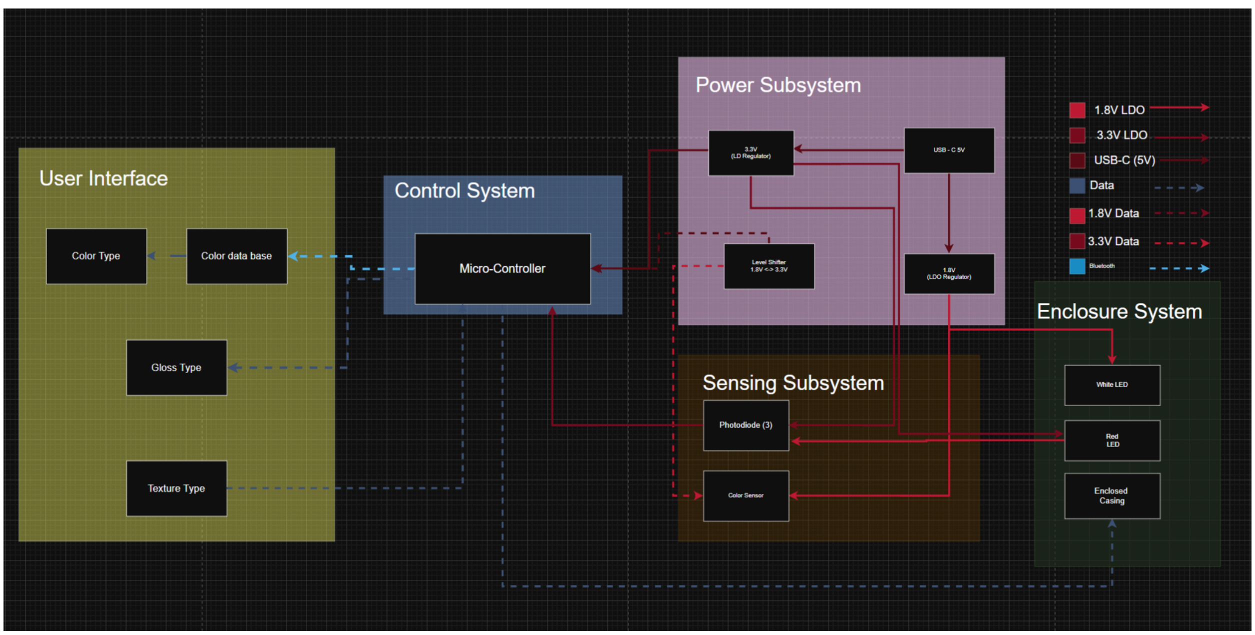

Figure 5: High-Level Block Diagram

2b) Physical design

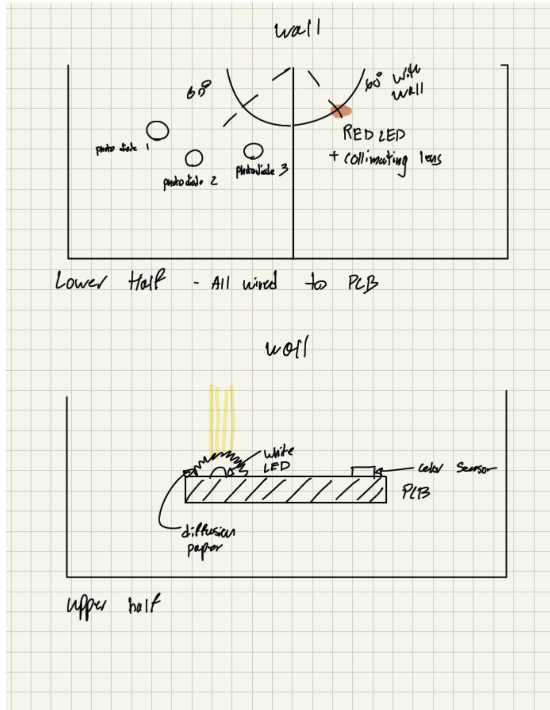

Figure 6: Physical Design

We plan for our enclosure to be a cardboard box with cutouts, as shown at the top of our diagram, against the wall with the paint. We anticipate that the texture of a wall might prevent us from pressing fully against the wall, and ambient light may seep through.

