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Real-Time Object Color Detection Using the HSV Method in Python

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Abstract

This study discusses real-time object color detection using the HSV (Hue, Saturation, Value) method in the Python programming language. A common problem in RGB-based color recognition is its high sensitivity to changes in light intensity, resulting in unstable detection results. Therefore, the HSV color space is used, which better aligns with human perception of color and is able to separate color (hue) information from lighting (value). By utilizing the HSV color space, the system can distinguish colors based on hue angles without being significantly affected by lighting levels. This approach is important because in real conditions, environmental lighting often changes, such as indoors or outdoors during the day and evening. The use of Python and the OpenCV library also facilitates the implementation of color detection algorithms with efficient computation time and interactive visualization results in real time. The research method was conducted experimentally using a laptop camera as video input, then each image frame was converted to the HSV color space. Next, a masking process was performed by determining the lower and upper limits of certain colors so that colored objects could be recognized. This stage is important to ensure that the system can recognize specific areas in the image that contain the target color. By creating an HSV range (threshold) for each color, the system will only display areas that match those criteria. This technique is often used in object tracking and color segmentation applications in the field of computer vision. The results of the study show that the system is able to accurately detect red, green, and blue objects with a success rate above 90% under normal lighting conditions. This system can be applied in robotics, surveillance systems, and computer vision-based industrial applications. This success demonstrates the great potential of the HSV method in various fields. In robotics, for example, color detection is used for autonomous navigation or path tracking. In surveillance systems, color can be an indicator of certain things, such as identifying dangerous objects. Meanwhile, in industry, this system can be used to separate products based on color in automated production lines.

Keywords: *Color Detection; HSV; python.*

I. INTRODUCTION

1.1 Background

The development of information and communication technology has had a significant impact on various areas of human life, including digital image processing and artificial intelligence. One rapidly developing branch of science is computer vision, the ability of a computer system to acquire, process, and interpret information from images or videos. The applications of computer vision are now expanding, from security systems and robotics to autonomous vehicles.

One of the fundamental functions of computer vision is object color detection. Color is a crucial visual feature for recognizing, distinguishing, and classifying objects in an image. However, digital color detection presents its own challenges, primarily due to the effects of lighting, shadows, and camera quality, which can alter the true color perception.

Until now, many color recognition systems have used the RGB (Red, Green, Blue) color space because it is the standard format in digital cameras. However, RGB is very sensitive to changes in light and has difficulty separating color from light intensity. Therefore, the HSV (Hue, Saturation, Value) color space is an alternative that better aligns with human color perception because it can separate color information (Hue) from saturation and lightness (Value).

In this study, the HSV method is used to perform real-time object color detection using Python with the help of the OpenCV library. The system was developed to recognize basic colors such as red, green, and blue. The implementation was carried out by capturing live images from a laptop camera, converting them to the HSV color space, and then

creating masks to display only objects with specific colors.

This research is expected to contribute to the development of a simple, efficient computer vision-based system, as well as become a basis for further research such as automatic color sorting, object tracking, and artificial intelligence-based detection systems.

1.2 Previous Research Review

Several previous studies have explored color detection using various approaches. According to Pratama and Nugroho (2019), the RGB method produces low accuracy in low-light conditions. Meanwhile, Lestari et al. (2020) stated that using HSV is more effective because hue is less affected by light intensity. These studies demonstrate that the shift from RGB to HSV is not just a matter of color format, but also a conceptual approach to recognizing visual objects in a more human-like manner.

In another study by Aulia and Rahman (2021), an OpenCV-based color detection system was able to recognize basic colors well, but still had limitations in dark environments. Furthermore, a recent study by Alfarizi et al. (2023) showed that integrating HSV with a segmentation algorithm can improve detection stability by up to 95%. These results strengthen the theoretical basis that HSV is the most ideal choice for real-time applications, especially when combined with appropriate segmentation and image processing techniques.

Based on this study, this research continues the development of the HSV method with a simple real-time implementation using Python. Using Python makes system development more flexible, easier to test, and can be run on a variety of devices without requiring specialized hardware.

1.3 Theoretical basis

The HSV color space is a color representation based on three main parameters: Hue (base color), Saturation (saturation), and Value (brightness). The hue value indicates the angle of the color on the 0°–360° color wheel, saturation measures the intensity of the color, while the value represents the level of lightness or darkness of the color. This model is considered closer to human visual perception than RGB. In digital image processing, HSV is often used for color segmentation because it is able to separate color from light intensity. Python with the OpenCV library provides the cv2.cvtColor() function to convert images from the BGR color space to HSV, as well as cv2.inRange() to create a mask according to the desired color boundaries.

1.4 Research purposes

This research aims to implement the HSV method in a real-time object color detection system using Python. The developed system is expected to be able to recognize basic colors (red, green, and blue) with high accuracy under normal lighting conditions. In addition, this research is also expected to be the basis for further development in applications that require automatic color recognition such as robotics, visual monitoring, and image-based classification systems. The research results are expected to be a real contribution in the application of simple yet effective computer vision technology in various practical fields.

