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A Specific Marker Approach to Improve Object Recognition in Bullet Launchers with Computer Vision

Umar Ali Ahmad[1,6*], Wildan Panji Tresna[1,2], Iyon Titok Sugiarto[2], Mera Kartika Delimayanti[3], Fahmi Charish Mustofa[4], Mohammad Reza Faisal[5] and Reza Rendian Septiawan[1]

[1]School of Electrical Engineering, Telkom University, Bandung, Indonesia
[2]Research Center for Photonics, National Research and Innovation Agency, South Tangerang, Banten, Indonesia
[3]Departement of Computer and Informatics Engineering, Politeknik Negri Jakarta, Depok, Indonesia
[4]National Land Agency, Regional Office of Central Java Province
[5]Computer Science Department, Lambung MangkuratUniversity, Banjarbaru, Indonesia
[6]Collaborative Researcher, Kanazawa University, Kanazawa, Ishikawa, Japan

Corresponding author: Umar Ali Ahmad (e-mail: umar@tekomuniversity.ac.id).

ABSTRACT Computer vision's ability determines the accuracy of object recognition. This study tested the camera's ability to recognize both passive and active markers using LEDs. A specific active marker is analyzed using blinking on the LED. One of the factors to consider when choosing a specific marker is the value of the duty cycle accuracy. The proposed system is confirmed by implementing an integrated control system and the hardware to develop a specific marker. The result shows that the commercial camera can recognize all colors used as the test markers. Here, a specific marker was improved in the bullet launcher system due to tracking, identifying, detecting, marking, locking, and shooting a target precisely. Generally, image processing obtained the comparison of the time to speed the process, the higher the pixel resolution, the longer the time. When the object moves at a certain speed, the camera can detect several marker shapes, such as circles, squares, and triangles. The result shows that a circle marker gives a higher accuracy at every speed level. In the duty cycle variation test, when the duty cycle value is set to 50%, the best accuracy is obtained when the red LED is used, with the accuracy value obtained reaching 96%. In the LED test, it is also found that the effect of light affects the color detection results on the LED. Moreover, using the highest accuracy results from the LEDs at the implementation stage would be very good.

INDEX TERMS Computer Vision, Object Recognition, Markers, Duty Cycle.

I. INTRODUCTION

Technological advances in visual data processing leading to computer vision significantly impact human development in today's modern era. Current technological advances cannot be separated from the need and efforts to develop computers that are far more sophisticated than before and even resemble humans [1-3]. The application of computer vision is more directed at recognizing objects like a vision in the human eye, such as recognizing visual objects and physical characteristics and identifying the characteristics of an object. Object recognition is a method applied to computer vision, where the principle of its work is to imitate the human eye to detect a recognized object [4][5]. There are several benefits related to the use of object recognition methods. One of the object recognition applications is detecting specific targets based on the color and shape of the object, as well as various other scientific parameters. This component can be applied to smart instruments, especially bullet launchers.

In an object recognition system, color is one of the main parameters in recognizing the target to be detected [6][7]. The color in an object can be easily distinguished using a certain recognition system. However, under normal conditions, the intensity of the surrounding light will affect the color. In conditions of over and under exposure, the color of an object will be faint, so the device or machine is difficult to detect the color precisely [8-10]. Therefore, using the color filter will be optimal in environmental conditions with the proper light conditions. Several other methods are still needed for an optimal object recognition system to obtain a specific object recognition.

In the development of this system, a camera with an image processing device is used to capture an object. The quality of the camera itself will limit the ability to capture objects visually. However, along with the development of technology, the capabilities of existing cameras are getting better and much more sophisticated, even though the camera's abilities cannot reflect precisely like the human eye.

Specific object recognition will be based on filter methods through OpenCV. Here, OpenCV is a software library intended for processing dynamic images in real-time, and its development began with Intel [11]. Here, the use of OpenCV is based on established usage, so many libraries support this research process. OpenCV is used for passive target markers; object recognition capabilities are obtained by color filtering, shape contour, filter size, or camera pixels. Also, OpenCV is often used for security, surveillance, traffic monitoring, navigation, and human-computer interaction [12-14]. As for active target markers, we propose light source encoding. Here, active markers can be very useful in extreme ambient light intensity, low light conditions, or overexposure conditions. These methods will be combined and matched according to their use and application to obtain an optimal recognition of objects moving horizontally and vertically [15].

Active specific markers are built from Pulse Width Modulation (PWM) signals to create blinking LEDs. LED is one of the lighting sources with very low power consumption[16], [17]. LEDs have different characteristics, such as the accuracy of the duty cycle based on color wavelength. Before an LED can emit light, it needs current to flow through. The higher the current flows in the LED, the brighter the light. However, it should be noted that the amount of current allowed is 12mA - 20mA and at a voltage of 1.2V - 3.6 V according to the character of the wavelength. When the current flow is more than 20mA, perhaps the LED will burn [18]. Changing the electric current on an LED according to a specific pattern at a particular time can produce LED blinking [19-21].

Furthermore, this research purposes to develop unique markers without distractions with a PWM control mechanism to create encoding light. This study will contribute to the optimization of unique markers without distraction. Moreover, it describes the characteristics of the variant of LEDs for an object recognition system that employs a blinking laser as a unique marker. The results of this study are expected to contribute as follows:

a. Novelty is achieved by integrating LED blinking as a unique marker in the object recognition system.
b. Providing an understanding of the performance of unique markers by PWM signals in object recognition systems.
c. Providing analysis of the characteristics of red, blue, green, and yellow LEDs implemented in the object recognition system. This can make it easier to read unique markers in various ambient light conditions.

