Sound and Light Immersion with Application of Image Processing and Artificial Intelligence

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Chapter I

The Problem and Its Background

Introduction

Senses are an essential part of a living being, it is used as a mechanism to receive information that influences it to act accordingly. A human has many senses which can be expanded further depending on how the sensory system is classified starting from 5 senses (Visual, Auditory, Somatosensory, Olfactory, and Gustatory) based on the sensory cells; and up to 20 senses if based on the specialized cell types, what signals perceived. The Visual followed by the Auditory sense is the most important sense as they are the most used senses making people reliant on them (AGEI Educational Team, 2022), many use these senses without a thought as it is used with the majority of actions from complicated actions such as processing information to the mundane tasks like entertainment, by adhering to the senses is what creates Ambience or Atmosphere.

Using ambiance is prominent when it comes to businesses as by implementing it, the customer experience is increased therefore also increasing customer satisfaction which correlates to a high spend per customer (Morse, 2023). Ambiance is also present in the entertainment field. In movies, sounds can accentuate the tone that is trying to portray in the film. This is displayed in horror movies where the atmosphere is that it makes use of stagnant sounds and visuals which can elicit a sense of foreboding

feeling to the watcher. The use of ambiance in films not only increases the cinematic narrative of the film but also the perception, engagement, and Immersion of the audience (Dobrev, 2020).

Contrary to popular belief, Machine Learning or just commonly known as "ML" is a branch of Artificial Intelligence (AI). It is one of the new frontlines when it comes to the computer science field which focuses on creating machines that learn and make decisions or do a process to achieve a goal ("Artificial intelligence", 2024). ML is a tool used by many as its ability to answer queries with a high percentage of success and quality is helpful, ML can also be used to accomplish tasks however the more complex the action is the higher the chance for failure to complete the task with 100% certainty.

With how helpful AI and ML is, it is continuously being integrated into existing technology as it helps facilitate and complete tasks more smoothly and opens other possibilities for processes that were not possible or sustainable before the AI integration; AI chatbots, AI-assisted pattern recognition, and Image analysis are examples of this. That said, there is a lack of existing and accessible technology when it comes to the ambiance or atmosphere of content. By making use of Image analysis, software that can enhance the ambiance is possible by influencing the user's senses with more emphasis on sound and light designs. The user can manipulate the sound and light design by image inputs which are processed by the AI to analyze.

Background of the Study

The role of ambiance in the entertainment field such as movies and games is important warranting scrutiny from the filmmakers and producers before deploying their work, that said current movies and games often limit user customization of ambiance or completely disregard it, leading to a one-size-fits-all experience. The opportunity to customize and personalize the ambiance according to the content will help the user experience as it can encourage users to interact more with the content. If users feel that they have control over their entertainment experience, they are more likely to invest attention to the content.

Despite the importance of ambiance, there is still a gap when it comes to applications and tools that enable user-driven customization of ambiance. While advancements and developments in AI and Machine Learning have become beneficial across various sectors, its application in enhancing and personalizing ambiance in entertainment is still underexplored. One of the many applications of AI is image analysis which will be used to identify dominant colors, which can then be paired with suitable sounds and be displayed in lighting to create a tailored sensory experience.

This study's main purpose is to address this gap by developing a program that allows users to customize sounds and lighting based on their personal preferences through image input using an ML algorithm to analyze provided images by the user returning the dominant color in the image. The program will offer personalized ambiance options with the returned dominant color of the

image and display custom sounds and lighting therefore enhancing the user experience with entertainment content. The effectiveness of this prototype will be evaluated to determine its impact on the overall user experience

Rapid Application Development

There are numerous development methods that developers can employ. Rachmad et al. (2024) originally determined the development approach for the system. When evaluating the SDLC, developers have three options: Waterfall, Prototype, and Rapid Application. This system was developed using the Rapid Application Development strategy, which was chosen because it is versatile and quick in the development process, as well as adaptable to changing user needs. Aside from that, it works well for developing systems that meet user requirements.

According to Ichsan et al. (2024), Rapid Application Development is the simplest version of the waterfall model. This software development model's high-speed adaption allows development to occur more quickly since it employs a component-based construction method. Rapid Application has four stages process such as requirement planning, user design, construction, and cutover. The development begins with identifying the system requirements this is the crucial stage for the researchers, to achieve the system development goal. The details and functions are required and needed In the study, there are two people involved with the system the administrator from the company and the agents who work at the company. The role access management system was integrated into

the system. where you can access the system's features and functionalities based on your role inside the firm or system. The unified modeling language was used to model the system, which would serve as a visual for developers to quickly understand the design of the system.

In the study of Singgalen (2024) on coastal and marine tourism monitoring system design using rapid application development, they carried out a prototype design using Oracle Apex that includes the dashboard display to the data needed. As for the construction stage, they implement a data configuration where they are able to display data so that managers of beach tourist destinations can understand the context and priority. The last is cutover when all the system features and functions are being tested to evaluate the application performance. And as for the results of their study show that it was successful and can be used in decision-making.

Satyawati et al. (2024) integrate Rapid Application Development (RAD) into the development of accounting information systems for micro, small, and medium-sized firms (SMEs). Demonstrating a solution that improves their operational efficiency and financial report. The development process utilized is RAD, which emphasizes rapid prototype development iteration to enable a user-centered approach that benefits (SMEs) and allows the creation of personalized, user-friendly, and easily adjustable products to satisfy company demands. The rad application addresses the management competency gap by incorporating end users in the development process. It ensures that the system is practical and intuitive, while also boosting the accuracy of financial reports.

Artificial Intelligence

Incorporating AI into system development has become promising garnering substantial attention across diverse fields as advancements grew in Transportation, Business, and the Economy. AI has been found to be useful in processing data that pharmaceutical firms use and benefit such as making use of AI in healthcare in the field of drug process and automating the identification of diseases and ailments. According to Shasheen (2021), the use of AI in clinical trials helps with processing vast amounts of data and generate quite accurate results. Another point in his article is the use of AI and digital technology can improve maternal care by predicting high-risk pregnancies and increasing patient access to regular and high-acuity care.

On the Transportation Systems, (Gangwani & Gangwani, 2021) conducted a study about transportation systems in the United States to address traffic congestion, accidents, and environmental concerns by making use of AI and ML when it comes to creating smart and efficient transportation solutions to the transportation problems. They pointed out in their study that AI and ML are being applied to the creation of Intelligent Transportation Systems (ITS) to tackle real-time transportation issues such as road anomalies, accidents, energy usage, infrastructure, traffic congestion, and parking availability. The use of AI and ML in Intelligent Transportation Systems includes applications like accident prevention, intelligent road lighting, AI assisted vehicles, parking management, incident detection, and predictive models to solve the issues.

As businesses continue to get ahead of each other in a continuously evolving market where efficiency is tantamount and where inefficiency will sure to bleed money, businesses have begun to understand the potential of using AI in their systems and the production of these systems to speed up development. With the use of AI in the DevOps approach where software development and IT operations are used side by side, companies are able to use the benefits of machine intelligence to expedite processes, enhance decision-making, and drive improvement to the product (Alenezi et al., 2022).