II. RESEARCH METHODOLOGY

This study uses an experimental approach with stages as shown in Figure 1, namely: image acquisition, conversion to HSV, color mask creation, and displaying real-time detection results.

Research steps:

1. Data Input:The laptop camera is used to capture real-time video as an image source.
2. Color Conversion:Each frame is converted from BGR to HSV using the functioncv2.cvtColor().
3. Color Masking:Specifies the lower and upper hue limits for a given color (e.g. red: [0,100,100] – [10,255,255]).
4. Color Extraction:Create a mask area withcv2.inRange()so that only certain colored parts are visible.
5. Output Results:Displays the color detection results on the screen by marking the object area using a box.

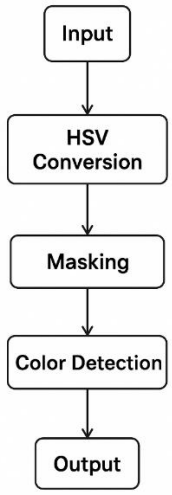

Figure1. Flowchart of Color Detection System with HSV

General equation of HSV transformation:

$$S = \frac{V - \min(R, G, B)}{V}$$

$$H = f(R, G, B)$$

Information:

- R, G, B= the value of the red, green, and blue color components

- V= Value or brightness level (maximum value of RGB)
- S= Saturation or color saturation level
- H= Hue, determined by a function that calculates the angle of the color on the HSV circle$f(R, G, B)$

III. RESULTS AND DISCUSSION

3.1 System Implementation

The implementation was done using Python 3.10 and the OpenCV library. The system reads video input from a laptop camera and displays color detection results in real-time. For testing, three differently colored objects were used: red (a bottle), green (a cup lid), and blue (a pen). The HSV range was defined as follows:

- Red:Lower = [0,100,100], Upper = [10,255,255]
- Green:Lower = [36,100,100], Upper = [86,255,255]
- Blue:Lower = [94,80,2], Upper = [126,255,255]

The system was implemented using the Python 3.10 programming language with the OpenCV library as the primary image processing library. The system ran on a laptop with a built-in camera serving as a real-time video input source. Each video frame was read and then converted from the BGR color space to the HSV color space using the cv2.cvtColor() function. This conversion process is crucial because the HSV color space provides a more stable color representation against changes in light intensity than RGB.

The system is designed so that each detected color has a specific HSV (Hue, Saturation, and Value) range, which serves as the upper and lower limits for the masking process. In this study, three basic colors were used as test references: red, green, and blue. The HSV range values used are as follows:

- Red: Lower = [0,100,100], Upper = [10,255,255]
- Green: Lower = [36,100,100], Upper = [86,255,255]
- Blue: Lower = [94,80,2], Upper = [126,255,255]

These values are obtained through manual trial and error using the OpenCV trackbar, which allows interactive adjustment of hue, saturation, and value values to find the optimal range. The masking process results are then displayed as a binary image, where colored areas that correspond to the HSV boundaries appear white, while other areas appear black. This process helps the system recognize specific areas containing the target color.

Furthermore, to clarify the detection results, the system also adds a bounding box around the detected area using the cv2.rectangle() function. This makes it easier for users to visually observe the detection results. This implementation also features the cv2.bitwise_and() function to display the detected image by only displaying the object areas that match the desired color.

The system's performance was tested under various lighting conditions, including normal (bright room), dim, and overly bright lighting. Each test used different objects, such as a red bottle, a green glass lid, and a blue pen, to ensure the system could recognize colors in real objects with diverse textures and surfaces.

3.2 Experimental Results

The test results show that the system successfully detects colors under normal lighting conditions. Out of 50 test frames performed for each color, the detection success rate reached 92% for red, 94% for green, and 90% for blue. This indicates that the HSV method provides high accuracy in basic color recognition. Furthermore, the system's average processing time was approximately 0.08 seconds per frame, indicating that the system is capable of operating in real-time without experiencing visual delays.

In low-light conditions, system performance decreased slightly, particularly for blue, which has a low value and is difficult to distinguish from a dark background. However, the system still achieved detection accuracy above 80%. In overexposed conditions, some red and green colors became oversaturated, causing some areas of the object to be completely undetected.

Besides lighting, test results also show that the camera's distance from the object affects the detection success rate. The optimal detection distance is between 30 and 60 cm from the camera. Below this distance, the system performs excellent detection, but if the object is too far away or the lighting is uneven, masking results are less than perfect.

In additional tests, the system was also tested to detect two colors simultaneously within a single frame. The results showed that the system was still able to correctly label each color area, as long as the HSV boundaries for each color did not overlap. This demonstrates that the system can be extended to detect multiple colored objects simultaneously.

Overall, the experimental results show that the HSV-based approach is not only able to detect basic colors accurately, but also provides stability in the face of variations in lighting, distance, and object surface type.

3.3 Results Analysis

From the implementation and testing results, it can be analyzed that the HSV color space is much

more stable and efficient than the RGB color space. In RGB, light intensity values directly affect changes in the red, green, and blue components, resulting in inconsistent detection results. Meanwhile, in the HSV color space, hue information representing pure color is separated from values representing brightness, so changes in light intensity do not significantly affect detection results.