II. METHODOLOGY

The Specific objects are objects that are specifically selected to be detected from the shape and characteristics of the object [22], [23]. The selection of specific objects makes it easier for the system to classify objects based on their characteristics. Classifying objects requires the application of several object recognition methods with computer vision, which aims to provide an understanding of the machine to recognize specific objects. The following flowchart is a system that detects an object.

The description of the system workflow in Figure 3 is as follows. First, the camera will be tested to determine whether it functions correctly and can be detected. If the camera is working correctly, then the camera can recognize objects. The resulting image or video from the RGB camera will be converted to Hue-Saturation-Value (HSV). Next, the value of the upper and lower limits on HSV is determined, which is used to mask the selected color detected on an image. Following this masking, the color area is determined, and the object looks for contours. The next stage is to determine the object's shape by using the number of angles from each shape obtained using the approximation function and calculating its area using the contour Area function provided by *OpenCV*. From the result of the c*ontour Area* function, we can determine the smallest and largest objects by comparing the area of each object.

The analysis continues to test object detection on the LED, which is controlled using Arduino Uno. If the system can detect the object, it will be delayed. In contrast, it will get a delay-off. The calculation process for duty cycle, delay time, and accuracy is carried out from the delay value on and off. The final stage is to display the calculation results on the monitor screen.

A. OBJECT RECOGNITION

Detection of objects using markers is one of the easiest methods of detection. Markers are artificial objects that are designed to be easily recognized and identified. Markers are markers at known positions or sizes, serving as reference points or measures for other objects.

This work uses a camera with image processing software OpenCV to recognize the targets. Meanwhile, a Galvano Mirror is used to steer the laser beam. Galvano mirror is a pair of devices consisting of a mirror, motor, and encoder [24]. A web camera is used to identify the target. This camera can capture images with a resolution of 1280 × 720 pixels for 30 fps and a 55° angle of view. The camera also needs a specific program to recognize the object intended as the target. The target in this research is a dynamic (moving object). In this case, the shape and size of the target, recognized by the camera, might slightly change when it moves.

The development of OpenCV in object-specific recognition is based on proven methods. Hierarchically, it can be classified in color filtering to filter out specific colors as various shapes and sizes of objects. Then the filtering results from the color filtering will be continued in the shape and contour filter to select only specific colors and shapes that the camera will detect. Moreover, the last is the pixel size used to choose an object of a particular size.

Regarding the recognition processes, the color filtering method classifies the object. Then, the filter size is a method used to detect objects based on the large area of an object. The large area of the object caught by the camera
can be taken from the contourArea() function in OpenCV. As shown in Eq. (1)-(4), this function will return the integer area value of each detected object. The mathematical calculation used to calculate the area of an object is to use the Green's theorem. [25].

$$\oint P\,dx + Q\,dy = \iint_D \frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\,dA$$

$$\oint_{\partial D} -Q\,dx + P\,dy = \iint_D \frac{\partial Q}{\partial x} - \frac{\partial p}{\partial y}\,dA \qquad (1)$$

where P and Q are functions with continuous partial derivatives on an open region containing. By entering dimension limits on the x-axis and y-axis,

$$\oint_{\partial D} P\,dx + Q\,dy = \int_{b_1}^{b_2} Q(a_2, y) - Q(a_1, y)\,dy - \int_{a_2}^{a_1} P(x, b_2) - P(x, b_1)\,dx \qquad (2)$$

solving equations using the basic theorem of calculus,

$$Q(a_2, y) - Q(a_2, y) = \int_{a_1}^{a_2} \frac{\partial Q}{\partial x}\,dx,$$

$$P(x, b_2) - P(x, b_2) = \int_{b_1}^{b_2} \frac{\partial P}{\partial y}\,dy \qquad (3)$$

Therefore,

$$\oint_{\partial D} P\,\mathrm{d}x + Q\,\mathrm{d}y = \int_{b_1}^{b_2}\int_{a_1}^{a_2} \frac{\partial Q}{\partial x}\,dx\,dy - \int_{a_1}^{a_2}\int_{b_1}^{b_2} \frac{\partial P}{\partial y}\,dy\,dx$$

$$= \int_{a_1}^{a_2}\int_{b_1}^{b_2} \frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\,dx\,dy$$

$$= \iint_D \frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\,dA \qquad (4)$$

Green's theorem is generally used in solving two-dimensional flow integrals. In the case of size filters in object recognition, Green's theorem is usually applied to determine the area and center of a plane simply by integrating the circumference.

Moreover, the size filter affects other segmentations, such as color filtering and contour shape. When the camera captures two objects with the same color but different sizes, only one object is detected according to the specified size. On non-homogeneous objects, this system calculates the area of each object individually, where non-homogeneous objects will be detected as two different objects and have dissimilar contours based on each object's known contours, which will be calculated using the green theorem.

One of the problems encountered is when performing object recognition on several almost identical objects with different sizes. Therefore, an experiment was conducted by drawing three triangular objects with the same shape and color but different sizes so that the system is expected to be able to detect objects with an area value returned by the contourArea() function between 5000-6000 pixels.

