Traffic Light Detection in Autonomous Vehicles Using Image Processing Methods

Teeba A. Touma[1*], Heba Kh. Abbas[2]
[1*,2]*Department of Physics, College of Science for Women, University of Baghdad, Baghdad, Iraq*
[1*]teba.ali1104a@csw.uobaghdad.edu.iq , [2]hbphysics82@gmail.com

Abstract:
Despite the great development that the industry has achieved in the field of self-driving cars, However, there are difficulties encountered in detecting traffic light, in this research an intelligent system was designed to recognize traffic lights at different times and conditions (day and night). The system is based on digital image processing techniques, which consists of three main stages: image subtraction, traffic signal segmentation, and traffic signal discrimination using two methods, Circular Hough Transform (CH) and morphological operations and comparison between them. The results indicated the efficiency and accuracy of the proposed system in both methods where Traffic lights are detected and the area of each signal is determined over time and the decision is made to detect whether the signal is bright or dark over time.
Keywords: Traffic Light, Detection, Circle Hough Transform, Morphological Methods.

Introduction:

The progress of innovation in the automotive sector over the last century has provided safer and cleaner vehicles, but this progress has occurred gradually [1]. The industry today appears to be witnessing it a major development brought about by autonomous or "autonomous" vehicle technologies [2]. This technology offers significant benefits for you the level of social welfare, in terms of saving lives, reducing collisions and traffic congestion and fuel consumption and pollution, and increasing mobility for people with special needs and the disabled, and, finally, its progress in improving land use [3].

Susmitha B. and his et.al. proposed a system to detect road codes for vehicles in normal environmental conditions, where he set it up to eliminate noise and automatically direct cars using (Python) for real-time image processing and commands [4]. Jinkyu K. and his et.al. proposed ways to detect traffic lights using real-time deep neural networks for self-driving vehicles and thus impose fines on violators and detect them [5]. Lucie H. and his et.al. introduced adaptive methods for autonomous vehicles to operate in outdoor environments for long periods of time under the influence of differences in lighting and nature to achieve long-term autonomy [6]. Wael O. and his et.al. they proposed a system for measuring the distance of a traffic signal in autonomous vehicles using holographic digital image processing where the location of the traffic signal was determined by integrating the algorithm for detecting, classifying and locating the signal colors simultaneously, as the proposed system succeeded at a distance of (20m) from the sensor and failed when the distance is further away In addition, there are problems with the accuracy of the results due to the type of camera used [7]. Chinju P. and his et.al. proposed a system that works with a combination of robotics, machine learning, artificial intelligence, and the use of a low-cost central processing unit, in order to develop technologies for self-driving vehicles with less damage, so that everyone can be able to, through machine learning, detect traffic lights using a camera that takes pictures and sends them to the machine learning algorithm, where The vehicle has been trained to travel safely [8].

In this study, an intelligent system was proposed to operate at different times (day and night) and distances by filming a video clip of traffic lights at road junctions where the video clip was cropped to obtain images by extracting frames per second. Those frames were analyzed to reveal the circles in each frame, the color of each circle, the luminous color of any circle, and the adoption of the threshold technique in determining the color. Two methods were adopted to detect traffic lights, the first is the Circular Hough Transform (CHT) method, and the second is the use of morphological methods and comparison between them in terms of the results of the detected circuits and their accuracy in real time, and this helps to make the right decision for the driver.

Detection of Circular Objects:

Hough Transform (HT)is a technique that can be used to isolate features of particular shape within an image. It requires desired features specified in parametric form such as radius and angle. The classical Hough transform commonly used for detection of regular curve such as line, circle and ellipses [9]. The Circular Hough Transform (CHT) relies on the equation of the circle, which is expressed as:

$$r^2 = (x-a)^2 + (y-b)^2 \dots\dots\dots (1)$$

a and b represent the coordinates for the center, (r) is the radius of the circle. The parametric representation of this circle is [10]:

$$x = a + r * \cos(\theta) \dots\dots..(2)$$

$$y = b + r * \sin(\theta) \dots\dots..(3)$$

For each edge point, a circle is drawn with that point as origin and radius r. The CHT also uses an array (3D) with the first two dimensions representing the coordinates of the circle and the last third specifying the radii [11]. The values in the accumulator (array) are increased every time a circle is drawn with the desired radii over every edge point. The accumulator, which kept counts of how many circles pass through coordinates of each edge point, proceeds to a vote to find the highest count. The coordinates of the center of the circles in the images are the coordinates with the highest count [12].