With regards to the Economy more specifically E-commerce, research conducted by (Zhang et al., 2020) discussed how recommender systems are enhanced using AI techniques where content, collaboration are the focus in regard to the need for assisting users in making choices amidst a sea of information. It also talked about the challenges of concept drift detection in recommender systems due to evolving user preferences over time, necessitating the development of time-aware recommender systems. AI techniques are integrated into recommender systems through various methods such as fuzzy techniques, transfer learning, neural networks, deep learning, active learning, natural language processing, computer vision, and evolutionary computing. These methods enhance prediction accuracy, address data sparsity, and solve cold-start problems in recommender systems. They are applied to improve the development and use of recommender systems by making predictions on the user preferences according to their past behaviors and patterns.

Image processing

The field of image processing gives a diverse methodology utilized within the image processing that includes segmentation (that divides the image into a smaller part to easily analyze), denoising (to help reduce image noise), enhancement (improve visual quality), feature extraction (identifying important features within an image), and classification (categorizing images). DL-based denoising and image restoration contributed to the improvement of image quality, while the DL-based model enhanced visual quality by contrast and brightness adjustments, helping human interpretation (Archana & Jeevaraj, 2024).

A study on Image Processing Techniques views image processing as one of the fascinating fields—the tool that is normally used to improve images that are used in many resources. The image processing gives outlines to their work, the focus of their study is to characterize the different techniques or methods used at the image processing stages.From this point, the study performs a segmentation process. It is an image processing that refers to gathering the pixels based on the similarities or differences. This divides the image into a smaller part to easily analyze, the accomplishment of the investigation depends on how well the Region of interest (ROI) is segmented from the given images. Measuring the effectiveness of segmentation, the researchers used metrics, which determined the result of the study (Gupta., 2020).

In the study by Zhan et al. (2024), 3D image processing technology is applied to interactive entertainment within the design of cultural and creative products. The study collects 3D image data as training samples and uses

machine learning algorithms to create a training model capable of recognizing patterns and features within the images. The approach allows automated feature extraction and processing of new 3D images, and it also allows prediction and processes based on the previously learned pattern resulting in more accurate and efficient design outcomes. The experimental result shows that their study based on 3D image processing technology performs better than traditional techniques, especially when handling complex images.

In the paper Application of Graphic Image Processing Technology in 2D Game Interfaces (Liang, 2023),. Emphasizing the role of image processing in collecting and analyzing relevant data, contributed greatly to social gaming development. The study addresses the balance of constraints in encoding dictionary coefficient weighting, aiding in the processing of feature images and the alignment of grayscale and transformed images to enhance visual elements. The outcomes of the image graphics technology give an accuracy rate of 87.25% for image recognition, an indication of its reliability in precisely interpreting visual data. however, the user satisfaction rate for the 2d game design interface is 78.60% as a result of advancement in graphical image processing fostering a more interactive and satisfying experience, with the users aged 30-40 representing the largest consumer demographic in the study.

Measure the Level of User Immersion

Through the years virtual reality has become rampant, and researchers have focused on exploring and developing metrics for assessing immersive experiences in virtual reality. Selzer and Castro (2022) conducted a thorough

investigation of virtual reality immersion measures, revealing information about how sensory cues such as visual, auditory, and tactile features influence the perceived level of immersion in VR settings. The study gives information on the success of captivating virtual reality experiences. The research provides information on the achievement of an alluring virtual reality experience. The researchers use questionnaires along with surveys to manage statistical analysis of user presence and immersion. Furthermore, classifying the effect of technical elements such as visual and audio, and movement on immersion level.

The VR experiment of Lu et al. (2022), investigation the impact of visual and audio on soundscape parameters in home areas. The study corresponded with the study of Selzers and Castro's investigation into immersion measurements. Lu et al. investigated the auditory-visual interaction of user ratings in judging the immersive experience. Using a user-centered approach, researchers addressed the difficulty of harmonizing statistical data with subjective experience. Provides critical insight into the complexity of sound perception in urban environments.

Eriksen et al. (2021) provide a study game audio immersion that discusses music, ambient sounds, sound effects, and background music. The components work together to improve the whole gaming experience and influence player engagement and emotional sensibility. at the end of the investigation, researchers found out that sound effects are the most crucial component of the video after accomplishing a test to assess the influence of game audio on emotional engagement and immersion. By employing feedback

and analysis. The study underlines the impact of audio in affecting gameplay and player satisfaction, emphasizing the need to use well-designed sound features to provide an engaging gaming experience.

Software Quality Assurance ISO 25010

ISO/IEC 25010 is one of the critical standards in the SQuaRE family, which serves as a comprehensive framework to evaluate ICT products, which includes software. These will ensure that ICT products have met their functional and non-functional requirements while providing value and reducing risks (ISO/IEC, 2023). This research will use ISO/IEC 25010 standards to evaluate the quality of the system developed for light and sound immersion, which employs image recognition and artificial intelligence. It seeks to ensure that the system developed meets general standards on software quality as set forth by the ISO framework, hence dependable, efficient, and user-friendly. Very recent studies have also applied the ISO/IEC 25010 to different contexts, and it can be seen that it is up to date in the evaluation of software quality.

In this research by Peters and Aggrey (2020), a new quality model for the evaluation of ERP systems in higher education institutions (HEIs) was proposed, applying the ISO/IEC 25010 standard. This model has adjusted the eight key attributes of ISO/IEC 25010 better towards assessing the quality of the ERP systems in educational contexts. By using ISO/IEC 25010, this study provides a structured approach for quality assessment and brings light to the relevance of that standard to particular contexts. Future research will be conducted on the

relationship between these quality factors in the proposed model and their effects on the performance of the ERP systems (Peters & Aggrey, 2020).

Following other applications of the ISO/IEC 25010 standard, a more recent study by Canlas, Piad, and Lagman (2021) utilized this framework to evaluate a system designed for monitoring and predicting faculty research productivity. This descriptive and developmental study employed a quantitative approach, using the Knowledge Discovery in Databases (KDD) process for data mining and the spiral model for software development. These methodologies offered a structured approach for both system development and performance assessment. The ISO/IEC 25010 standard was specifically applied to evaluate key quality characteristics. The evaluation, conducted by 15 expert respondents—comprising administrators, IT professionals, and research experts—showed high approval across all criteria. The study adequately showed applicability toward the measurement of software systems by ISO/IEC 25010 in educational and research settings, hence confirming readiness for deployment (Canlas, Piad, & Lagman, 2021).

Another is the case where the ISO/IEC 25010 standard was used to evaluate the quality of the KAMI 4.1 Index system, a web-based application that aims to implement controlled audit. The quality-in-use model of the ISO/IEC 25010:2011 was used to evaluate the system, and it scored a total quality of use rate of 81.45%, thus classified as "very good.". Although the system received a high rating for user-friendliness and potential implementation of audits, in the

study, areas need further research and improvement: data security, content coverage error tracking. This study illustrates the relevance of ISO/IEC 25010 not only in the course of system evaluation but, also in continuous improvement that may be brought to its software development process (Prabowo, 2024)

Significance of the Study

This study aims to create a program that allows users to customize and personalize sounds and lighting according to the dominant color of a picture entered by the user. An AI algorithm will be used to describe the picture and derive a series of adjectives that will be used to search for suitable music and lighting in the library. Customizability and personalization will enhance the user's experience with their content through the generated ambiance. The following will benefit the following.