Color filtering is a digital image processing technique based on selected colors, as shown in FIGURE 1. The system will detect the specified color and ignore colors that are not needed. Moreover, two color classifications are applied to compare each existing color classification based on RGB and HSV values.

The RGB color model is the most common in color image processing. RGB has three color spaces: red, green, and blue. Each RGB pixel has a value range from 0 to 255. The HSV value is the value of the color content contained in the color. Value has a range from 0 to 1. When the value is 0, the color will be black, whereas if the value is 1, the level of black content in the color will disappear. To get the HSV color model, it is necessary to convert the object color from RGB to HSV using Python programming [26].

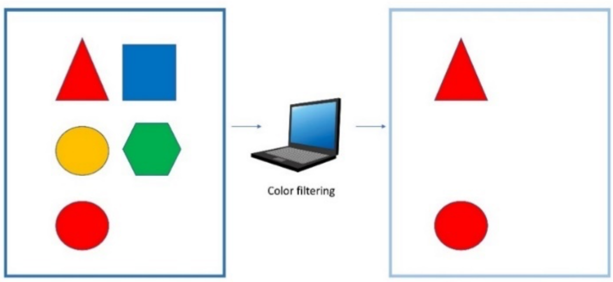

FIGURE 1. Selecting color to filter mechanism. Moreover, it can be applied in shape and size filter mechanism

B. CHARACTERISTIC OF LED BLINKING

The modulation makes the specific markers of the LED PWM signal. Here, light is generated when electricity is run through the semiconductor [27]. The most convenient method for LED dimming without altering the current is the Pulse-Width-Modulation (PWM). A driver and LED response times are two factors limiting the shortest PWM pulse duration. Usually, a manufacturer clearly states the driver's response time. LED manufacturers are generally unaware of the need for faster LED response times. Typically, it is fast enough to satisfy dimming requirements. Commercial LED manufacturers usually do not specify the response time. Therefore, the analysis was needed to evaluate the current state of the response time of visible light LEDs.

Moreover, a microcontroller controls the LED to show the continuous or blinking light, as shown in FIGURE 2. Meanwhile, an Arduino Uno will control the motor and issue a PWM. In addition, the Arduino Uno can adjust the blinking signal with the various frequency and duty cycles. Furthermore, for the optimum condition, the maximum speed of the duty cycle on LED depends on the speed rate of the spectrometer.

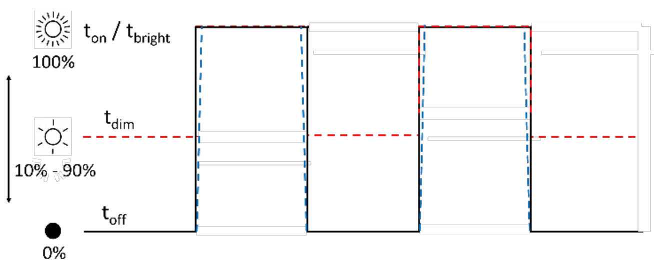

FIGURE 2. The PWM of laser blinking consists of the t_{on}/t_{bright}, t_{off}, and t_{dim}. Microcontrollers could control all modes.

This work has characterized and analyzed LEDs of various colors regarding their resolution and precision values. The colors used in this experiment are red, yellow, green, and blue. First, the LED has a 50% duty cycle, which means that in the blinking system, the length of time it turns on is the same as the length of time it turns off, and the PWM signal is analyzed. The duty cycle is calculated in this experiment by t_{on} = 1 second and t_{off} = 1 second, as shown in Eq. (5). [28-29].

$$Duty\ cycle = \frac{t_{on}}{(t_{on} + t_{off})} \quad (5)$$

Therefore, the duty cycle correction value for the color LED can be calculated by comparing the input and output duty cycle cycle values.

III. EXPERIMENTAL SETUP

The LED variant consists of red, green, blue, and yellow colors. Here, a specific color of blinking LEDs forms the target marker. The web camera's ability will also be optimized so that it is about the color of the commercial LED and the shape and size of markers. Then, Arduino as a microcontroller will be connected to a PC as a power source for Arduino and LED controllers.

The Arduino pin is connected to each LEDs, thus providing power to the LED, making it turn on and off according to the program on the Arduino IDE. Furthermore, the webcam camera will detect the color produced by the LED, as shown in FIGURE 3, then provide a contour on the edge of the object and perform calculations to determine the value of the duty cycle on the LED with the help of the Python program. Furthermore, the monitor screen displays the result.

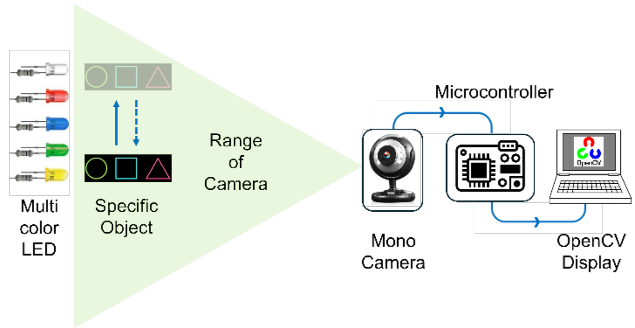

FIGURE 3. The experimental set up of multicolor LED as a unique marker. The system consists of a mono camera, microcontroller, and computer.

