REAL-TIME INDOOR AIR QUALITY AWARENESS: LUMIGEN'S INTEGRATION OF VISUALIZATION AND SENSING TECHNOLOGIES

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ABSTRACT

Lumigen is an innovative air quality monitoring system designed to enhance indoor environmental awareness using real-time data visualization [1]. The system combines an air quality sensor connected to a Raspberry Pi with a set of Philips Hue lights that change color based on detected air quality levels [2]. This setup provides immediate visual feedback, alerting users to air quality changes without requiring them to check a separate device. Users can interact with Lumigen through a mobile app that facilitates real-time monitoring, historical data analysis, and customization of air quality alerts and light settings [3]. Experimental evaluations demonstrate that Lumigen effectively detects and responds to variations in air quality, with a rapid response time and high accuracy. Unlike other solutions that may require separate displays or offer limited data insights, Lumigen seamlessly integrates into everyday life, providing both visual and data-driven cues about air quality. Future developments could enhance its portability, integrate automated responses with air purifiers, and offer advanced data analytics to further empower users to manage their indoor environments proactively [4].

KEYWORDS

Indoor Air Quality, Real-Time Data Visualization, Environmental Sensing, Smart Home Automation

1. INTRODUCTION

Lumigne is inspired mainly by allergic rhinitis which is largely caused by poor air quality or specific substances in the air Environmental risks cause 12% of the global burden of disease, with air pollution ranking first [5].In 2021, WHO issued updated and more stringent air quality guidelines to reflect adverse health effects at lower concentrations than previously recognized.Air quality monitoring is the first step for understanding a population’s exposure and taking action.Report provides an overview of the strengths and weaknesses of different measurement and modeling methods.

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Every year, 7 million people die prematurely from exposure to air pollution [6]. At the foundation of this mortality. This problem affects everyone, especially people with cardiovascular diseases that are vulnerable to air pollution or people who have allergic rhinitis. This problem causes health issues worldwide and countless people to suffer from diseases due to air pollution. This problem is important for us to solve because it can potentially advise people who are sensitive to air pollution to take action and know their environment in advance of facing further troubles.

In the modern world, lights are an inevitable part of our lives, which is why we wanted to use house lighting as a tool to inform occupants about the air quality in their living or working spaces. Our app connects to the Philips Hue System, utilizing its capacity to control multiple lights effortlessly. The concept behind our application is straightforward and user-friendly, employing simple color codes to indicate different levels of air quality. For example, green light for good air quality, yellow for moderate, and red for poor air quality. This visual approach ensures that everyone, including children and the elderly, can easily understand and react to the air quality status without needing to check a separate device or application.

We decided on this method because it integrates seamlessly into everyday life, providing constant, non-intrusive feedback on air quality. Unlike other solutions that require checking an app or device, our system ensures that air quality information is always visible. This unique approach, combined with the ease of setting up the Philips Hue System, makes our solution more effective and accessible. By transforming essential health information into an integral part of the home or office environment, our app not only informs but also promotes healthier living conditions in a more intuitive and immediate way.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Particle Detection Device

Skeptical question: How accurate and reliable is the particle detection sensor?
According to our repeated experiments, the particle detection sensor is 99% reliable and accurate, giving the users correct data about the air quality and suggest them to take certain actions based on the quality.

2.2. User Interface

Skeptical questions: How can the app of the device successfully alert users to take certain actions when the air quality is not ideal?

We have designed a notification system that alerts the user when the air quality decreases to a certain point based on the users personal settings and conditions. It will notify the user when the air quality is not good.

2.3. Portability

Skeptical question: Since the product is described as a portable air quality sensor, how does it work if it depends on the philips hue light to show the air quality by changing colors. For portability, we suggest the user to use the app we created to check for the air quality while outside traveling. The philips hue light is a great addition for home usage that gives a more visual representation to the air quality when the user is at home.

3. SOLUTION

In this part, you will discuss the architecture of your program, what technologies you used, and how somebody is meant to use the application.

Lumigen utilizes an air quality sensor that detects the amount of particles in the air which is connected to a Raspberry Pi that controls Philips Hue lights [7]. These lights will change color depending on the quality of air inside of that room. It utilizes Circuit Python to read data from the air quality sensor on and process them [8]. Moreover, the data is sent to the Philips Hue bridge to control the lights and the color based on the air quality.

