Jurnal Mantik,7 (2) (2023), ISSN 2685-4236 (Online)

IOCSCIENCE

Published by: Institute of Computer Science (IOCS)

Jurnal Mantik

Journal homepage: www.iocscience.org/ejournal/index.php/mantik

Color blind assistant app based on computer vision using openCV

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ARTICLEINFO

Article history:

Accepted Jun 30, 2023
Revised Jul 03, 2023
Accepted Jul 12, 2023

Keywords:

Android Application;
Computer Vision;
Object Color Detection;
OpenCV.

ABSTRACT

One of the health problems is color blindness. This disease is the inability to determine certain types of colors. The number of people with color blindness in Indonesia is increasing every year. Based on this problem, a color detection application was created to help color blind people based on computer vision. This application is made to be able to detect the color of objects in real-time using OpenCV library to detect color, taking objects using a smartphone camera. This application can detect an object moreover it can display color information in the form of sound from the smartphone. The color detection application aims to enhance the daily lives of color blind individuals especially in Indonesia by assisting them in perceiving and distinguishing colors in real-time, thereby promoting inclusivity and improving their overall experiences.

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1. INTRODUCTION

Human beings perceive color when white light interacts with objects and the reflected rays enter the eye. Within the retina of the eye, there are two types of light-sensitive cells known as rods and cones. Rods function effectively in low-light environments, aiding in night vision, while cones operate in daylight and are responsible for discriminating between different colors (Thoreson & Dacey, 2019). There are three distinct types of cone cells, each possessing varying sensitivities to different wavelengths of light. One type of cone primarily detects blue light, another is most responsive to green light, and the third is particularly sensitive to red light (Wright, 2022).

The majority of individuals with color vision deficiencies experience this condition due to genetic factors, typically inherited from their mother. However, certain people may develop color blindness as a result of underlying diseases such as diabetes or multiple sclerosis. Additionally, color blindness can manifest gradually over time due to factors such as aging or the usage of certain medications (de Saxe, 2022). Acquired color blindness, also referred to as color vision deficiency resulting from cerebral infarctions, is another potential cause (Selim et al., 2021).

It is worth noting that color blindness exists on a spectrum, with varying degrees of severity and specific color impairments experienced by different individuals. While some individuals may exhibit a complete inability to perceive certain colors, others may have partial deficiencies or struggle with distinguishing specific shades (Munk et al., 2023).

Researchers have made significant progress in developing aiding tools for color blind individuals. One such advancement is an application for interactive sonification of images designed for mobile devices, targeting the education of blind children at the elementary school level (Radecki et al., 2020). It proposes innovative sonification algorithms that convert color and grayscale images into sound, allowing blind users to explore and interact with image content through multi-touch gestures. Another notable contribution is compares true-color RGB and multispectral high-resolution orthomosaics obtained from unmanned aerial systems (UAS) for marine habitat mapping (Papakonstantinou et al., 2020) and then, SAR technology (GF-3 Pol-SAR images) is employed to accurately interpret geological structures beneath meadow coverings in different study areas (Tu et al., 2019), compensating for limitations in field surveying and remote sensing. Additionally, (Brosseau et al., 2020), it has proposed an algorithm that detects the color of objects and provides speech output accordingly. By training the system with different colors using RGB LED light intensities, it can accurately identify the color of a given image. They (Huang et al., 2020) also propose a disease recognition method for plant leaf images based on Neural Architecture Search (NAS) and Bayesian Optimization (BO) algorithm. The method automatically learns the optimal deep neural network architecture for plant disease identification. Experimental results demonstrate that the proposed method achieves high accuracy in recognizing plant diseases and can simplify the design process of network architecture, offering a promising approach for disease control strategies in agriculture.

The problem at hand is the limited ability of color-blind individuals to accurately perceive and discern different colors in their environment. Traditional assistive tools such as color-filtering glasses can be costly and may not always be practical or readily accessible. Hence, there is a need for an affordable, portable, and user-friendly solution that can assist color-blind individuals in real-time color perception.

Extensive research has been conducted in the field of computer vision and color perception aids for individuals with color vision deficiencies. Various studies have explored the use of image processing techniques and machine learning algorithms to enhance color perception for color-blind individuals. Additionally, the advancements in smartphone technology and image processing libraries like OpenCV have opened up new possibilities for developing assistive applications.