IV. RESULT

In this study, we emphasize characterizing several types of LEDs as unique markers for object recognition systems. In object recognition using cameras, multicolor LEDs with specific colors must adjust several parameters to facilitate object recognition related to color processing, RGB, and HSV configurations. The experimental results of the comparison of the use of these configurations are shown in TABLE 1. However, the HSV model results are better than those of the RGB model compared to color filtering using RGB. The nature of the HSV model emphasizes perceptual variance in the hue saturation value of image pixels. The color segmentation obtained from HSV provides better object identification than that produced by the RGB. The color quality of RGB is influenced by the intensity of light that has not been predicted [30].

TABLE 1
The Range of Each Color in RGB and HSV

	RGB color configuration		HSV color configuration	
Color	HSV Low	HSV High	HSV Low	HSV High
Red	[87,0,0]	[255,80,104]	[137, 54, 0]	[255, 255, 255]
Green	[0,101,0]	[154,255,96]	[0, 74, 49]	[138, 255, 166]
Blue	[0,0,175]	[175,168,255]	[32, 39, 167]	[119, 255, 255]
Yellow	[100,153,0]	[255,255,103]	[0, 21, 150]	[41, 255, 227]

Therefore, the implementation of color segmentation in object recognition is shown in FIGURE 4. FIGURE 4 shows that later color filtering will filter each color from several colors provided. The color filtering method tests using images containing various object shapes and colors. However, what is focused on here is only classifying red. Meanwhile, the comparison of RGB and HSV configurations was tested in a red color filter, as shown in FIGURE 5. The measurement results show that the HSV configuration can detect the selected color according to the available object shape. The HSV configuration recognizes all object shapes in the selected color and even provides identification (edge lines)

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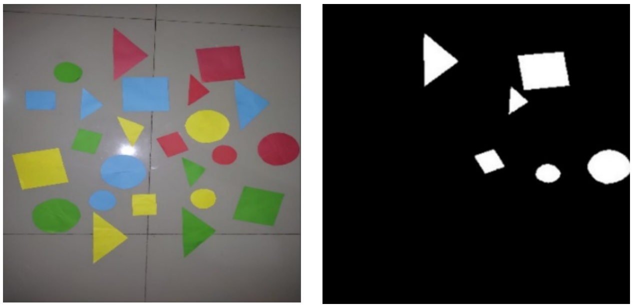
according to the object's shape. The default color filtering experiment results using the HSV color model are better than those of the RGB color model.



(a) (b)

FIGURE 4. Shape and color image (a) original image. (b) result of the masking object after the red color filter.

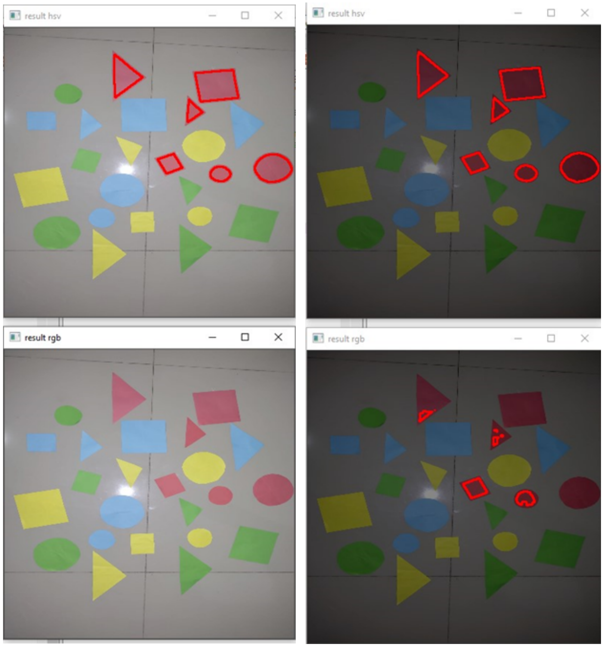


FIGURE 5. Comparison between RGB (below) and HSV (upper) in Color Filter, (left) after added lighten 57, (right) after subtraction lighten 132.

Henceforth, the author uses the HSV configuration in every further testing activity. Meanwhile, FIGURE 6 shows the results of experiments where the system processes color filters at different resolutions. The color filter process will take longer if the results are more significant than the resolution. The smaller the resolution, the faster the color filter process.

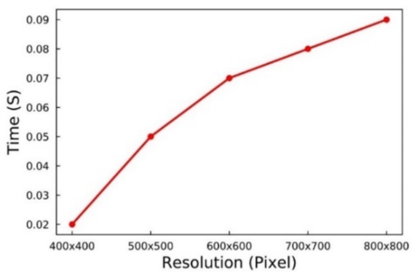


FIGURE 6. Time comparison with resolution size to speed the process.

Therefore, segmentation in object experience can also be reviewed from the shape of the detected object. This stage can be combined with color segmentation hierarchically or stand-alone. Testing the success of the detector requires several testing techniques, such as recognizing objects of the same type and characteristics or even searching for an object of a different type. This test is carried out to determine the system's success in classifying certain types of objects. Therefore, the examiner uses several samples of homogeneous objects and heterogeneous objects. In the image below, the default system must be able to recognize one object to detect a specific object.