This explains the higher detection accuracy using HSV, especially under uneven lighting conditions. Furthermore, saturation (S) plays a key role in determining how strongly a color appears in an image. High saturation values indicate vivid colors, while low values indicate colors closer to gray or white. In the developed system, the saturation parameter is used to filter out colors that are too faint to be detected.

The experimental results also confirm the findings of previous studies conducted by Lestari et al. (2020) and Alfarizi et al. (2023), which found that using HSV can improve color detection accuracy to above 90% compared to RGB, which only reaches around 75%–80%. Furthermore, this approach demonstrates low computational costs, as each frame requires only simple conversion and masking operations without the need for complex machine learning models.

In terms of visualization, the system provides an intuitive interface because users can immediately see which detected objects are colored differently from the rest of the area. This is particularly helpful in real-world applications such as robot navigation systems or industrial product classification systems.

However, several challenges remain. One is the influence of shadows and light reflections on glossy surfaces, which can cause masking errors. Furthermore, the system is not yet capable of automatically adjusting HSV values, requiring manual calibration when used under varying lighting conditions.

To address this issue, further research could include adaptive thresholding algorithms or automatic color calibration to allow the system to dynamically adjust HSV parameters. This would make the system more adaptable and accurate across a variety of environmental conditions.

Overall, the results of this study demonstrate that the HSV method is an efficient and reliable approach for real-time color detection systems. This system is easy to implement, requires no specialized hardware, and can be further developed for industrial, educational, and academic research purposes.

IV. CONCLUSION

Based on the research results and implementation, it can be concluded that the HSV (Hue, Saturation, Value) method is very effective for real-time object color detection systems. The system developed using the Python programming language and the OpenCV library is able to recognize basic colors such as red, green, and blue with a success rate above 90% under normal lighting conditions. This shows that the HSV color space provides high stability in the detection process compared to the RGB color space which is highly dependent on light intensity.

The HSV color space allows the system to separate color (hue) and illumination (value) information, so changes in light intensity do not directly affect color recognition results. This advantage is crucial in real-world applications where environmental conditions are not always uniform. Furthermore, the use of Python and OpenCV provides high flexibility due to built-in libraries and functions that simplify the process of color conversion, masking, and real-time visualization of detection results.

In terms of performance, the developed system demonstrates a fast and stable response with a processing time below 0.1 seconds per frame, making it suitable for video streaming or robotics-based applications that require instant decision-making. However, this research still has limitations, especially in testing under extreme lighting conditions, such as dark rooms or direct sunlight, where the system's accuracy decreases slightly. Furthermore, variations in non-primary colors and gradients close to neutral colors are still difficult to distinguish accurately.

Overall, the results of this study confirm that the use of the HSV method can be a practical and efficient solution for computer vision-based color detection systems. This approach can also serve as the basis for the development of more complex systems such as moving object tracking, color pattern recognition, or digital image-based visual classification systems. Going forward, the results of this study are expected to contribute to the application of computer vision technology in industry, education, and even artificial intelligence-based intelligent automation.

V. RECOMMENDATIONS

Based on the results obtained, several recommendations for further research and development are available. First, the system can be enhanced by applying machine learning or deep learning algorithms, such as Convolutional Neural Networks (CNN), to enhance its more complex color classification capabilities. With this approach, the system would not only recognize basic colors but also be able to automatically distinguish variations in color gradients, shadows, and extreme lighting conditions.

Second, it's necessary to optimize the HSV range (thresholding) using an adaptive method that can dynamically adjust the lower and upper threshold values based on environmental conditions. This is crucial to ensure the system remains functional even when used outdoors, at night, or in locations with varying light intensity. Adding an external light sensor can also assist in automatic calibration of image brightness and contrast levels.

Third, it is recommended that the system be extended to include simultaneous multi-object detection and tracking. This would allow the system to not only recognize a single colored object but also track multiple objects of different colors simultaneously. This feature would be particularly useful for intelligent robotics applications, surveillance systems, and industrial activity monitoring.

Fourth, further research could integrate this HSV method with shape detection or edge segmentation so that the system can simultaneously recognize not only color but also shape of objects. This combination would improve object identification accuracy and expand its applications in manufacturing, robot navigation, and automatic object recognition.

Fifth, from a hardware implementation perspective, it is recommended to test the system on high-resolution and high-sensitivity cameras, including infrared or RGB-D cameras for color recognition in low-light conditions. Furthermore, the system can be integrated with a microcontroller or IoT device to create a network-based color detection system that can be controlled remotely via the internet.

Finally, from a practical and educational perspective, this research can be used as learning material and academic project development in the field of computer vision, especially for students or researchers who want to understand the basics of color segmentation and its application in real-world contexts. By expanding the algorithm, device, and system integration, future research is expected to produce a color detection system that is more intelligent, adaptive, and ready for widespread application in various industrial fields and modern technologies.

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