Gamers: By having the ability to customize the lighting and sounds that they can perceive in the background as they play, users can enjoy a more immersive and enjoyable gaming experience that aligns with their preferences. This can lead to increased satisfaction and enjoyment of gaming content.

Home Decor Enthusiasts: Users can personalize lighting effects and soundtracks based on their chosen images, creating an ambiance that reflects their unique aesthetic preferences. This feature enhances the experience of designing and decorating living spaces, offering a more immersive and satisfying way to craft the perfect home environment.

Retail Stores: Businesses outside of the entertainment industry like retail stores can also benefit from the use of this program creating a welcoming and

engaging shopping environment, potentially increasing customer dwell time and sales.

Entertainment Industry: Understanding the importance of customizable sensory experiences in driving user engagement and satisfaction. The entertainment industry can tailor their content to meet its audience's diverse preferences and create a new profit avenue with the development of programs that can interact with the content.

Researchers: This research will be helpful to the researchers as it will train their skills in programming, give them experience on creating systems, and understanding of software engineering and product development.

Future researchers: The development of this program can serve as a reference to the development of programs that interact with lights and sounds with regards to inputs. The methodology and implementation as well as the use cases can be expanded further to improve the study.

Statement of the Problem

General Problem:

While current entertainment systems have many different ways to control and customize ambiance, there is a lack of systems that use a unique approach for personalizing sound and lighting by applying Artificial Intelligence and Image Processing. This gap requires a system to allow user creation of their own ambiance by analyzing images to create sound and light settings based on dominant colors, offering a different method for enhancing user satisfaction and immersion.

Specific Problems

Development of a Unique System:

A system that will be designed and documented using AI and Image Processing for manipulating sound and light settings based on the dominant colors of user-provided images is needed. It will be created following the Rapid Application Development (RAD) model.

Application of AI and Image Processing:

The challenge is in applying AI and Image Processing technologies to extract information from which the dominant colors of an image can be analyzed

and used to adjust the sound and lighting ambiance and lighting ambiance in a unique and personalized way.

Enhancing User Immersion through Customization:

While some systems allow users to control ambiance, this study is new in that it lets users personalize sound and light based on image inputs. Thus, it provides a unique and customizable immersive experience. A method for measuring immersion using user feedback is also necessary to evaluate this experience.

Scope and Limitations

The system, "Sound and Light Immersion with Application of Image Processing and Artificial Intelligence," is designed to provide an immersive audiovisual experience for gamers and individuals seeking ambient lighting for their homes. Unlike existing software that syncs light colors in real-time based on-screen content, this system generates lighting effects based on the dominant color detected in uploaded images, without being influenced by real-time screen changes.It employs advanced image processing and picks dominant colors in an uploaded image so that effects from the lighting would be integrated. The AI algorithms go along with soundtracks from its own library that match up with detected colors for enhanced immersive effects. The easy uploading of images and quick changes of settings make this system suitable for gaming as well as for home setup. However, there are some drawbacks like delay caused by processing, hardware inconsistency, a probable inaccuracy of color detection, too

limited audio tracks, as well as the complicated menu system that not everyone in a family could use to his or her advantage. Additionally, there are no provisions made with respect to health hazards triggered by continuous audiovisual stimulations. In the further development of the system, the researchers could focus on perfecting their algorithms processing times, enhance the type of devices that are capable of operating with, work on the accuracy of identifying colors, extend the varieties of soundtracks, as well as reduce the complex user interface that would contribute much to the accessibility of the system.

CHAPTER II

Introduction

The purpose of this chapter is to explain the processes, methods, and techniques to justify the procedures. The study aims to utilize Sound and Light Immersion with Application of Image Processing and Artificial Intelligence. This methodology will explain the groundwork of the systems used in reaching the findings making sure that the results are correct and reliable.

The study utilized a mixed-method approach, integrating qualitative and quantitative research methods for Sound and Light Immersion with the use of Image Processing and Artificial Intelligence. The study used descriptive aspect research methods based on qualitative research methods that focus on collecting and detailing information to understand the nature of an object. The study adopted an iterative methodological approach quantitative method to evaluate the specific system performance that includes the dominant color detection, consistency, and user satisfaction through measurable feedback metrics.

The system of Sound and Light Immersion using Image Processing and Artificial Intelligence is an excellent case for applying this approach. Using this method, researchers can explore the origin, schematics, and operations of the system in detail. It is this detailed information that will assist in arriving at a

comprehensive understanding of what is supposed to be expected from the system.

Conceptual Framework

      This section outlines the conceptual framework for a system designed to create an immersive audiovisual experience through the integration of image processing, sound, and lighting control. The system leverages various technologies to analyze visual content and synchronize corresponding auditory and visual outputs, thereby enhancing user engagement and personalization. The conceptual framework is built around three main parts: input, process, and output.
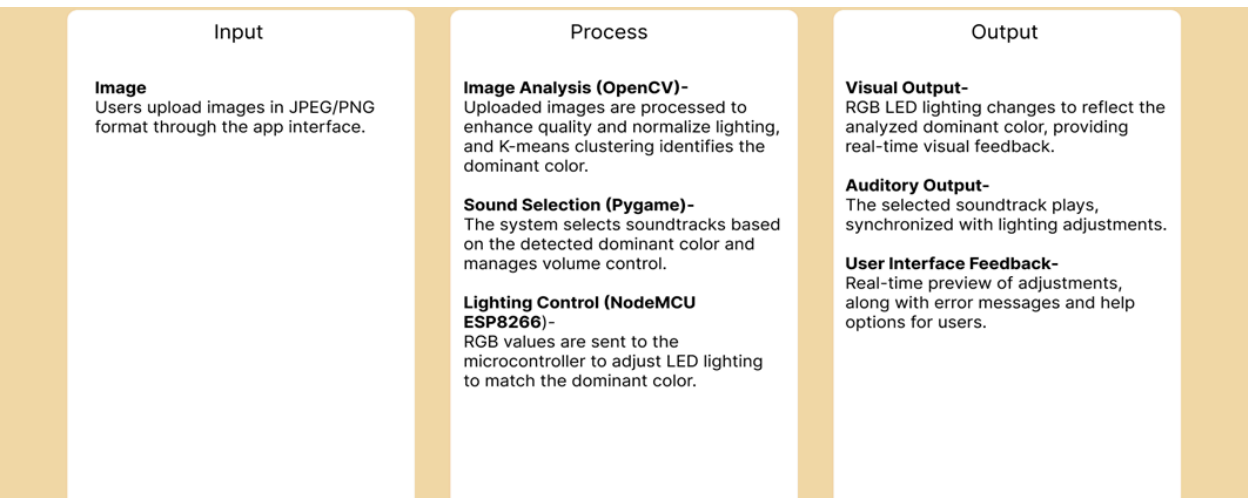
Input	Process	Output
Image Users upload images in JPEG/PNG format through the app interface.	**Image Analysis (OpenCV)-** Uploaded images are processed to enhance quality and normalize lighting, and K-means clustering identifies the dominant color. **Sound Selection (Pygame)-** The system selects soundtracks based on the detected dominant color and manages volume control. **Lighting Control (NodeMCU ESP8266)-** RGB values are sent to the microcontroller to adjust LED lighting to match the dominant color.	**Visual Output-** RGB LED lighting changes to reflect the analyzed dominant color, providing real-time visual feedback. **Auditory Output-** The selected soundtrack plays, synchronized with lighting adjustments. **User Interface Feedback-** Real-time preview of adjustments, along with error messages and help options for users.