We plan to put an easily moldable material, such as Play-Doh, along one side of our enclosure to allow for a better fit. We also understand that some level of light from the LEDs may be reflected along the interior walls of the enclosure. We intend to use a light-trapping self-adhesive material to prevent this. [7] This will reduce light from the white LED bouncing from the enclosure back into the spectral sensor.

Our enclosure will have an upper and a lower half to reduce mechanical issues where the LEDs from the color system block the gloss system and vice versa. The upper half will contain our PCB and be dedicated to finding the correct color. There will be diffusion paper over the white light to have a more even light source. We will place the color sensor a reasonable distance away from the white LED to reduce the amount of white light that shines directly into the color sensor.

The lower half of our enclosure will contain a circle that we intend to 3D print. This will make sure that our photo diodes are at the correct curve and maintain 60 degrees from the light reflected off the wall. The circle will also keep our Red LED at 60 degrees. There will be a divider in the middle to prevent the Red LED light from shining directly into the photo diodes.

2c) Subsystem Descriptions

Power Subsystem

- **Description and Purpose**
  - The power subsystem is designed to provide reliable, regulated power to all components. We have streamlined the design by utilizing a standard 5V USB-C wall charger as our primary power source. Because our company operates across different logic levels, the 5V rail is split into two Low-Dropout (LDO) regulators. The first LDO steps the 5V down into 3.3V to supply the ESP32 microcontroller and the LED MOSFET driver circuits. The second LDO steps down 5V into 1.8V. A dedicated supply is required to power the special sensor output. The LDOs were chosen to keep a fast transient response for the varying loads of the LED sequence while minimizing electrical noise that could discount sensor readings. With each power system, we have added a capacitor to stabilize the voltage.
- **Interactions**
  - The 5V USB receptacle powers the voltage regulators. The 1.8V LDO and the 3.3V LDO. The spectral sensor communicates with the microcontroller with the level shifter.

Sensing Subsystem(Optical and illumination)

- **Description and Purpose**
  - This subsystem captures the raw environment data from the wall surface. There is an AS7343 14-channel special sensor and controlled illumination. To protect the microcontrollers GPIO limits the white (color matching) and red (gloss detection) LEDs, which are driven by N-Channel MOSFETS, low-side switches. Since the AS7343 sensor operates at 1.8 V power and logic domain, and the ESP32 microcontroller operates at 3.3 V, direct communication would destroy the sensor. A level shifter sitting on the I2C bus between them would safely transfer signals between the ESP32 and the sensor. We intend to find color and gloss sequentially.
- **Interactions**
  - Powered by 3.3 V LDO for the LEDs and a level shifter high side and 1.8V LDO for the special sensor and the level shifter low side. Digital control signals are received from the control subsystem to sequence the LEDS and transistor raw color and sheen data back to the microcontroller via the level-shifted I2C bus.

Control Subsystem (Microcontroller)

- **Description and Purpose**
  - Act as the central brain of the device. The microcontroller (ESP32) coordinates the timing and data processing of the entire system. It triggers the MOSFETs to begin the lighting sequence, reads data from special sensors, and converts data

into the CIELAB color space. It then runs the Delta E algorithm to query the database and find the closest paint match.

- **Interactions**
  - Requires 3.3V given from the 3.3V LDO. Acts like the master device between the sensory subsystem and transmits finalized data arrays to the User Interface Subsystem.

User Interface (UI) Subsystem

- **Description and Purpose**
  - The UI bridges the gap between the mathematical data and the consumer. There will be a display monitor and a way to input wall texture. The user will input tactile or visual wall texture (Smooth, Medium, Heavy) before scanning, triggering the software's Texture compensation LUT. Once the scan is complete, the UI translates the microcontrollers about into readable feedback, displaying the Paint Brand, Hex Color, Gloss type, and any relevant confidence warnings (EX: Low Confidence Match)
- **Interactions**
  - Receives finalized Delta E match data and screen classification from the control subsystem and sends user-initiated start/restart commands and texture inputs back to the microcontroller

Enclosure Subsystem

- **Description and Purpose**
  - The enclosure is intended to be a cardboard box with non-reflective photography paper to create a standardized, darkroom-like environment for the Sensing Subsystem. The enclosure houses all internal electrics and is pressed flush against the wall. This should physically block external ambient lighting, such as room lights or sunlight, from contaminating the special sensor's readings. Furthermore, the internal geometry of the enclosure would hold our gloss detection LEDs and the precise angle required for accurate sheen classification.
- **Interactions**
  - Mechanically aligns the sensing subsystem to the target wall.