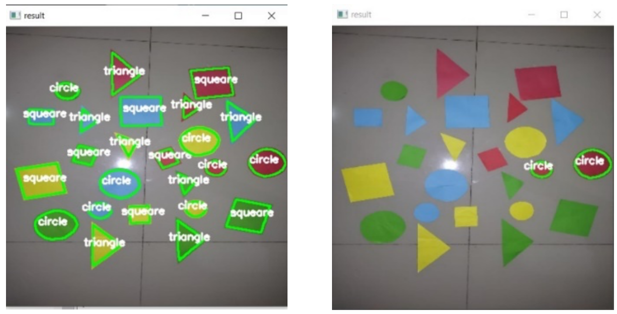


FIGURE 7. Shape filtering of all objects and all colors (left) shape filtering for circle object with red color only (right).

Contour only detects the object's edges so that the contour will resemble the object's shape. However, the question is, what if the object is of a different shape but has the same characteristics, such as the same color. The value of HSV is also very influential in finding the object's contour. In this case, the value is sought to determine the shape and color of a particular object (FIGURE 7).

Furthermore, by using the same detection object after going through the color and shape segmentation stages of the object, pixel segmentation can be carried out to identify the size of the detected object. The filter shape is also carried out as in a trial to detect moving boxes, triangles, and circles, where objects will be moved from the far-left corner to the far-right corner with a distance of 50 cm and with six-speed levels. These try to determine the camera's ability to detect the object Moving. Based on the results of the experiments obtained, the object of the circle has a high level of accuracy at each level of speed compared to box-shaped objects and triangles.

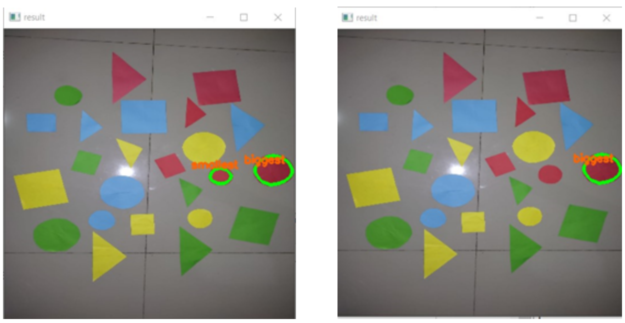


FIGURE 8. Before pixel filter (a) after pixel filter (b).

The pixel filter will filter the shape based on the most significant object size. It aims to obtain a more accurate detection quality. Figure 8 shows the filtering size results, and FIGURE 8 shows the results before the object filtering process.

In testing multi-colored LEDs, using a 50% duty cycle calculation, which means that the length of time the LED is on and the length of time the LED is off is the same, it can be seen that the longer the on and off time will result in increased object recognition accuracy. As shown in FIGURE 9, the four colors have different wavelengths, resulting in different precision values. It can still be seen in the same table that the variations in the duration of t_{on} and t_{off} are carried out to see the maximum speed that the photodetector can capture. When the t_{on} and t_{off} are getting smaller, which means the blinking speed is increasing, the correction value is also increasing.

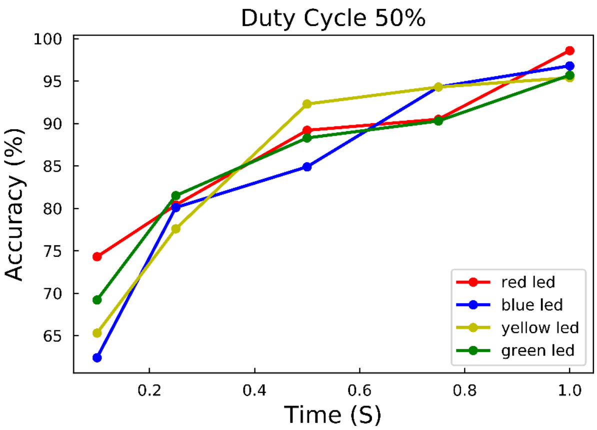


FIGURE 9. The correlation between time and accuracy with 50% duty cycle

Meanwhile, testing was also conducted using moving objects at speeds from 0.1 m/s to 2 m/s on several forms of objects. The goal is to test the camera's capabilities with frames per second of 15 fps at a distance of less than 2 meters that has been armed with a programming language for object recognition. The test results in TABLE 2 show that the detection accuracy that describes the quality of object recognition decreases along with the increased speed of motion of the detected object. Dynamic testing like this will be very useful when this system is implemented in a computer.

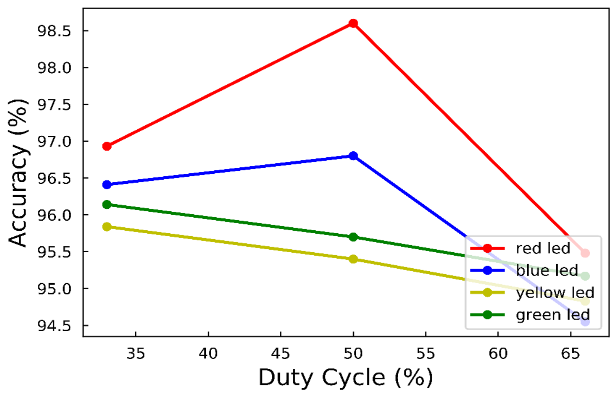


FIGURE 10. The correlation between duty cycle and accuracy.

Meanwhile, FIGURE 10 shows that the testing of duty cycle variants affects object recognition accuracy. The experimental results show that increasing the length of the tone time does not necessarily increase the accuracy of object recognition. In the comparison of the same on and off time in one blink, it gives a greater accuracy value than other time comparisons.