Figure 1 Conceptual Framework

In the input stage, users interact with the system by uploading images through an intuitive application interface, which supports formats like JPEG and PNG.

In the processing stage, uploaded images undergo analysis using OpenCV and K-means clustering. OpenCV enhances image quality and normalizes lighting, while K-means clustering identifies the dominant color through iterative centroid stabilization. Based on the dominant color, the system selects a suitable soundtrack from a library using Pygame, managing volume control for seamless integration with existing audio hardware. Additionally, RGB values corresponding to the dominant color are transmitted

to a NodeMCU ESP8266 microcontroller, which adjusts RGB LED lighting to match the detected color

The output stage presents processed data through real-time visual and auditory feedback, with RGB LED lighting changing to reflect the dominant color and a soundtrack playing to enhance immersion. User interface feedback provides real-time previews and error messages, ensuring smooth navigation and troubleshooting for users.

Research Design

The study can significantly improve the output quality if the team has a defined and documented software paradigm. The team used Rapid Application Development (RAD) as the general method because its principles suit the team's

need for flexibility and quick iterations. This approach allows the team to rapidly prototype and refine the ideas in the development of a Sound and light immersion system with theThe study can significantly improve the output quality if the team has a application of artificial intelligence and image processing.
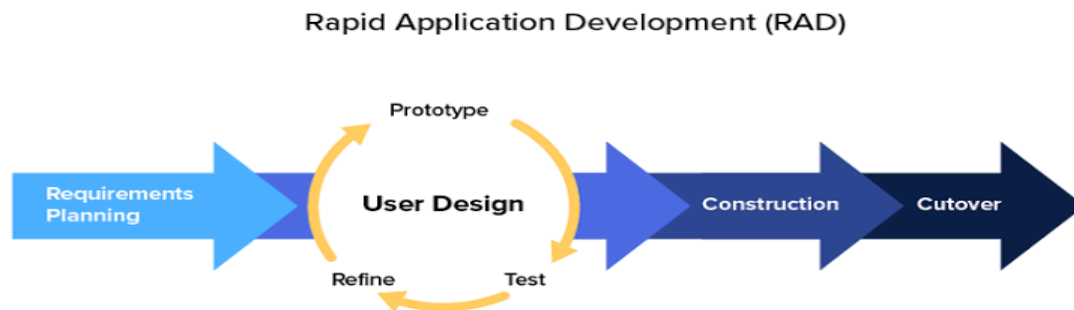

Figure 2. Rapid Application Development

Requirements Planning

The Requirements Planning stage is essential for defining the hardware and software requirements necessary for the development of "Sound and Light Immersion using Artificial Intelligence and Image Processing, implemented through the Rapid Application Development (RAD) methodology. This stage focuses on identifying the specific technical needs to support the system's functionality and performance.

1. **Requirement Specification**

Marketing Requirement	Engineering Requirement	Justification
1, 5	1	Provides an interface for the user to modify, insert, and remove data that the system will be using (soundtracks, images)
2	2	OpenCV provides a comprehensive set of tools for computer vision tasks and is designed to be highly efficient for real-time applications.
3	3	It is an affordable and capable variant of RGB lights with the functionality of changing RGB values based on outside input.
4	4	A collection of Python modules created to build video games that work across multiple platforms. It includes computer graphics and sound libraries, making it easy to create games and multimedia applications in Python.

Marketing Requirements

1. Can accept images.

2. Can identify the RGB value of the dominant color of an Image.

3. The device can display the RGB value as colors.

4. Display appropriate soundtrack based on the RGB values.

5. The user can manipulate the light and sound level.

Engineering Requirement

1. Utilize an application that serves as a terminal.

2. Make use of OpenCV to identify the dominant color of an image

3. Use a WS2812B RGB led strip to display the RGB values as color.

4. Use pygame python module for music handling.

Image Upload is needed for the system to function; thus, it must provide an intuitive application that allows users to easily upload images. It should support commonly used image formats such as JPEG and PNG to ensure compatibility and ease of use. This functionality is crucial for users to input the visual content that the AI will analyze and process to generate customized lighting. Users should have the ability to manually adjust sound and lighting settings through the interface. This feature will allow users to fine-tune the ambiance according to their personal preferences, ensuring a more tailored experience. Furthermore, the system must enable a preview of these adjustments so users can immediately see and hear the effects of their changes.

OpenCV is responsible for analyzing uploaded images and analyzing the dominant color. This color should be the prominent color and must take into consideration the lighting in the image. Accurate and detailed analysis is essential for the next step in the process, where appropriate soundtracks are played depending on the RGB combination. The system will match suitable soundtracks and lighting schemes. It will utilize a pre-existing library of sound and lighting configurations to find the match that reflects the image's dominant color.

The system should be capable of controlling the volume of the soundtrack. It must integrate seamlessly with existing audio hardware, ensuring that users do not need to make additional hardware modifications. The system should pass the dominant color to the Nodemcu ESP8266, adjusting color and intensity to align with the analyzed image's dominant color. The lighting effects should synchronize with the soundtrack to deliver a unified and immersive ambiance. This feature is crucial for achieving the desired level of user immersion.

The system must be compatible with widely available audio systems, minimizing the need for users to purchase specialized equipment. This broad compatibility ensures that the system can be adopted by a larger user base without significant additional costs. The system should process and analyze images within 3 seconds to provide a responsive user experience. Sound and lighting changes should be applied with less than 2-second latency to ensure close to real-time interaction and feedback. With regard to feedback, Users should receive meaningful error messages that help them understand and resolve issues. The Application interface should be intuitive and easy to navigate, ensuring that users can quickly learn how to use the system. Help should be readily accessible from the interface, providing users with guidance and support when needed.