2d) Requirements and Verification Table

Requirements	**Verification**
Power subsystem: The 3.3V LDO must output a stable 3.3V +/- 5% under the maximum expected continuous load of the ESP 32 and White LED The 1.8V LDO must output 1.8 +/- 5% to safely powers the AS7343 sensor without exceeding its max voltage rating	Use a DC electrical load and digital multimeter (DMM) to measure the output voltage under load.
Power subsystem The voltage ripple on both the 3.3V and 1.8V rails must not exceed 50 mV peak-to-peak to prevent analog noise from corrupting the special sensor readings	Use an oscilloscope to measure the output voltage ripple. Connect the oscilloscope prob to the 3.3 V and 1.8V test points, set the oscilloscope to AC coupling, simulate LEDs, and verify the oscilloscope screenshot, verifying the peak-to-peak ripple is less than 50mV
Sensing Subsystem (Optical and Illusion) The I2C level shifter must step down the 3.3 V ESP32 signals to 1.8 V +/- 10% and for the AS7343 step up the 1.8 V sensor to >2.5V.	Use an oscilloscope to verify logical level voltages on data lines. Connect to each side of the level shifter. Transmit an I2C message from the ESP32. Measure the HIGH voltage level on the 1.8V side and 3.3V side. Record the oscilloscope waveforms to prove the logic levels meet the thresholds.
Control Subsystem Must control the timing of the color and gloss subsystem, compute the CIELAB and gloss measurement values, and communicate the data with the web application via Bluetooth. -Delta E between reference CIELAB value and computed CIELAB value must be < 5 -Gloss must be correctly classified(high-gloss, low-gloss, medium-gloss) with 90% accuracy -Cycle time of entire process must be < 1.0s	-Test with oscilloscope on key control lines (LED enable, MOSFET gate) to confirm timing order and delay between processes -Compare computed CIELAB values with reference color by calculating Delta E over multiple runs. -Measure gloss of glossy and matte surfaces, ensure its correctly classified over multiple runs. -Timestamp start time and stop time of cycle over multiple runs.
User Interface Subsystem	-Separately calculate Delta E value between reference sample and predicted color, verify it

The UI Subsystem must correctly match the CIELAB values given via Bluetooth from the ESP32 with the corresponding paint color in the database within Delta E <5 It must also display the correct gloss level. It must correctly update the matched paint color and gloss level within	matches within Delta E < 5 -Correctly classifies gloss level according to set ranges -Timestamp packet arrival from ESP32 and when the UI updates. Must update within 1.0s<2.0s
Enclosure Subsystem The enclosure must block the external ambient list ensuring that the AS7343 sensor's raw baseline reading varies by less than 10% when external lighting changes from 0 lux to 500 lux.	Use an external 500 lux light source and a serial monitor to test light isolation. Place the enclosure flush against a wall in a completely dark room. Record the baseline reading via the serial monitor. Turn on the extra 500 lux light source directly outside the enclosure. Recoding the new reading and calculating the percentage variance to verify that it is <10%.
Enclosure subsystem The internal geometry of the enclosure must hold the Red LED at a precise angle of 60 degrees +/- 2 degrees relative to the surface normal of the wall. The internal geometry of the enclosure must hold the Middle PhotoDioide at a precise angle of 60 degrees +/- 2 degrees relative to the surface normal of the wall.	Place a protractor against the Red LED and the flat base plane of the enclosure. Read the measured angle and record its measurement to verify it falls between 58 and 62 degrees. Place a protractor against the middle photodiode and the flat base plane of the enclosure. Read the measured angle and record its measurement to verify it falls between 58 and 62 degrees.

2.e Tolerance Analysis: LED Drive Current and GPIO Limitations

The Problem: GPIO Current Limits

To ensure accurate spectral readings and surface sheen analysis, our device requires high-brightness 2835 SMD White and Red LEDs. These optical components require significant forward current to provide adequate luminous intensity. The microcontroller's GPIO pins are typically rated for a maximum continuous current of only 20mA. Attempting to source the necessary LED current directly from the GPIO pins would exceed their absolute maximum ratings, leading to severe voltage droop, potential microcontroller brownouts, or permanent destruction of the internal logic gates.