Our proposed approach involves leveraging the capabilities of OpenCV, an open-source library with powerful computer vision algorithms, to develop a Color Blind Assistant App. The app will utilize the smartphone's camera to capture live video or images, which will then be processed in real-time using image analysis techniques. By applying appropriate color correction algorithms and enhancing color contrast, the app will assist color-blind users in perceiving colors more accurately.

The research on the Color Blind Assistant App based on computer vision using OpenCV has important implications for both the field of computer vision and healthcare. In terms of computer vision, the research advances the accuracy of color detection algorithms, contributing to the development of more sophisticated computer vision systems for various applications. In the realm of healthcare and assistive technology, the app provides a practical solution to assist color-blind individuals, enhancing their quality of life and promoting inclusivity. The findings from this research can inspire further advancements in assistive technology and bridge the gap between technology and healthcare, benefiting individuals with visual impairments and disabilities.

2. RESEARCH METHOD

The development and evaluation of the Color Blind Assistant app in this research utilize the system development life cycle methods. The first step is conducting a literature review to gather information from various written sources such as books, journals, and papers. The review focuses on topics related to color blindness, including types of color blindness and color combinations that cannot be distinguished by color-blind individuals. Additionally, materials related to the Android platform and computer vision algorithms are studied to ensure a comprehensive understanding.

The next step involves requirement analysis, where the structure of the OpenCV algorithm is designed. This algorithm includes converting frames from the BGR color format to the HSV color format, defining color boundaries for upper and lower ranges of each color, dilating colors to eliminate image noise, performing bitwise operations to identify specific colors, and creating contours for each color to display the detected colored regions (Mohibullah et al., 2022).

Following the requirement analysis, the application design phase begins. Based on the findings from the literature review and the analysis, the design of the color detection object application is determined. This phase involves identifying the features to be implemented, designing the application interface, and selecting the computer vision algorithm to be utilized (Sigut et al., 2020).

The development phase of the Color Blind Assistant App involves translating the finalized design into functional code using Kotlin programming language and tools like Android Studio and PyCharm. The developers write code to incorporate the OpenCV algorithm for computer vision tasks and ensure that the code follows best practices and coding standards. Rigorous testing is conducted throughout the development process to identify and resolve any bugs or issues.

By translating the design into functional code, the developers aim to create an application that accurately detects colors and provides assistance to individuals with color blindness. The development phase requires expertise in programming and Android app development, and it involves careful implementation and testing to ensure the application functions as intended (Abdelhamid et al., 2020).

After the application development is complete, the testing phase is carried out. This phase aims to identify and rectify any errors or issues that may arise in the application. Testing is conducted in three stages: code quality testing, functionality testing, and usability testing for the end-users. By conducting thorough testing, the developers ensure that the application functions correctly and meets the users' needs (Martinez-Alpiste et al., 2022).

From the research methods mentioned above, a color detection camera app based on computer vision using an OpenCV system is designed. A novelty approach of speak the text of the color detected is also proposed.

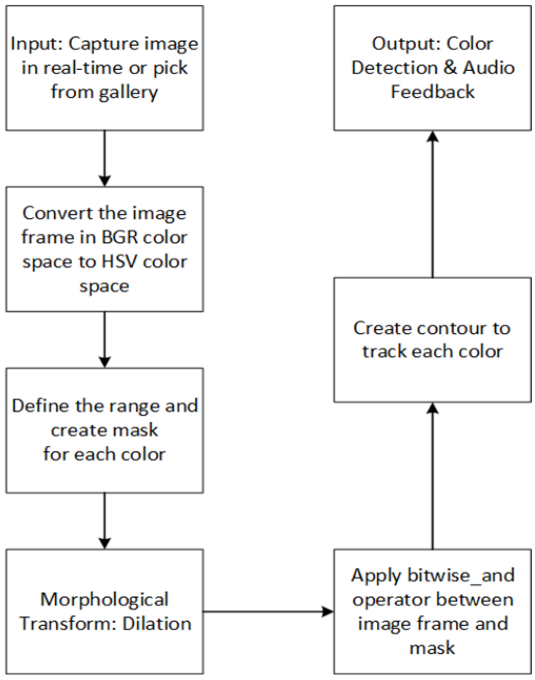

Figure 1. Work Flow of Proposed Color Detection System

The flowchart in the detailed Figure 1, can be explained as follows (Arali et al., 2021).