User Design

User Design constitutes a critical phase within the framework of Rapid Application Development (RAD), focusing on the iterative creation and

refinement of prototypes based on continuous user feedback. This phase is paramount in ensuring that the "Sound and Light Immersion" system under development aligns closely with the operational needs and expectations of its intended users.
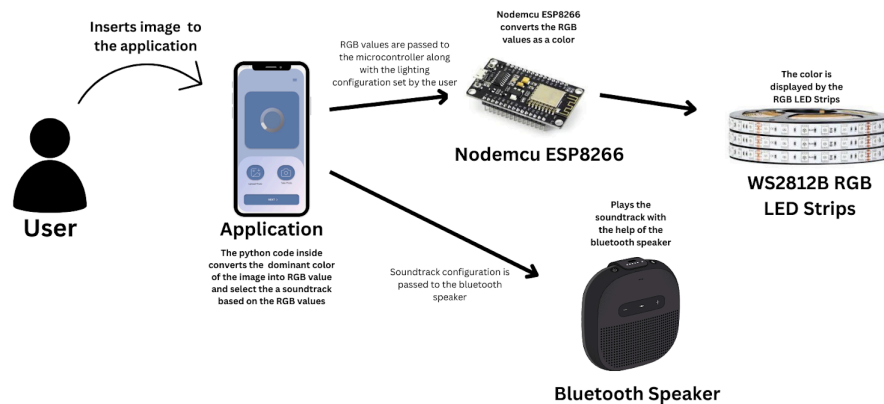

Figure 3. Components Interaction

The dominant color is identified using an Image Processing Module which is responsible for analyzing input images using advanced image processing techniques, in this case, the K-means clustering, and powered by the OpenCV library in Python, this module works by enhancing the image quality and normalizes lighting conditions, then determining the most prevalent color in the image. By enhancing the images first, the more accurate the color detection is across various lighting environments and image complexities.
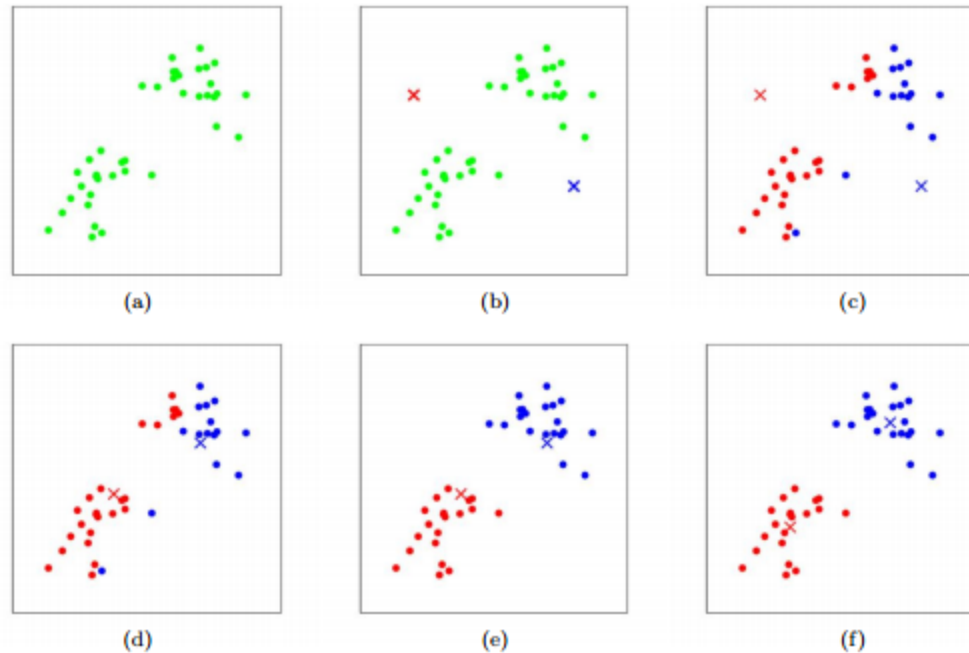
Figure 4. K-Means Clustering Process

In the figure above, the process begins as the centroids (X) are randomly selected from the color space. Each circle (function as a pixel however for the sake of better understanding it is considerably lessened) is then assigned to a centroid according on the Euclidean distance in the space, grouping similar colors together. After assigning all pixels to the nearest centroids, the centroids are recalculated as the mean position of all pixels within each cluster. This process of assigning pixels and updating centroids is repeated until the centroids stabilize, indicating convergence. The final centroids represent the dominant colors of the image. This method effectively reduces the color complexity of the image by highlighting the most significant colors.

The Nodemcu ESP8266 functions as the receiver of the RGB values from the Application to the hardware components of the system using microcontrollers. The RGB color values are transmitted to control the RGB LED. This interaction enables the real-time visualization of the detected dominant color, providing users with a tangible color representation of the analyzed image.

Simultaneously, the Sound Module contributes to the multi-sensory experience by selecting and playing soundtracks that best fit the detected dominant color. This module used the Pygame library in Python, orchestrating the integration of auditory stimuli with visual feedback. The RGB color values are connected to specific soundtracks, users can enjoy a personalized and immersive audiovisual experience tailored to the content of the analyzed image.

The application contains the Main program logic of the system, it is also the bridge between the software and the hardware by facilitating the input of images and the passing output that the hardware can then use. Python serves as the primary language for this logic, ensuring seamless integration with the rest of the components.
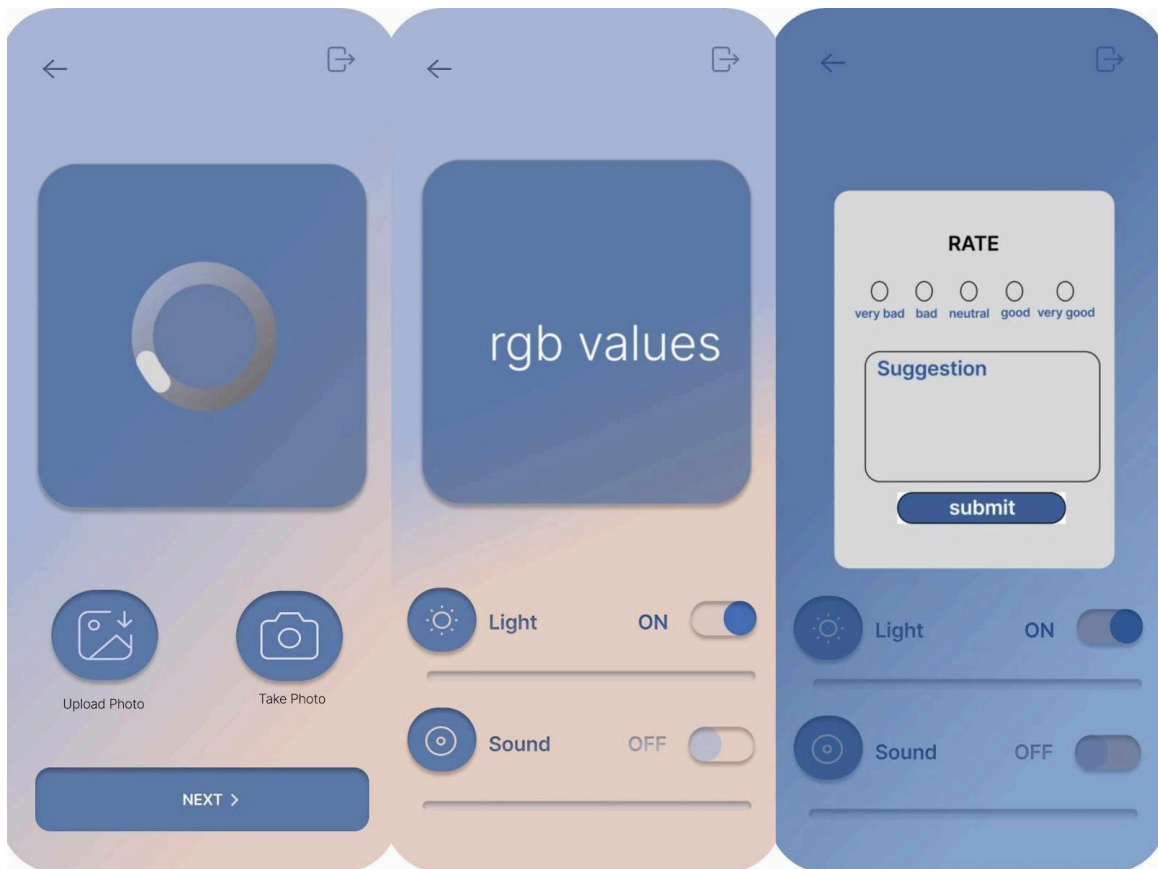
Prototypes