The Solution: N-Channel MOSFET Low-Side Switching

To safely control the LEDs without overloading the microcontroller, we isolate the control logic from the power delivery by utilizing an N-Channel MOSFET configured as a low-side switch. The MOSFET Gate is connected to the MCU's GPIO pin. The MOSFET acts as a voltage-controlled switch, drawing virtually zero continuous current from the microcontroller. A 10kohm Pull-Down Resistor is placed between the gate and ground. This is a critical safety measure that forces the gate to 0V when the microcontroller is booting up or reset (when GPIO pins are floating). This guarantees the LEDs remain off until explicitly commanded to turn on, preventing accidental current spikes. A Current-Limiting Resistor 10 ohms is placed in series with the LED to restrict the current flowing from the 3.3V rail through the LED and down through the MOSFET to ground.

2.4.3 Mathematical Analysis: Worst-Case Maximum Current IMAX
IMAX = (VCC - Vf - VDS (ON)) / R_limit

VCC (Supply voltage) = 3.3 V +/- 5% (ranging from 3.135 V to 3.465 V)
Vf (Forward Voltage) = Stated by datasheet 2.8 V but could range from 2.8 V to 3.4 V
Rlimit (Resistor Tolerance) = 10 ohms Standard Resistors have a +/- 5% or +/- 1% tolerance
VDS(ON) = .05 V

2.4.4 Worst Case Scenario

IMAX (white LED) = (3.465 V - 2.8V - .05V) / 9.5 ohms = 64.7 mA

64.7 mA maxis within the safe operating limits of the 2835 package, which handles up to 150 mA.

The red LED we are using has a lower forward voltage of 2.15 V.

IMAX (red LED) = (3.465 V - 2.15 V - 0.05 V) / 9.5 ohms = 133.2 mA.

2.4.4 Conclusion and Safe Operating Area

By utilizing the N-Channel MOSFETS we can reduce the current draw on the microcontroller’s GPIO pins to a safe logic level.

However, our tolerance analysis shows that a 10 ohm current-limiting resistor keeps the White LED in a conservative operating range, while the lower 2.15 V forward voltage of the Red LED pushes the current to its worst-case limit. The current is more than double that of the White LED. Even if the 133.2 mA falls within the maximum conduction rating of our specific data age, it introduces the engineering risks of thermal stress.

Corrective Action: To maintain an equitable and safe opening area across all components, we will install a 10 ohm resistor for the white LEDs, but substitute a 22 ohm current-limiting resistor for the Red LED channel.

Recalculating for the worst-case minimum resistance of a 22-ohm resistor with a 5% tolerance (20.9 ohms)

IMAX (red LED NEW) = **(3.465 V - 2.15 V - 0.05 V) / 20.9 ohms = 60.5 mA.**

This safely reduces the worst-case current to around 60.5 mA, which is more in line with the current from the Red LED.

2f) Color Analysis Matching Algorithm

CIELAB Color Space

To mimic human visual perception or software algorithm professes color data within the CIELAB (L* a* b*) color space rather than a standard RGB.

The CIELAB space protects colors of a 3-dimensional perceptually uniform coordinate system.

L* = Lightness Ranges from 0 black to 100 white
a*: Green Red. Negative values indicate green and positive values indicate red
b* = Blue - Yellow. Negative values indicate blue, positive values indicate yellow.

Upon receiving raw special data from our special sensory the microallergy converts the leading into these L*, a*, and b* coordinates to establish the baseline measurement of the scanned wall.