TABLE 2
Testing moving object at a certain speed

Speed (m/s)	Object	Detected	Undetected	Accuracy (%)
0.1 m/s	Circle	88	18	83.02
	Triangle	83	14	85.57
	Square	87	22	85.57
0.2 m/s	Circle	41	14	74.55
	Triangle	31	16	65.96
	Square	44	16	65.96
0.5 m/s	Circle	18	3	85.71
	Triangle	12	7	63.16
	Square	17	4	63.16
0.67 m/s	Circle	11	3	78.57
	Triangle	11	8	57.89
	Square	11	4	57.89
1.0 m/s	Circle	10	3	76.92
	Triangle	7	5	58.33
	Square	8	4	58.33
2.0 m/s	Circle	5	1	83.33
	Triangle	5	2	71.43
	Square	5	2	71.43

V. DISCUSSION

Object recognition with a mono camera is done without machine learning. Several stages that must be passed in order to maximize identification include color segmentation, which has been tested on RGB and HVS configurations. In this case, the author interprets that each pixel in the camera sensor used responds to various colors caused by the base color and is sensitive to color depth, brightness level, and background brightness. Meanwhile, with the help of the OpenCV library, there is sometimes bias in objects with the same color but different shapes and sizes. So that the application of shape and size segmentation is carried out in order to optimize object recognition. Combining the three segmentations makes a powerful formula in object recognition with cameras and OpenCV.

Meanwhile, object recognition with cameras and OpenCV cannot work optimally in extreme light conditions. So, the author continues learning about the intervening object, namely LEDs, which are known to be easy to control and have low power consumption. Using LEDs based on basic colors, namely red, green, and blue, added yellow as additional data in understanding their characteristics. With the same voltage input, the measurement of the light intensity that can be propagated on each LED produces red which has the highest accuracy value in the object recognition system with a mono camera and OpenCV. mean

Previous research results [15][18][28-29] show that LEDs that are continuously turned on will consume power continuously, can potentially cause heat, and reduce the lifetime of the LED material, so this study proposes using LED dimming with PWM signal control. Several accuracy values discussed previously are greatly influenced by the type of color and LED material used and the selected duty cycle value. A duty cycle of 50% shows the highest accuracy value in object recognition, and this is because objects that flash with a long on-and-off time are more accessible to recognize. When the duty cycle is gradually decreasing, the accuracy of the duty cycle decreases. The smaller the duty cycle, the toff is higher than a ton, the duty cycle's accuracy drops significantly. Due to the photo detector's response, these phenomena are also affected by the speed ratio (t_{on} and t_{off}). Meanwhile, the duty cycle data after 50% show no significant accuracy shift. Therefore, a 50% duty cycle is a more straightforward form of PWM signal and gives a higher accuracy of the duty cycle.

The weakness of the target marker system using LED is that the light is too bright; the dominant color will be white with the ambient basic color, thus creating a significant contrast difference. This situation makes recognizing the target difficult for the object recognition system. Meanwhile, The PWM signal of LED does not form a perfect pulse square signal, this will microscopically affect the resulting power distortion and different response times. Apart from that, the power consumption of an LED to emit light has received challengers with lower power consumption, such as organic LEDs, etc. Another thing that still needs attention is that the color rendering index of an LED intensity spectrum cannot be obtained at a single wavelength.

Finally, the PWM LED will be dim and bright to see if the system can recognize the LED object. Since the red LED has the best accuracy, the dim light PWM test only tests the red LED. This test is performed when the LED is bright, dimmed, and dim.

V. CONLUSION

The aim of this research is to build an integrated system that is capable of producing, reading, and analyzing a specific marker. LED characteristics are analyzed by testing the PWM signal and its accuracy value. In another section, the ability of commercial cameras is tested in identifying various objects (color, shape, size) and recognizing LED flashes as specific markers. It is hoped that the integration of these two systems can become a specific target marker and monitoring system. Motion speed tests in 3D are important for further research. Several test scenarios were carried out to find the best accuracy of the specified duty cycle. The red LED achieved the best accuracy at 50% duty cycle with an accuracy of 96%. In the future, using LEDs as target markers opens good opportunities in various strategic fields, including the military, such as implementation in sniper weapons.

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REFERENCES

[1] A. Samuel, K. Gunadi, and J. Andjarwirawan, “Fitur Pengkategorian Otomatis dari Gambar Berbasis Web dengan Metode SURF dan Haar Cascade Classifiers.,” J. Infra, vol. 5, no. 2, pp. 243–249, 2017.

[2] Silica Kole et al. “SURF and RANSAC: A Conglomerative Approach to Object Recognition.” International Journal of Computer Applications, vol. 109, no.4, pp. 0975-8887, 2015.

[3] Chen, C., Chen, Q., Xu, J., Koltun, V., 2018. Learning to see inthe dark. In: Computer Vision and Pattern Recognition (CVPR),2018 IEEE Conference

[4] E. R. Davies, Computer Vision: Principles, Algorithms, Applications, Learning: Fifth Edition. 2017.

[5] M. Ramalingam, et al.. “A Comprehensive Analysis of Blockchain Applications for Securing Computer Vision Systems,” IEEE Access, 2023, Vol. 11, Page 107309.

[6] S. Sergyán, “Color Content-based Image Classification,” Image (Rochester, N.Y.), pp. 427–434, 2007.