Threshold

Threshold is one of the most important stages in image segmentation strategies. In this step, pixels that are identical in scale value (or some other function) are bimodal images often tend to be clustered to calculate the best tuning for the threshold (Th) of such images (such as scanned text), and other images can have several modes and manifold thresholds may be useful for a single threshold [13]. Multilevel thresholding is typically less precise than single-level thresholding. Especially because the identification of thresholds that sufficiently distinguish objects of interest is very difficult [14].

$$Th = Th[i, j, p(i, j), f(i, j)] \dots\dots (4)$$

Where *Th* is the threshold value, *i* and *j* are the coordinates of the threshold value point. p (i, j) and f (i, j) are points the gray level image pixels.

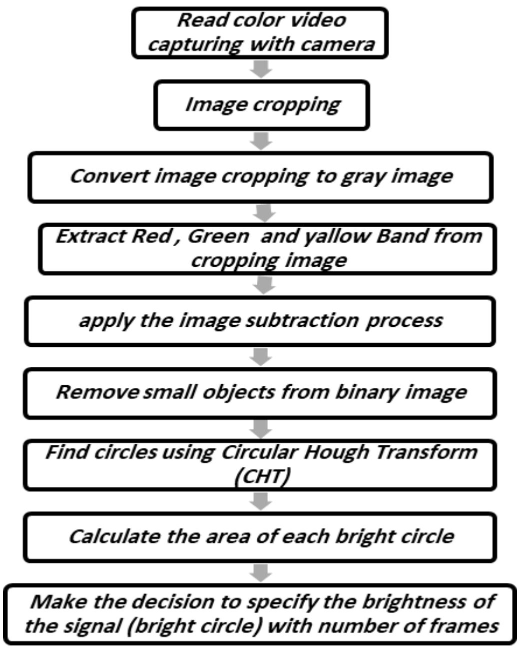
Threshold image g (i, j) can be define:

$$g(i,j) = \begin{Bmatrix} 1 & if\ f(i,j) > 1 \\ 0 & if\ f(i,j) \le 0 \end{Bmatrix} \dots\dots..(5)$$

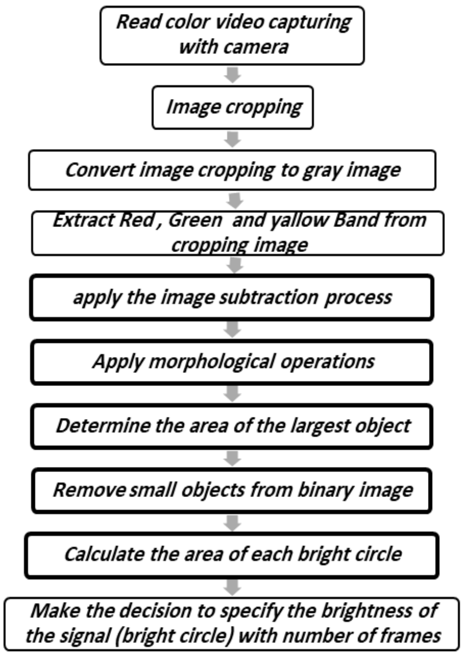
Thus pixels labeled 1, say, correspond to objects, and pixels labeled 0, say, correspond to the background where the threshold is set manually for an image contains objects with homogeneous intensity or the contrast between the objects, and the background is high best choice is threshold to segment the objects and the backgrounds [15].

Methodology:

The proposed system includes recording a video clip of a traffic light site at different times of the day (day and night). The video file is cut into a number of frames according to the length of the video, and then each frame is first divided into a red and green bar, and then converted into a gray image per second. The red and green bar image is subtracted from the gray image. It is then converted into a binary image according to the threshold of each color (red, green), and since yellow is a secondary color resulting from the process of mixing the two primary colors red and green, it is calculated on two thresholds resulting from red and green to obtain the yellow signal. And to discover the circles and their area, where each of the two methods has a function of its own imfindcircles function was used in the Circular Hough Transform (CHT) method and the regionprob was used to determine the area of the largest object in the frame in the second method, then using morphological methods to give the decision by defining the circle of bright colors in each frame (traffic light) using the strel function that rearranges the elements Required (the edge forms disc-shaped points and a center with a value of 1 and with a given radius) then we expand the center using the imdilate function, we close the formed shape using imclose , the possibility of forming gaps and filling them with an imfill function possible. Then calculate the area of each color light illuminated (the sum of pixels) by the number of frames and give the decision to calculate the actual time of each color light by the number of frames. As in the following diagrams:



(a)



(b)

Figure (1) Charts of proposed system (a) *Circular Hough Transform (CHT) method (b*) morphological operations method.