The Delta E Calculation

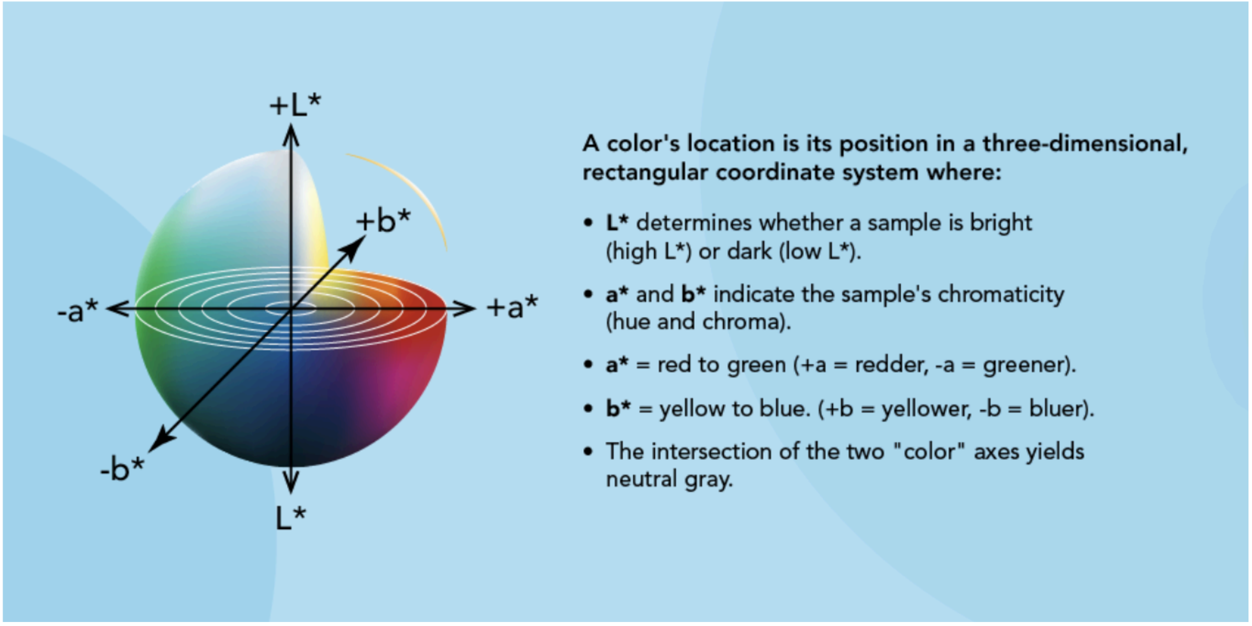

Figure 7: CIELAB Color Space Diagram[8]

To find the closest paint match, our software must quantify the difference between the walls' measured color and the standard paint colors stored in our database. To do so, we calculate the color collar difference represented by our metric Delta E.

Since CIELAB is a uniform 3D space, delta E is calculated using the standard Euclidean distance formula between measured Sample coordinates (L1*, a1*, b1*) and the database reference coordinates (L2*, a2*, b2*)

$$\Delta E^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

Figure 8: Equation for Delta E

Matching Logic and Thresholds

When the user initiates a scan with our prototype, our software integrates through a database of standard paint colors (EX: the Sherwin-Williams color desk) and calculates the delta E for every entry relative to the scanned wall. The algorithm sorts the results by the smallest delta E value to identify the closest match.

To ensure the device is acting ethically and not overpromising accuracy (outlined in our Ethics and Safety section), the algorithm evaluates the lowest Delta E against strict threshold parameters.

As previously mentioned, our goal is to have color accuracy within Delta E < 5.

Delta E < 1: Perceptually identical to the human eye. The UI outputs the exact paint name with high confidence

1< Delta E < 3: A high acceptability commercial match. The UI outputs the closest paint name and indicates a successful match.

3 < Delta E < 5.: This becomes a noticeable visual difference. To prevent the user from purchasing incorrect points and wasted materials, the UI will state the closest paint match along with a warning displaying, "No Close Match Found: Low Confidence Warning."

Delta E > 5: This high of a delta E becomes a very stark difference in color match. The UI will no longer state a color and display a warning " No Match Found."

Scope Management and Justification

For the scope of this project, the local database is intentionally constrained to a single major paint manufacturer. The Sherwin-Williams color deck contains over 1,5000 distinct colors. Create an exhaustive database of every point brought on the market or introduce unnecessary data-entry overhead. A dataset of 1,500 colors provides a statistically significant and sufficiently dense color space to validate our delta E matching algorithm, sorting logic, and threshold boundaries.

Data Structure

The database is structured using SQLite to ensure fast, lightweight querying on our application. To facilitate the matching algorithm, each entry in the database will contain the following relational data points

1. Brand Name
2. Paint Name / ID
3. HEX Code
4. Reference CIELAB Values

Scalability for Future Iterations

While the prototype dataset is constrained, the underlying architecture is designed to be scalable. Because the matching algorithm evaluates Euclidean distance regardless of the dataset's size, adding new brands such as Behr or Benjamin Moore in a future commercial iterations will not require any functional changes to the software logic.