Provide a flowchart of your program. This flowchart should cover every single large system in your program. If a backend server or an external database is integral to your program, then include those too in your flowchart.

Start from the first screen that you are met with when you open your program. What does the user do next? Can you interact with this screen, and if so, what the program do in the background? Can you go to another screen from here, and if so, what does the program do in the background?
Let's use Instagram as an brief example. When you open Instagram, we have to either make an account or log into an existing account. Then from there, we have our feed, and we are shown posts made by other people. We can view their accounts by clicking on the user icon in those posts, and we can view their other posts and follow them. Or, we could go to another screen in Instagram at the bottom by using the hotbar. We can view short-form videos or use the built in messenger.

When you open the Lumigen App, the user has to create an account or log in if they have one already, after creating an account, the user has to go to device settings to input the device id which pair the Raspberry Pi to the user. After the Pi is connected, the app will simply retrieve data from the Pi and display it to user the air quality at the moment or the tread in 7 days, 1 month, or all time. The user can also change the color of the light for each air quality level in the app for optimization.

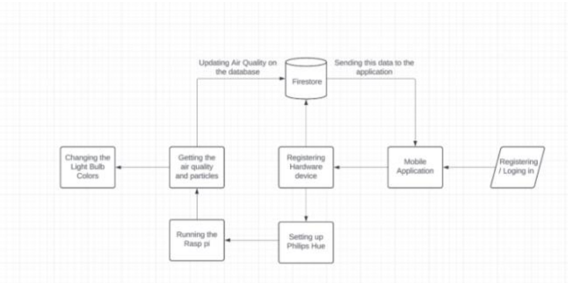

Figure 1. Overview of the solution

What is the component's purpose in your program? Did you have to use any services (backend, database) in this system? Does your component rely on a special concept (eg Machine Learning, Pose Estimation, Natural Language Processing)? If so, briefly explain what the concept is about.
Mobile app: The mobile app is used to retrieve data from the Raspberry Pi and display it to the user. We utilize firebase as the server for the app to store user information and air quality information recorded by the raspberry Pi.

Rasp Pi and air quality sensor: Raspberry Pi processes the information receive from the air quality sensor and sends the data to the firebase which to be taken to the app and be displayed to the user. The air quality sensor simply records the air quality data and sends to the Raspberry Pi for further processing.

Philips hue: The Philips hue runs on the Pi and displays the color based on the air quality detected [9].

Figure 2. Screenshot of code 1

Hue: The raspberry Pi connects to the philips hue through the Bridge's Ip. After it is connected, the rasp pi will start changing the color of the lights based on the air quality of the sensor. Worth mentioning that the changes get recorded constantly to identify any changes in the air quality. This will help the App: The provided snipped of code is getting the air quality data from firestore. Which will later be shown in the home page and the insights page of the application. In the homepage every refresh allows the user to see real time Air Quality Index (AQI) of their environment and the insights page will allow for more data for the past week, month or overall runtime of the device [10].

4. EXPERIMENT

4.1. Experiment 1

Expected				
Board Name	Raspberry Pi 5	Raspberry Pi 4B	ESP32 Feather	Raspberry Pi Zero
Speed(change of light)	0.5s	0.7s	1.3s	1.0s
Actual				
Speed	0.5s	0.7s	1.66s	1.2s

Expected					
Perfume	10%	5%	3%	8%	6%
Vacuum	15%	10%	10%	5%	10%
Breath	200%	100%	150%	100%	10%

Actual					
Perfume	30%	60%	15%	40%	0%
Vacuum	>2%	50%	35%	40%	15%
Breath	400%	30%	100%	20%	5%

Figure 3. Figure of experiment 1

In this experiment, the speed and reaction time of the sensor, and the lights would be put to the test. This is important as it has a major significance in the user experience. Another point worth noting is that if the sensor is not rapid enough to pick up signs of change, it will lose its value.

The speed of the sensor and the change of lights is going to be calculated with several independent variables including: the change of color on each of the lamps, the speed of detection, and more importantly the speed of changing back to more healthy as the air gets more clear. In each of these categories, different test environments have been made to simulate different levels of pollution and changes in the environment for optimum results.

The accuracy of the sensor was also tested during these experiments with replication of different particles such as bug spray, perfume, car exhaust, Vacuum Cleaner, and human breath.

and accuracy of the Lumigen will be tested using several independent variables including: Exhaust, perfume, vacuum, breath, and body spray. Then the expected value and actual value is recorded.