Software and Tools Utilization

In this study, MATLAB (R2019a 64bit) used to build and developed the proposed algorithm. Whereas, the imaging system record an intersection where the traffic lights are located.

The specifications of imaging system are illustrated in Table 1, tools used in data acquisition are:

Sony camera DSC-HX1 ,

TABLE 1. Specifications of Imaging [16].

Sensor	• 1/2.4 Type CMOS, 9.1 million effective pixels
Maximum Image Size	3456 x 2592
Lens	• 28-560mm equality. (4:3), 1-620mm (16:9), 20x Optical zoom, F2.8-8.0(W)-5.2-8.0(T)
Video Recording	HD Up to 1440x1080 30fps
Sensitivity	• Auto, ISO 125-3200
Special Scene Modes	Sweeping Panorama, Twilight, Anti-Shake,
LCD screen	• Tilting, 230,000 pixels, 3.0inch TFT LCD
Continuous shooting	max 10 fps
Weight (no batteries)	514g (18.1oz.)
Other	HDMI output

Results and Discussion

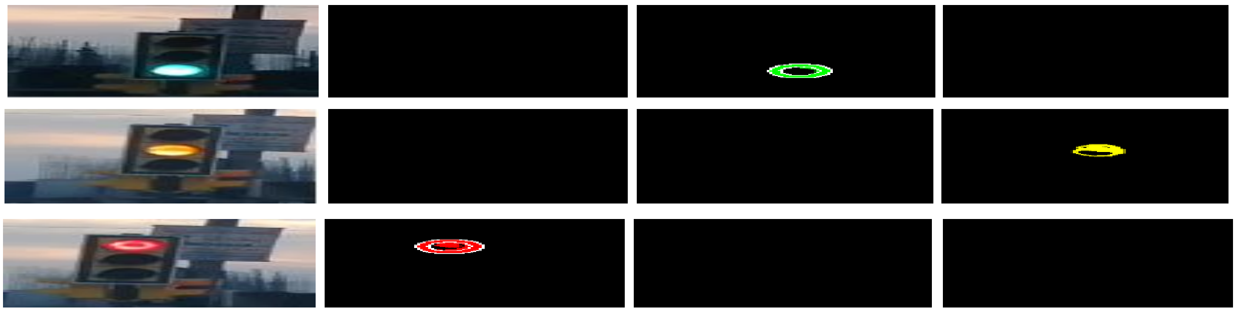
The application of the proposed system at different intersections of the city of Baghdad:

Filming the Intersection of Qatar Al Nada Street in AL-Baya in the city of Baghdad at 5:30 AM, it was filmed at a distance of (30 m) from the traffic light, at 2 mm zoom, and the length of the video was 21 seconds, as shown in Figure (3a),and in the same place at night time at 8:30 PM. as shown in Figure (3b),

(a) (b)

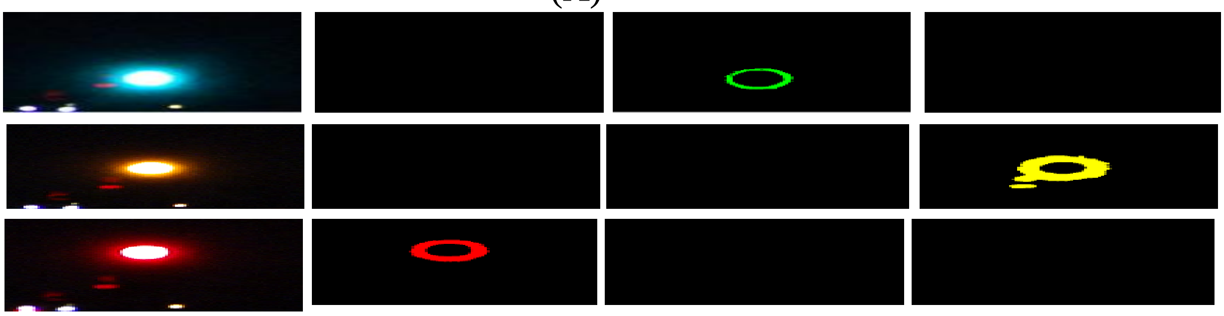
FIGURE 1. Different video location to film traffic lights at (a) Intersection of Qatar Al Nada Street in AL-Baya at 5:30 AM (b) Intersection of Qatar Al Nada Street in AL-Baya at 8:30 PM.