2h) Texture Compensation Lookup Table (LUT)

The Problem: Optical Noise from Physical Texture STRETCH GOAL

While our core algorithm assumes a relatively smooth surface, real-world walls often have physical features (EX: orange peel or knockdown). These three-dimensional variations create microscopic shadows that can shift the light used for sheen analysis and/or shift the color from special color readings.

Methodology and Testing

If time allows, after core color and sheen subsystems achieve their required accuracy thresholds, we will impact a Texture LUT to account for this real-world optical noise. Our methodology will involve:

1. Creative physical drywall test samples featuring varying degrees of texture (Smooth, Medium, Heavy)
2. Painting these shells with initial colors across stand sheens (Matte, Semi-Gloss, Gloss)
3. Scan textured samples and compare outputs against smooth-wall baseline data
4. Quantify exactly how the sheen/color changes from texture, mathematical skew the L*a*b* coordinates, and sheen reflectance.

Software Integration

Once these systematic shifts are compiled into the LUT, we will update the software UI to allow the user to input the wall's texture. Before scanning, the user will perform a visual or tactile assessment of the wall and select the corresponding texture profile (Smooth, Medium, Heavy) in the app. The software will automatically cross-reference the LUT and apply the calculated mathematical offset to the raw sensor data. This filters out the physical noise before the algorithm calculates the final Delta E match, ensuring higher accuracy across real-world wall conditions.

3)Planning

3a) Cost

Item Description	Manufacturer	Link	Part Number	Retail Price	Our Cost	Quantity	Total Cost
AS7343-DLGMOLGA8 LF T&RDP	ams-OSRAM USA INC.	DigiKey	4991-AS7343-DLGMTR-ND	$7.92	$7.92	5	$39.6
LP5907MFX-1.8	LP38852MRX-ADJ/NOPB	DigiKey	LP38852MRX-ADJ/NOPB	$2.58	$2.58	5	$12.9
OpAmp	MCP6004-I/P	DigiKey	MCP6004-I/P-ND	$0.59	$0.59	6	$3.54
Photodiode	BPW46	DigiKey	751-1017-ND	$0.791	$0.791	10	$7.91
LED White	LedLightsWorld	LedLightsWorld	2835 SMD LED in White Color	$3.5	$3.5	5	$17.5
LED RED	Dialight	Dig6iKey	350-2684-ND	$1.3	$1.3	6	$7.91
USB-UART Adapter	zhayouqingdzsw	Amazon	FT232RL USB UART T/TL 5V 3V3 to 6PIN 0.1" Pitch	$31.60	$31.6	3	$94.8

			D/UPO/NT Jumper Download Cable Compatible T/TL-232R-5V T/TL-232R-3V3(5M,TTL 3.3V 1X1 6P)				
N MOSFETS	**T2N7002AK,LM**	[DigiKey]	**T2N7002AKLMR-ND**	**$0.14**	**$0.14**	**10**	**$1.4**
ESP-32	**Espressif**	[Eshop]	**ESP32-S3-Dev**	**$5.49**	**0**	**3**	**0**
Level Shifter	**NXP USA Inc.**	[DigiKey]	**568-4243-2-ND**	**$0.7**	**$0.7**	**5**	**$3.5**

Total Parts Cost = $189.06

Name	**Hourly Rate**	**Hours Invested**	**Total**
Victoria Lee	**$45**	**64**	**$7200**
James Lee	**$45**	**64**	**$7200**
Charis Wang	**$45**	**64**	**$7200**

Labor Cost = Hourly Rate X Actual Hours Spent X 2.5

Type	Total
Labor	**$21,600**
Parts	**$189.06**
Total	**$21,789.06**

3b) Schedule

Weekly

- **Update Project Notebook (Individual)**
- **Send TA updates after meeting and after group meetings (Victoria)**

Week	Task	Responsibility
2/23	Prepare for PCB review date	**All**
	Research hardware parts and place an order with the TA	**All**
	Design document due (2/27)	**All**
	Complete PCB KiCAD for First Round PCB Order (2/26)	**All**
	Order paint samples (paper)	**Victoria**
	Order blackout material	**Victoria**
	Order Play-Doh	**Victoria**
3/2	**Attend Design review (3/2 1pm)**	**All**
	Take feedback and prepare for Second Round PCBway orders	**All**
	Build breadboards for Instructor / TA review	**All**
	Build enclosure	**All**
	Prototype photodiode subsystem on breadboard, Verify ESP32 receives sensor data	**James**
	Connect Bluetooth with ESP32	**James**
	Finish the routing and the extra connectors to Main-PCB	**Charis/Victoria**