Figure 5. Application Screens

The initial screen of the system presents two distinct buttons: "Upload Photo" and "Take Photo." Upon clicking the "Upload Photo" button, users are prompted to select and upload an image from their device's local storage. This action allows users to utilize pre-existing images from their gallery or external sources. On the other hand, selecting the "Take Photo" button triggers the device's camera functionality, enabling users to capture a new image in real time using the built-in camera. This feature provides users with the option to instantly capture images without relying on pre-existing files.

After a photo is uploaded or taken, the system will process the image to extract the dominant color.

In the second screen of the system, users are presented with several interactive elements. Firstly, the screen displays the RGB (Red, Green, Blue) values extracted from the uploaded or captured image. This visual representation offers users insight into the dominant colors detected within the image. Additionally, two toggle switches are featured on the screen: one labeled "Light On" and the other labeled "Sound On." These switches provide users with control over the activation of lighting effects and sound playback within the system.

Furthermore, upon clicking the exit button on the top-left of the screen, users will be presented with a pop-up window for feedback. This pop-up consists of a rating system ranging from "Very Bad" to "Very Good," allowing users to rate their experience or satisfaction with the system. Below the rating options, there is a suggestion box where users can provide additional comments, feedback, or suggestions for improvement. This feature encourages user engagement and helps gather valuable insights for further enhancing the system.
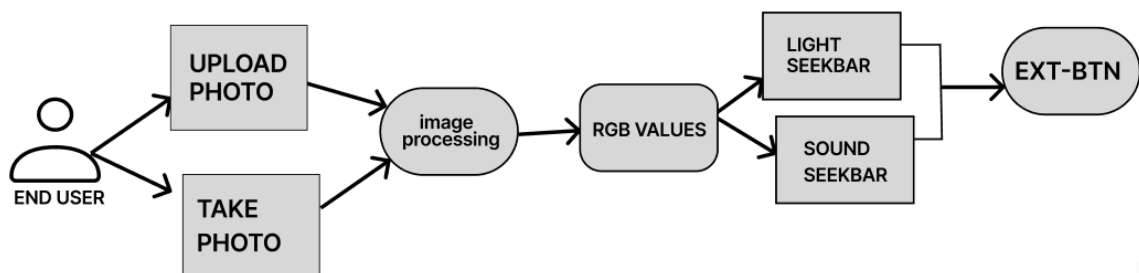

Figure 6: Use case diagram

Verification and testing

Testing the prototype is important to test each part of the system to identify as planned and whether the interactions between them are producing the right results. The testing phase will focus on Image Pathing, Image Processing, Color Accuracy, and Color Consistency

In the initial phase of testing, the image pathing is critically examined to ensure that images are properly obtained and processed by OpenCV. This process starts with uploading a sample image through the user interface. During this step, the system verifies that the image path is accurately relayed to OpenCV if an error message is not displayed. The successful relay of the image path confirms that the system can access and process the image without encountering errors. This step is crucial because it establishes the foundation for subsequent image processing tasks, ensuring that images are correctly uploaded, stored, and accessible. The image processing is tested, where the normalization and augmentation of images using OpenCV are tested. Multiple sample images are uploaded to verify consistency in processing. Normalization involves scaling pixel values to a common range, ensuring that all images have a uniform appearance, which is vital for accurate analysis. Augmentation includes transformations such as rotation and flipping, which enhance the robustness of the AI model by providing diverse variations of the images. This testing phase ensures that the system reliably preprocesses images, thereby improving the accuracy and effectiveness of the AI analysis and subsequent customizations in sound and lighting.

To validate the system's ability to accurately identify the dominant color in an image, the color accuracy component is rigorously tested. The detected dominant color is then visually compared with the expected color to ensure accuracy. This step is crucial because the identification of the dominant color directly influences the customization of soundtracks and lighting schemes. Accurate color detection ensures that the system produces relevant and aesthetically pleasing customizations. Finally, the color consistency of the system is tested to ensure that the system consistently produces the same dominant color result across multiple attempts. The same image is uploaded multiple times, and the color detection algorithm is run for each upload. The results are compared to ensure consistency to verify that the system can reliably reproduce the same results for the same input, which is crucial for maintaining user trust and satisfaction.

[1st Try]

```
PS C:\Users\acer> & C:/Users/acer/AppData/Local/Programs/Python/Python312/python.exe c:/Users/acer/PythonProj/colorDetection.py
Dominant color: RGB(70, 75, 33)
PS C:\Users\acer>
```


Converting Colors   ✏ Color Bucket 📖 Blog ☰ Lists ✏ Tools ▾ ⚙ Membership ⚙ About

RGB 70, 75, 33 color

RGB(70, 75, 33)   ▼   Convert

♥ Add this color to the bucket (0)   ✏ Share on Twitter   ✏ Share on Facebook   🖨 Download PDF

```
PS C:\Users\acer> & C:/Users/acer/Ap
Dominant color: RGB(70, 75, 33)
PS C:\Users\acer>
```

Image 1 (forrest.jpg)	RGB (70, 75, 33)

[2nd Try]
| ```
PS C:\Users\acer> & C:/Users/acer/AppData/Local/Programs/Python/Python312/python.exe c:/Users/acer/PythonProj/colorDetection.py
Dominant color: RGB(70, 75, 33)
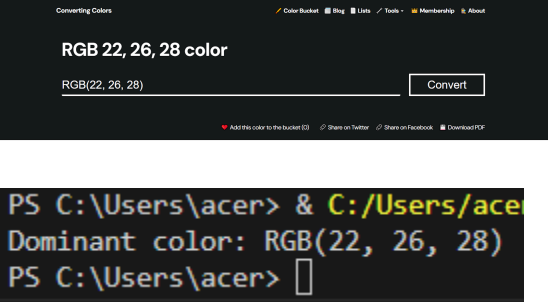PS C:\Users\acer> & C:/Users/acer/AppData/Local/Programs/Python/Python312/python.exe c:/Users/acer/PythonProj/colorDetection.py
Dominant color: RGB(70, 75, 33)
PS C:\Users\acer>
``` |


Image 1 (forrest.jpg)	RGB (70, 75, 33)

Unit Test ID	Component	Test Description	Expected Result	Status (Pass/Fail)	Date of Testing
1	Image Pathing	Verify if the image is properly	Images are properly	Pass	Thu, 12 Jun 2024

		obtained and processed by OpenCV	relayed to OpenCV		
2	Image Processing	Test images normalization and augmentation using OpenCV	Images are consistently normalized and augmented correctly.	Pass	Thu, 06 Jun 2024
3	Color Accuracy	Verify if the color is in the picture and likeness.	System produced the dominant color in the image	Pass	Thu, 12 Jun 2024
4	Color Consistency	The Color is Consistent throughout tries	System produced the same result	Pass	Thu, 12 Jun 2024

[1st Try]