a. Input: Capture image in real-time or pick from gallery

To start the image processing process(Juneja et al., 2021), the first step is to record visual content using the built-in camera and the user's device video recording capabilities. The camera that opens captures the surrounding conditions in real-time, like recording a video. Users can also detect color by picking an image from the camera or gallery on the user's device.

b. Convert the image frame in BGR color space to HSV color space

Convert the image frame in BGR (RGB color space represented as three matrices of red, green and blue with integer values from 0 to 255) to HSV (hue-saturation-value) color space (Chakravorty, 2020). Hue describes a color in terms of, saturation represents the amount of gray color in that color, and value describes the brightness or intensity of the color. This can be represented as three matrices in the range of 0-179, 0-255 and 0-255, respectively.

c. Define the range and create a mask for each color

Defining the range of each color and creating the corresponding mask serves the purpose of isolating specific colors or color ranges in an image. This allows selectively processing or analyzing regions of interest based on their color characteristics. By defining the lower and upper bounds of a color range in HSV color space, we can create a binary mask that marks the pixels falling within that color range as white (255) and all other pixels as black (0) (Dody et al., 2019).

d. Morphological Transform: Dilation

This process enhances or enlarges the boundaries of foreground regions in a binary image or mask, removes noise, closes gaps, and modifies objects or regions' shape or size in a binary image (Liu et al., 2019). Dilation works by scanning through the binary image and replacing each pixel with the maximum value within its neighborhood, defined by a structuring element. The structuring element specifies the shape and size of the neighborhood around each pixel. The maximum value is assigned to the pixel if any of the neighboring pixels within the structuring element have a value of 255 (Zhao et al., 2020).

e. Apply the bitwise_and operator between the image frame and mask

A bitwise AND between the image frame and the mask can be used for background removal or extraction. By creating a mask that identifies the color range of the background, the bitwise AND operation will zero out the pixels corresponding to the background, effectively removing it from the image frame (Lazarus et al., 2022).

f. Create a contour to track each color

Creating contours around color regions allows us to separate and identify objects based on their color properties. Contours provide a way to detect and segment individual objects or regions in an image based on color characteristics (Kylili et al., 2021).

g. Output: Color detection and audio feedback

Figure 2. Android OpenCV Color Blind App Design

After all processes are complete, the screen on the smartphone will display the image processing data and it comes with audio feedback of the color, as shown in the following Figure 2 (Annapoorani et al., 2021).

3. RESULTS AND DISCUSSIONS

In this paper, the detection of colors relies on a predefined range of HSV values, with Table 1 presenting the specific HSV ranges used for reference.

Table 1. The range of HSV color space used in this research.

Color	HSV Lower Range	HSV Upper Range
Red	160, 87, 50	180, 255, 255
Red2	0, 87, 50	5, 255, 255
Purple	132, 87, 50	156, 255, 255
Orange	6, 150, 50	22, 255, 255
Green	35, 43, 46	77, 255, 255
Blue	86, 100, 65	131, 255, 255
Yellow	23, 93, 0	33, 255, 255
Gray	0, 0, 70	180, 20, 120

Once an object’s color falls within the range of HSV values provided in the table above, the detection system will identify the object and proceed to the subsequent stage, which involves further analysis for color recognition.

Figure 3. Screenshot of Android OpenCV for Color Detection: (A) Detecting red plastic; (B) Detecting orange tote bag; (C) Detecting purple eyeglasses case; (D) Detecting green bottle.

Experiments are applied using a mid-cost Oppo A31 smartphone powered by Octa-core 2.3GHz processor with 6GB RAM. It runs on Android 9 Pie. The device is tested using seven different objects. Tests were carried out on several types of colors and lighting levels.

In Figure 3, the test was carried out with four objects and different color types: red, orange, purple, and green. It can be seen that the system succeeded in detecting the types of colors in objects A, B, and D, even though object B detected two different colors. Whereas object C in Figure 3 cannot detect the color correctly, which should be purple, but what is detected is instead red. Purple colors can sometimes be visually similar to other colors, such as blue or red, it can vary depending on factors such as lighting conditions, camera settings, and the specific shades of purple you detecting. Tests were carried out from several types of colors and lighting levels. To see all the results obtained can be seen in Table 2.

Table 2. All color of object detection result.