3/9	**Breadboard Demo (3/?)**	**All**
	Third Round PCBway (3/12)	**All**
	Teamwork Evaluation 3/11	**Individual**
	Work on PCB redesign with any modifications and/or additional parts that were missed during PCB orders 1 or 2	**All**
	Finish Routing/Order PCB round 2	**Charis/Victoria**
	Finish Enclosure - Orders | photo paper, diffusion paper, collimating lense, order paint samples,	**Victoria/Charis**
3/23	**Fourth Round PCB Way (3/26)**	**All**
	Implement computational code for CIELAB and gloss Connect Bluetooth with ESP32, Verify data packet is received by the web application	**James**
	assemble enclosure, assemble with PCB for initial testing, solder	**Charis/Victoria**
3/30	**Individual Progress Reports due (4/1)**	**Individual**
	Solder	**Charis/Victoria**
	Create Database of colors and web application	**James**
4/6	**Progress Demo (4/?)**	**All**
	Team Contract assessment (4/10)	**Individual**
	Solder	**Victoria/Charis**
	Create Database of colors and web application	**James**
4/20	**Mock Demo (4/?)**	**All**
	Create Database of colors and web application	**All**
4/27	**Final Demo (4/?)**	**All**
5/4	**Final Papers (5/6)**	**All**
	Lab NoteBook Due (5/7)	**All**

Ethics and Safety

4.1 Ethics

Honesty, Realism, and Avoiding Harm

LINK LINK REF REF HERE

A primary ethical consideration includes IEEE Code of Ethics Section 1.5 (Honesty & Realism).[3] Color matching, while it can be measured by Delta-E, is subjective when observed with the human eye. This creates the ethical risk of overpromising the device's accuracy. For instance, if the device scans a wall and calculates a color difference with a Delta E greater than 5, but the UI still displays a "perfect match" EX: Shermal Williams "Bee" that would be misleading to the user. This could result in the user purchasing the wrong paint, ruining their wall, and wasting money. To mitigate this, our device will display a 'low confidence' warning or state "no close match found" if Delta E is greater than 3 instead of forcing a blind guess.

Furthermore, another potential issue is IEEE Code of Ethics 1.2, avoiding harm. We must consider economic harm if used by, say, a professional contractor. If a contractor uses our device for a client and the device fails to provide an accurate match due to extreme wall texture, the contractor could lose money and professional credibility. We will prevent this by clearly labeling the device as a prototype or reference tool and including a disclaimer that results may vary on highly textured surfaces.

Social Impact and Accessibility

Additionally, 1/12 men and 1/200 women are affected by vision deficiency or blindness. For these individuals, it can be incredibly difficult to match paint without assistance. Our device can act as assistive technology and empower independent living and decision-making for color blind or color-deficient individuals.

Environmental Responsibility

Our device makes a positive environmental contribution by reducing chemical waste [9] common when homeowners or renters buy test cans of paint that end up not matching, leading to gallons of unused paint sitting in basements or being improperly disposed of. Our decision increases the "first-time success rate" of paint purchases matching specific hex code and gloss type, reduces the volume of wasted paint, and continues entering landfills or water systems.

Power and Thermal Safety

Power and Thermal Safety UL 60950-1: We are using a 5V USB-C receptacle that powers the LDOs to generate heat. If the 5V USB-C receptacle fails, it could cause 3.3V to be sent to our 3.3 V microcontroller, which could cause a thermal failure (fire/smoke). This could be prevented by using a UL-listed external wall adapter and including an over-current protection on the 5V input line on our PCB to prevent overheating in case of a short circuit.

Laboratory Safety Compliance

Development, soldering, and testing will be conducted in the electrical engineering laboratories. We will ensure full compliance with campus safety policies by following standard electrical safety procedures, handling PCB components with ESD-safe practices, and ensuring our enclosure testing does not interfere with other students' workspaces.

End-of-Life Disposal

To maintain environmental responsibility at the end of the project lifecycle, we will adhere to campus e-waste disposal guidelines. Any faulty PCBs, burnt-out LEDs, or damaged sensors will be properly recycled through the Sustainable Electronics Center rather than being thrown in standard trash receptacles.

5) References

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