```
PS C:\Users\acer> & C:/Users/acer/AppData/Local/Programs/Python/Python312/python.exe c:/Users/acer/PythonProj/colorDetection.py
Dominant color: RGB(22, 26, 28)
```

| Image 2 (hospital.jpg) | RGB (22, 26, 28) (Deep Dark Green) |

Unit Test ID	Component	Test Description	Expected Result	Status (Pass/Fail)	Date of Testing
1	Image Pathing	Verify if the image is properly obtained and processed by OpenCV	Images are properly relayed to OpenCV	Pass	Thu, 12 Jun 2024
2	Image Processing	Test images normalization and augmentation using OpenCV	Images are consistently normalized and augmented correctly.	Pass	Thu, 06 Jun 2024

3	Color Accuracy	Verify if the color is in the picture and likeness.	System produced the dominant color in the image	Pass	Thu, 12 Jun 2024
4	Color Consistency	The Color is Consistent throughout tries	System produced the same result	Pass	Thu, 12 Jun 2024

[2nd Try]

```
PS C:\Users\acer> & C:/Users/acer/AppData/Local/Programs/Python/Python312/python.exe c:/Users/acer/PythonProj/colorDetection.py
Dominant color: RGB(22, 26, 28)
PS C:\Users\acer> & C:/Users/acer/AppData/Local/Programs/Python/Python312/python.exe c:/Users/acer/PythonProj/colorDetection.py
Dominant color: RGB(22, 26, 28)
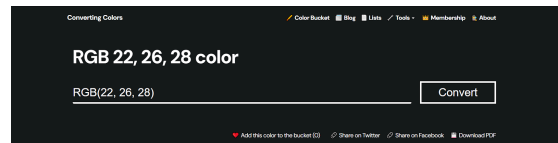PS C:\Users\acer>
```

	Converting Colors ✎ Color Bucket ☰ Blog ☰ Lists ✎ Tools ⌄ 🔳 Membership ℹ About **RGB 22, 26, 28 color** RGB(22, 26, 28) [Convert] ❤ Add this color to the bucket (0) ⬀ Share on Twitter ⬀ Share on Facebook ⬇ Download PDF Dominant color: RGB(22, 26, 28) PS C:\Users\acer> & C:/Users/ace Dominant color: RGB(22, 26, 28) PS C:\Users\acer>
Image 2 (hospital.jpg)	**RGB (22, 26, 28) (Deep Dark Green)**

Unit Test ID	Component	Test Description	Expected Result	Status (Pass/Fail)	Date of Testing
1	Image Pathing	Verify if the image is properly obtained and processed by OpenCV	Images are properly relayed to OpenCV	Pass	Thu, 12 Jun 2024
2	Image Processing	Test images normalization and augmentation using OpenCV	Images are consistently normalized and augmented correctly.	Pass	Thu, 06 Jun 2024
3	Color Accuracy	Verify if the color is in the picture and likeness.	System produced the dominant color in the image	Pass	Thu, 12 Jun 2024
4	Color Consistency	The Color is Consistent throughout tries	System produced the same result	Pass	Thu, 12 Jun 2024

```
import cv2
import numpy as np
from sklearn.cluster import KMeans
```

Figure 7.1 Libraries

In Figure 1.1 the cv2 package is imported which is the OpenCV Library an open-source library that contains many libraries and functions for computer vision and image processing making use of its function to read and manipulate images. NumPy is another library that is used for reshaping and manipulating pixel values, it is defined as np which will be a substitute name to use it. Lastly, we make use of the KMeans class of sklearn.cluster module which is a clustering algorithm that groups data points into a specified number of clusters by the distance between points respective cluster centers.

```
image = cv2.imread('C:/Users/acer/PythonProj/iruna.jpg')
pixels = np.reshape(image, (-1, 3))
```

Figure 7.2 Image pathing and manipulation

Figure 1.2 shows how the image is read with .imread, a function of OpenCV that loads the image as a multidimensional array (height[1000], width[1200], color channels[BGR]), where each pixel is represented by its BGR. An image is composed of pixels which is the product of the image's dimensions

(pixels = height × width). The color information for each pixel is a combination of Blue, Green, Red values from 0 to 255 (pixel=[B,G,R])

np.reshape(image, (-1, 3)) reshapes the image array into a 2D array called pixels. the -1 in the reshape function tells NumPy to automatically calculate the needed number of rows based on the image's original size. In this case, it flattens the dimensions (height and width) of the image into a single list of pixels, each with 3 color values (B, G, R).

```
SHAPE of image (183, 275, 3)
ELEMENTS of 'pixels' [[ 0  3  8]
 [ 0  3  8]
 [ 0  4  9]
 ...
 [ 6  6 12]
 [ 5  5 11]
 [ 5  5 11]]
LENGTH of 'pixels' 50325
```

Image Pixel Information

In the pixel array, every element is a pixel in the image and its color value, the total number of elements stored is 50325, this step is important for KMeans to analyze the dominant color without taking the location of pixels into

```
colorClusters = 5
kmeans = KMeans(n_clusters=colorClusters, random_state=0)
kmeans.fit(pixels)
```

Figure 7.3 KMeans Clustering

kmeans is an instance of KMeans, this initializes the clustering model. n_clusters is the number of colors the machine needs to extract from the image and random_state makes sure that the colors are consistent and will produce the same results with multiple tries.

kmeans.fit(pixels) assigns each pixel to one of the clusters, based on their BGR color values. The clustering process iteratively adjusts cluster centers to minimize the distance of the pixels and their cluster center, effectively grouping similar colors together. After fitting, the kmeans model contains information about the cluster centers (dominant colors) and labels for each pixel's assigned cluster

```
imageColors = np.array(kmeans.cluster_centers_, dtype='uint8')
colorPercentages = (np.unique(kmeans.labels_, return_counts=True)[1]) / pixels.shape[0]
color_info = zip(colorPercentages, imageColors)
```

Figure 7.4 Color Distribution

After getting the dominant colors, they are now stored in imageColors and convert the color value calculated with the proportion of pixels that belong to each color cluster into an integer. np.unique counts how many pixels were assigned to each cluster and then dividing by pixels.shape[0] normalizes these counts to get the proportion of pixels in each cluster, so the sum of all percentages will be equal to 1 (or 100%).

colorPercentage and imageColors are now then combined into a single object as color_info to be able to easily show the dominant color and its percentage of scope in the image.