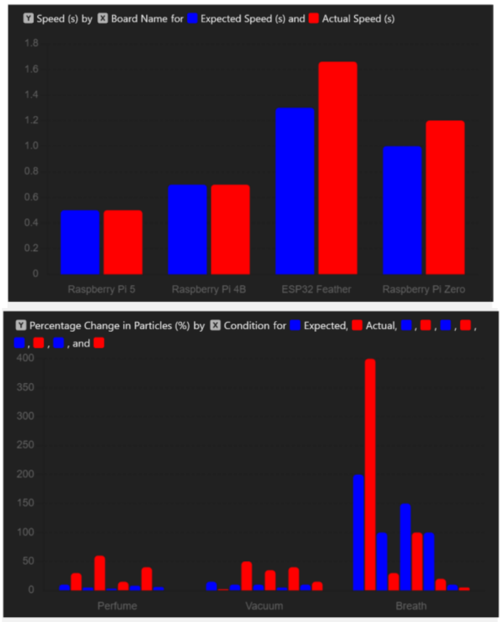

Figure 4. Figure of experiment 2

For the second experiment, about the accuracy of the sensor, out of the 5 trials of 3 different pollutants we have done, we got 4 of them wrong and 8 of them right. Initially, the overall accuracy of the system was not the most accurate due to inexperience of the testers. Another point worth mentioning is that, due to the environment's inadequacy in the number of particles measured, we decided to try again and recorded the median change of the number of particles in the air. with got the medians of all the measurements. With these experiments, the commonality in mistakes was the attempt to decrease the quality of air while the AC unit was running. The main disturbance of the experiments was the AC cycling through the room, but it was not audible for the testers in the first few runs. This caused some of the experiments that were expected to show moderate, or unhealthy for sensitive groups on the Air Quality Index measure, to not change only spikes of a few seconds and bounce back to normal.

5. Related Work

The project is a air monitor and purifier that has wireless transmission controlled by the The STC12C5A60S2 single-chip microcomputer [11]. optical air quality sensor GP2Y1010AU0F MQ138 detects formaldehyde gas and send the data to the microcomputer through transceiver module NRF24L01 for processing. For our project, we utilized The Raspberry Pi which has the ability to control electronic components such as the philips hue light to change color. We also use Adafruit Industries LLC 4632 PMSA003I Air Quality Sensor which detects the number of particles in the air not only formaldehyde. Finally, we have an application that allows users to see the air quality with almost no delay.

This article is a research about how thermal temperature affect people's perception on indoor air quality(IAQ) stating that without seeing the IAQ data, people would tend to judge the IAQ based on temperature [12]. Basically the more comfortable the temperature, the better IAQ people perceive. This research highlights the importance of our project because it is a IAQ sensor that has live data sent to the users reminding them of the IAQ eliminating the biases caused by temperature which may cause further issues.

The article describes a high-sensitivity, portable device for hourly formaldehyde monitoring in indoor air [13]. It uses a stable lutidine derivative reaction, with a detection limit of 5 $\mu g/m^3/h$. The device tracks formaldehyde levels and estimates air exchange and adsorption rates for improved mass balance equations in indoor environments.Compared to our project, the device lacks reliability because it only detects formaldehyde, many other information and particles in the air may be dismissed which may cause the data to be unreliable. It also lacks an application that tracks air quality overtime to inform the users about the trend of IAQ in order to alert the user in time.

6. CONCLUSIONS

There is a limitation in connectivity for this project, the Raspberry Pi must be connected to a power source using a USB-C cable which means the device most likely can be only placed somewhere near a viable outlet limiting the portability. Also, to allow the light to change color based on the air quality detected by the sensor, a Philips hue bridge is required which needs ethernet connection. If we were given more time for development, we would develop the mobile app further to gather data collected by the IAQ and use AI to analyze the data to give suggestions to users [14]. We could also make the device more compact and stylish as well as making it able to pair multiple devices to each other at the same time. In the future, there are endless possibilities such as pairing the IAQ sensor with an air purifier to automatically turn the purifier on when the IAQ is below the user's expectation. We can also make it more portable by adding a light into the device, making it rechargeable or run on batteries which can significantly increase travel convenience. We can also add real time alarms to users' mobile devices to notify them of any hazardous air quality [15].

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