[7] Szabolcs Sergyan, “Color histogram features based image classification in content-based image retrieval systems,” IEEE Xplore, 2008, doi: 10.1109/SAMI.2008.4469170

[8] A. Patil, T. Chaudhari, K. Deo, K. Sonawane, and R. Bora, “Low Light Image Enhancement for Dark Images,” Int. J. Data Sci. Anal., vol. 6, no. 4, p. 99, 2020, doi: 10.11648/j.ijdsa.20200604.11.

[9] Jung, C., Yang, Q., Sun, T., Fu, Q., Song, H., 2017. Low lightimage enhancement with dual-tree complex wavelet transform.J. Vis. Commun. Image Represent. 42, 28–36.

[10] Everingham, M., Eslami, S. A., Van Gool, L., Williams, C. K.,Winn, J., Zisserman, A., 2015. The pascal visual object classeschallenge: A retrospective. Int. J. Comput. Vis. 111, 98–136.

[11] F. Sindy, “Pendeteksian Objek Manusia Secara Realtime Dengan Metode MobileNet-SSD Menggunakan Movidius Neural Stick pada Raspberry Pi,” p. 77, 2019.

[12] B. Micusik and T. Pajdla, “Simultaneous surveillance camera calibration and foot-head homology estimation from human detections,” Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit., no. June, pp. 1562–1569, 2010, doi: 10.1109/CVPR.2010.5539786.

[13] C. Beleznai and Horst Bischof, “Fast Human Detection in Crowded Scenes by Contour Integration and Local Shape Estimation,” IEEE Xplore, pp. 2246-2253, 2009.

[14] H. G. Schantz, “A real-time location system using near-field electromagnetic ranging,” IEEE Antennas Propag. Soc. AP-S Int. Symp., no. July 2007, pp. 3792–3795, 2007, doi: 10.1109/APS.2007.4396365.

[15] H. Adinanta, H. Kato, A. W. S. Putra, and T. Maruyama, “Enhancement of beam tracking response using color filtering method for optical wireless power transmission,” AIP Conf. Proc., vol. 2256, no. September, 2020, doi: 10.1063/5.0022440.

[16] E. F. Schubert, “Light-emitting diodes,” 1993.

[17] G. Leschhorn and R. Young, “Handbook of led and ssl metrology, instrumentation system,” GmbH, 2017.

[18] W. P. Tresna, U. A. Ahmad, R. R. Septiawan, I. T. Sugiarto, and A. Lukmanto, “Encoding LED for Unique Markers on Object Recognition System,” vol. 12, no. 12, pp. 678–683, 2021.

[19] L. Svilainis, “LED directivity measurement in situ,” Meas. J. Int. Meas. Confed., vol. 41, no. 6, pp. 647–654, 2008, doi: 10.1016/j.measurement.2007.09.003.

[20] J. Biswas and M. Veloso, “Depth camera based indoor mobile robot localization and navigation,” Proc. - IEEE Int. Conf. Robot. Autom., pp. 1697–1702, 2012, doi: 10.1109/ICRA.2012.6224766.

[21] Poppinga, N. Vaskevicius, A. Birk, and K. Pathak. Fastplane detection and polygonalization in noisy 3D rangeimages. In IROS 2008
[22] T. K. Gautama, A. Hendrik, and R. Hendaya, "Pengenalan Objek pada Computer Vision dengan Pencocokan Fitur Menggunakan Algoritma SIFT Studi Kasus: Deteksi Penyakit Kulit Sederhana," J. Tek. Inform. dan Sist. Inf., vol. 2, no. 3, pp. 437–450, 2016, doi: 10.28932/jutisi.v2i3.554.
[23] S. Garg and G. S. Sekhon, "Shape Recognition based on Features matching using Morphological Operations," vol. 2, no. 4, pp. 2290–2292, 2012.
[24] K. Nakade and S. Wakui, "Modeling of the galvano mirror by lumped mass system and verification for the model through the experiments," J. Adv. Mech. Des. Syst. Manuf., vol. 12, no. 1, pp. 1–14, 2018, doi: 10.1299/jamdsm.2018jamdsm0032.
[25] S. Brlek, G. Labelle, and A. Lacasse, "The discrete Green Theorem and some applications in discrete geometry," Theor. Comput. Sci., vol. 346, no. 2–3, pp. 200–225, 2005, doi: 10.1016/j.tcs.2005.08.019.
[26] T. A. T. S, "Perbandingan Model Warna RGB , HSL dan HSV Sebagai Fitur dalam Prediksi Cuaca pada Citra Langit menggunakan." 2020.
[27] O. D.R. et al., "Light-emitting diodes: A brief review and clinical experience," J. Clin. Aesthet. Dermatol., no. 6, pp. 36–44, 2015.
[28] H. Adinanta, W. P. Tresna, and E. Kurniawan, "Characterization of Blinking Laser-Target Designator for Target Tracking System." AIP Conf. Proc., 2652, 020007, 2022.
[29] J. Aulia, Z. Radila, Z.A. Azhary, A.M.T. Nasution, D.Y. Pratama, K. Indriawati, I.T. Sugiarto, W.P. Tresna, "The Bullet Launcher with A Pneumatic System to Detect Objects by Unique Markers." J. lnf. Commun. Converg. Eng. Vol. 21, no. 3, pp. 252-260, 2023. https://doi.org/10.56977/jicce.2023.21.3.252
[30] N. Mohd Ali, N. K. A. Md Rashid, and Y. M. Mustafah, "Performance comparison between RGB and HSV color segmentations for road signs detection," Appl. Mech. Mater., vol. 393, no. September 2013, pp. 550–555, 2013, doi: 10.4028/www.scientific.net/AMM.393.550.