```
for i, (percentage, color) in enumerate(color_info):
    print(f"Color {i + 1}: RGB {color[::-1]} - {percentage * 100:.2f}%")
```

Figure 7.5 Dominant Color Output

Using a for loop, the elements inside color_info is now then printed out, color is transformed to RGB while also showing its percentage.

Data Analysis Procedure

NumPy

NumPy also known as Numerical Python is an open-source library that provides an extensive framework for numerical computing in Python that include mathematical functions such as random simulations, statistical operations, and linear algebra. NumPy have many uses however what we utilized is NumPy's capability with multidimensional arrays and routines that enable efficient performance with various operations on arrays. NumPy was used to turn the 3-dimensional array which is a product of OpenCV into a 2-dimensional array to make sure each pixel is a data set with their BGR values in tow.

```
Image Pixels Information

SHAPE of image (183, 275, 3)
ELEMENTS of 'pixels' [[ 0  3  8]
 [ 0  3  8]
 [ 0  4  9]
 ...
 [ 6  6 12]
 [ 5  5 11]
 [ 5  5 11]]
LENGTH of 'pixels' 50325
```

In the pixel array, every element is a pixel in the image and its color value, the total number of elements stored is 50325, this step is important for KMeans to analyze the dominant color without taking the location of pixels into consideration.

OpenCV

OpenCV or Open-Source Computer Vision Library, is an open-source computer vision and machine learning library designed to enable computers to understand, analyze, and interpret visual information from the real world (OpenCV, n.d). Among the many uses of OpenCV is image manipulation which enables operations like resizing, cropping, rotating, and even changing color schemes, it can also represent the pixel of an image by its RGB value. In data collection, it serves as the eyes of the system capturing the image and presenting it as a 3d array (Height, Width, BGR).

Figure 8. OpenCV

KMeans Clustering

(Sherma, 2024) KMeans clustering is a type of machine learning that is under unsupervised learning using a pre-determined number of centroids to group similar data points together. It is used to divide a dataset into a predetermined number of clusters (K) to group together related data points. It was utilized by using NumPy to flatten the image's 3-dimensional array into a 2-dimensional array simplifying each pixel into as a single data point for clustering simplifying the color palette of an image by combining pixels of similar values. KMeans clustering follows a series of steps.

Initialization: This is the start and where centroids are randomly placed in the dataset that will act as the initial cluster centroids to affect surrounding data point with each centroid is a vector in the BGR color space, with initial values chosen from among the pixel colors.

Assignment: Find the distance between that point and each of the centroids and assign the data point to the cluster whose centroid is closest to it. To achieve this, we need to first calculate the distance between data point X and centroid C using Euclidean Distance metric with this formula

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$

Figure 9. Assignment to the nearest Centroids

Update centroids: Once all data points have been assigned to clusters, recalculate the centroids of the clusters by taking the mean of all data points assigned to each cluster and moving the centroid

$$C_i = \frac{1}{|N_i|} \sum x_i$$

Figure 10. Re-initialize centroids Formula

Repeat: continue the steps until the centroids no longer change significantly or when a limit set is reached

Result: Once the centroids remain still, the algorithm outputs the final cluster centroids and the assignment of each data point to a cluster.

Figure 11. K-Means Clustering Process

In the figure above, the process begins as the centroids (X) are randomly selected from the color space. Each circle (function as a pixel however for the sake of better understanding it is considerably lessened) is then assigned to the nearest centroid based on the Euclidean distance in the color space, grouping similar colors together. After assigning all pixels to the nearest centroids, the centroid's next position is

set as the mean position of all pixels within each cluster. This process of assigning pixels and updating centroids is repeated until the centroids show no change or the limit for repetition is reached. The final centroids represent the dominant colors of the image.

Population and Sampling

The study's target population consists of users familiar with ambient sound and light systems. Given constraints on large-scale testing, a small pilot group of

four participants was selected to represent a range of user familiarity, with two identified as novice users and two as expert users in ambient systems. These individuals were selected for their general technical background, enabling them to provide relevant insights into system usability without requiring extensive prior experience with similar systems.

The study used convenience sampling to recruit participants from colleagues and peers with varying levels of familiarity with ambient systems. This sampling method allowed the study to quickly gather feedback on the system's usability and functionality through a manageable and accessible group, facilitating the iterative refinement process. In addition to user sampling, the study also included image sampling, where participants selected images with dominant colors for the system to analyze. The images served as input for the system's lighting and sound adjustments, and each image was chosen to represent various real-world settings and visual aesthetics. These images were used to test the system's ability to adapt to different visual cues, ensuring its versatility and accuracy in delivering the desired ambiance.

The pilot group comprised four participants, divided evenly between novice and expert users (two participants per category). This sample size was chosen to allow for initial usability testing and feedback collection while remaining feasible given study constraints. Although small, this group provided critical insights for preliminary evaluation, enabling iterative improvements to enhance the system's user experience.

Data Collection Methods

Instruments

To gather data on the usability and effectiveness of the sound and light immersion system, the study used a combination of questionnaires and structured observation forms. The questionnaire included a mix of Likert-scale items and open-ended questions, designed to capture user feedback on system functionality, ease of use, and satisfaction with the immersive experience. The structured observation form allowed the researcher to record each participant's interactions with the system in real time, noting any usability challenges or areas of confusion.

Procedure

Data collection followed a structured, step-by-step process:

Participant Introduction: Each participant was briefed on the study's purpose and instructed on how to use the system. They were then given an overview of the tasks to complete, such as adjusting lighting and sound in response to different images.

Task Completion: Participants completed a series of tasks designed to test the system's capabilities, such as loading images for analysis, viewing the system's real-time adjustments, and providing feedback on each task.

Questionnaire Administration: Following the task completion, participants filled out a questionnaire, rating their satisfaction with system performance and offering suggestions for improvement.

Structured Observation: During each session, the researcher used an observation form to document participant actions, challenges, and notable reactions to specific features. This qualitative data helped identify areas for potential refinement in the system.

Data Compilation and Analysis: The responses from questionnaires and observations were compiled for analysis, focusing on common themes and insights that could inform iterative improvements to the system.

Pilot Study

A pilot study was conducted with four participants (two novice and two expert users) to identify initial usability issues and refine the data collection instruments. This preliminary phase aimed to assess the clarity of the questionnaire items and the effectiveness of the observation form in capturing relevant data. The pilot study findings revealed minor adjustments needed in both the system interface and questionnaire design, enhancing their clarity and alignment with the study objectives. These changes were implemented before conducting the main data collection.

Summary

This study employs Rapid Application Development (RAD) as its software paradigm to facilitate flexible and iterative prototyping, aligning with the objectives of quick refinement and adaptability in developing a sound and light immersion system. Powered by artificial intelligence and image processing, the system is implemented in Python, utilizing OpenCV for image processing and

KMeans clustering for data categorization and analysis. The research also integrates structured methods for population sampling and data collection, ensuring a solid data foundation to support testing and quality improvement. The iterative nature of this approach is central to the development process, allowing continuous enhancement and optimization of the system.

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