Color	Lighting (lux)	Result
Red	10	Detected
	30	Detected
	50	Detected
Purple	10	Undetected
	30	Undetected
	50	Detected
Orange	10	Detected
	30	Detected
	50	Detected
Green	10	Detected
	30	Detected
	50	Detected
Blue	10	Detected
	30	Detected
	50	Detected

Yellow	10	Detected
	30	Detected
	50	Detected
Gray	10	Detected
	30	Detected
	50	Undetected

From the data, it can be observed that the color red was consistently detected across all lighting intensities (10 lux, 30 lux, and 50 lux). This suggests that the detection system effectively identified the presence of the color red regardless of the lighting level. In contrast, the color purple showed different outcomes based on the lighting conditions. At 10 lux and 30 lux, the color purple was undetected, indicating that the detection system struggled to recognize this color under lower lighting intensities. However, at 50 lux, the color purple was successfully detected. This suggests that the detection system had a higher sensitivity to the color purple under brighter lighting conditions (Kwong, 2020).

On the other hand, colors such as orange, green, blue, yellow, and gray were consistently detected across all lighting conditions. Regardless of the intensity (10 lux, 30 lux, or 50 lux), the detection system was able to identify these colors accurately. The findings from this table provide valuable insights into the interaction between different colors and lighting conditions in relation to the detection system's performance. It highlights the importance of considering lighting conditions when designing color detection systems to ensure reliable and accurate results. It also emphasizes the variability in the detectability of different colors based on the lighting environment.

Table 3. Calculations Recall, Precision, F-Score, Accuracy on different color

	Precision	Recall	F1-Score	Accuracy
Red	1.00	1.00	1.00	1.00
Orange	1.00	1.00	1.00	1.00
Yellow	1.00	1.00	1.00	1.00
Green	1.00	1.00	1.00	1.00
Blue	1.00	1.00	1.00	1.00
Purple	1.00	0.90	0.95	0.90
Gray	1.00	0.60	0.75	0.60

Based on Table 3, the color detection system was evaluated using 20 sample photos with different angles and different lighting levels for each color. The results showed excellent performance for the colors Red, Orange, Yellow, Green, and Blue, with perfect precision, recall, F1-score, and accuracy scores of 1.00. These colors were accurately detected in all instances across the sample photos. The color Purple achieved a precision of 1.00 but had a slightly lower recall of 0.90, resulting in an F1-score of 0.95 and an accuracy of 0.90. The color Gray exhibited lower recall and accuracy rates of 0.60, indicating some challenges in its detection. Gray colors can sometimes appear similar to other colors, especially when the shades or brightness levels are close. This similarity might result in misclassifications or confusion between gray and other colors, leading to a lower accuracy. Overall, the system demonstrated high accuracy and effectiveness in detecting most colors, while highlighting potential areas for improvement, particularly for colors with lower recall and accuracy values such as Gray (Qiu et al., 2019).

4. CONCLUSION

From the result of research and discussion, the Color Blind Assistant App, powered by computer vision and OpenCV, shows great potential in addressing the challenges faced by individuals with color blindness. By utilizing advanced image processing techniques, the app offers real-time color analysis, correction, and enhanced differentiation, effectively assisting users in perceiving colors despite their visual impairments. User testing and evaluations have validated the app's effectiveness, usability, and positive impact on the lives of color blind individuals. Through continuous user feedback and iterative design improvements, the app can be customized to better cater to the specific needs and preferences of its users. The integration of computer vision algorithms and OpenCV has played a crucial role in developing a reliable and efficient color correction system, enabling accurate color detection and providing real-time assistance in various color-related tasks.

The Color Blind Assistant app based on computer vision using OpenCV offers significant advancements in assisting color-blind individuals. Future research can focus on refining the app in two key areas. One area of research involves enhancing the accuracy and robustness of color detection. This can be achieved by leveraging advanced computer vision algorithms and machine learning techniques to improve the app's performance under different lighting conditions and object textures. Additionally, further exploration can be done to refine color classification algorithms and ensure accurate color detection in real-time scenarios. User-centered design principles can also be employed to enhance the app's user interface and overall user experience, making it more intuitive and user-friendly for color-blind individuals.

Another area of research can be the expansion of the app's capabilities to provide additional features and functionalities. For example, researchers can explore incorporating object recognition algorithms to assist color-blind users in identifying and distinguishing objects based on their colors. Moreover, integration with other assistive technologies, such as wearable devices or augmented reality, can enhance the app's functionality and provide a more immersive experience for color-blind individuals. By focusing on these areas of research, the Color Blind Assistant app can be further improved to better cater to the needs of color-blind individuals and provide them with valuable support in perceiving and interacting with colors in their daily lives.

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