BIOGRAPHY

Umar Ali Ahmad was born in Cirebon, West Java. He completed his bachelor's and master's degrees at Electrical and Informatic Engineering in Telkom University in 2007 and 2012 respectively. Then, he continued his doctoral studies at Electrical Engineering and Computer Science, Kanazawa University. Recently, he is a full-time lecturer in Computer Engineering Department, School of Electrical Engineering at Telkom University since 2011. Until now, he also joints as a collaborative researcher in Emerging Media Initiative (EMI) Division at Kanazawa University, Japan since 2023. The research fields currently being carried out are computer vision, remote sensing, mobile application development, telecommunication, information technology, computer network and infrastructure.

Wildan Panji Tresna was born on 1985, in Brebes, Central Java, Indonesia. He received a B.Sc. from Department of Physics, Diponegoro University, Semarang, Indonesia in 2007. After that, he took master's degree in electrical engineering option micro device electronics, University of Indonesia in 2014. In addition to PhD degree in Electrical Engineering and Computer Science, Kanazawa University, Japan in 2020. To this day, he currently works as researcher at Indonesian Institute of Sciences (LIPI) since 2008. Meanwhile, his institution merge into National Research and Innovation Agency (BRIN) in Indonesia since 2021. His current research interest included laser applications, optical waveguides, object recognition system and sensors.

Iyon Titok Sugiarto was born on January 21st, 1984, in Yogyakarta, Indonesia. He received a BSc in Physics from Gadjah Mada University, Yogyakarta, Indonesia, in 2006 and a master's degree in electrical engineering Option Telecommunications Engineering, School of Electrical Engineering, and Informatics from Institut Teknologi Bandung, Bandung, Indonesia, in 2013. Then, He received a PhD in Mechanical Science and Engineering, Natural Science and Technology Kanazawa University, Japan, in 2020. He currently works as a researcher at the Research Center for Photonics, National Research and Innovation Agency in Indonesia. His research interests are optic, spectroscopy laser, laser surface structuring, and applied physics.

Mera Kartika Delimayanti received the Doctoral degree in Electrical Engineering and Computer Science from Kanazawa University, Japan with specialization in Bioinformatics. Her research areas are Machine Learning, Deep Learning, Bioinformatics, Medical Informatics, and Biomedical Engineering. Now, she is a lecturer at Department of Computer and Informatics Engineering, Politeknik Negeri Jakarta. She is a Head of Information and Communication Technology Unit at Politeknik Negeri Jakarta. She has supervised and co-supervised more than 80 undergraduate students and 2 master's students. She has authored or coauthored more than 30 publications: 15 proceedings and 15 journals, with 5 H-index Scopus. She was awarded as Exemplary lecturer in 2023 in Politeknik Negeri Jakarta.

Fahmi Charish Mustofa completed his basic education in Semarang City. His undergraduate program finished at The National Land College (STPN Yogyakarta), Ministry of ATR/BPN and finished his highest academic degree in year of 2008 (Master of Geomatic Engineering) and 2018 (Doctor of Geomatic Engineering) at The Faculty of Engineering, Gadjah Mada University. All funded by government scholarship program. He explores the application of advanced technologies and methods in land surveying, land registration, and cadastral systems. Overall, his works appears to an emphasis on participatory approaches and the integration of geospatial technologies including visual and automatization of recognizing and identifying in remote sensing.

Mohammad Reza Faisal was born in Banjarmasin. Following his graduation from high school, he pursued his undergraduate studies in the Informatics department at Pasundan University in 1995, and later majored in Physics at Bandung Institute of Technology in 1997. After completing his bachelor's program, he gained experience as a training trainer in the field of information technology and software development. Since 2008, he has been a lecturer in computer science at Universitas Lambung Mangkurat, while also pursuing his master's program in Informatics at Bandung Institute of Technology in 2010. In 2015, he furthered his education by pursuing a doctoral degree in Bioinformatics at Kanazawa University, Japan. To this day, he continues his work as a lecturer in Computer Science at Universitas Lambung Mangakurat. His research interests encompass Data Science, Software Engineering, and Bioinformatics.

Reza Rendian Septiawan received the S.Si. degree (in equal with B.Sc.) from Department of Physics, Institut Teknologi Bandung (ITB). After that, he took Double-Degree Program (DDP) from Department of Computational Sciences Kanazawa University and also Department of Computational Sciences Institut Teknologi Bandung, and got both M.Si. degree (in equal with M.Sc.) from ITB and M.Sc. degree from KU, after finishing two theses in two years. Then, he finished his doctoral program in computational mathematics and received his doctor in philosophy degree from Kanazawa University, continued with his post-doctoral research on particle method for fluid dynamics and elastic body in Kanazawa University as well. He started to be a part-time lecturer of Telkom University in 2019 and became a full-time lecturer in Department of Computer Engineering started from 2020 until now. He held a position as a Secretary of Department of Computer Engineering starting from August 2022 until now. Up to now, he received several research grants from Telkom University and from The Ministry of Higher Education in various research topics. His research interests includes Internet of Things (IoT), cloud computing, fluid dynamics, intelligent transportation systems, and artificial intelligent (AI).