- The video shown in Fig.1 was cropped into a number of frames (11 and 12 fps), and the images were subtracted to determine the color of the traffic lights using a threshold technique, in which the threshold for each color was determined manually. Red color was (BWr = J2> 90), Green threshold BWg = J3> 55, and yellow limit YB1 = J2> 35; YB2 = J3> 15. The circuit is detected in each frame as in Fig. 4.



(a) (b) (c) (d)

(A)

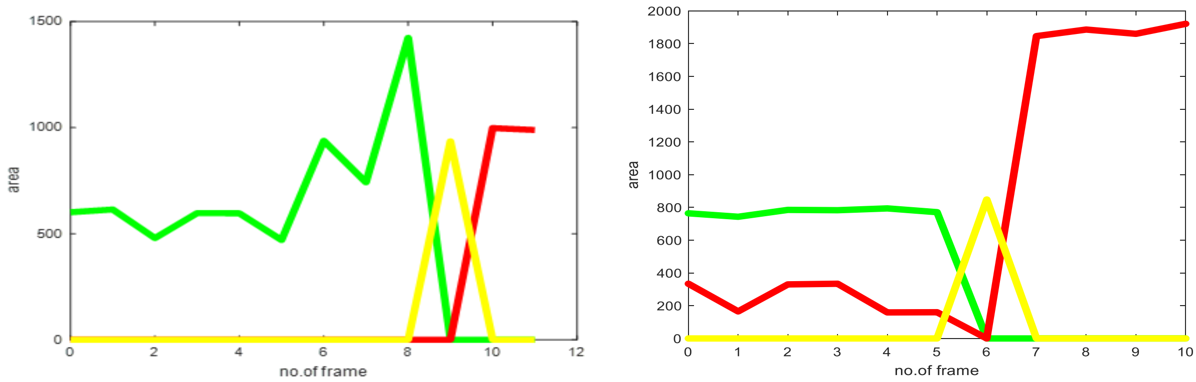


(a) (b) (c) (d)

(B)

FIGURE 2. Detection of videos of the Intersection of Qatar Al Nada Street in AL-Baya in the city of Baghdad: (A) First video at morning .(B) Second video at night.. Where (a): detection green traffic, (b): detection yellow traffic and (c): detection red traffic.

The relationship between the areas (S) of traffic light at y axis (red r, green g and yellow y) is plotted with the number of frames in x axis for distance 15m, as shown in figure 5.

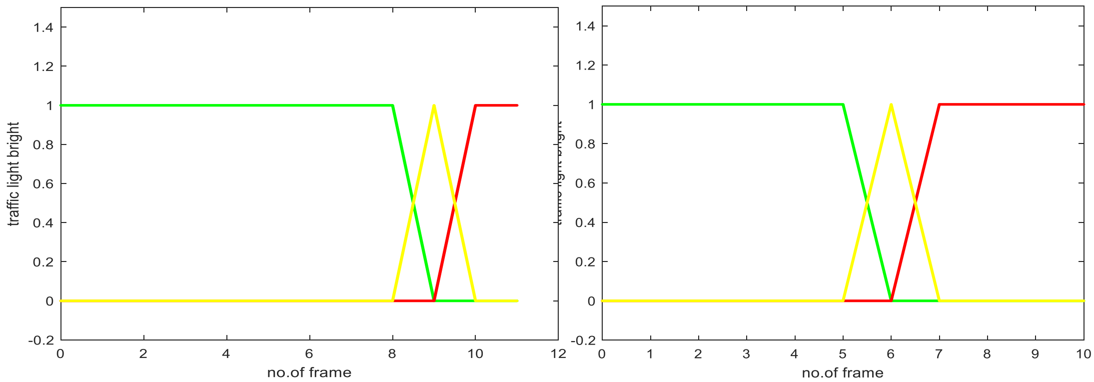


(a) (b)

FIGURE 5. The relationship between the area of traffic light with the number of frame .where (a) First video (b) Second video

Noticed from Figure (5) that the area in Figure (a) is greater than the area in Figure (b), meaning that the signal area in the morning time state is greater than the area at night. In addition, we notice a slight fluctuation in the area of Figure (a) but with a greater percentage than (b).

The relationship of bright traffic light (V) at y axis is plotted with the number of frames in x axis for distance (15m), as shown in figure 6.

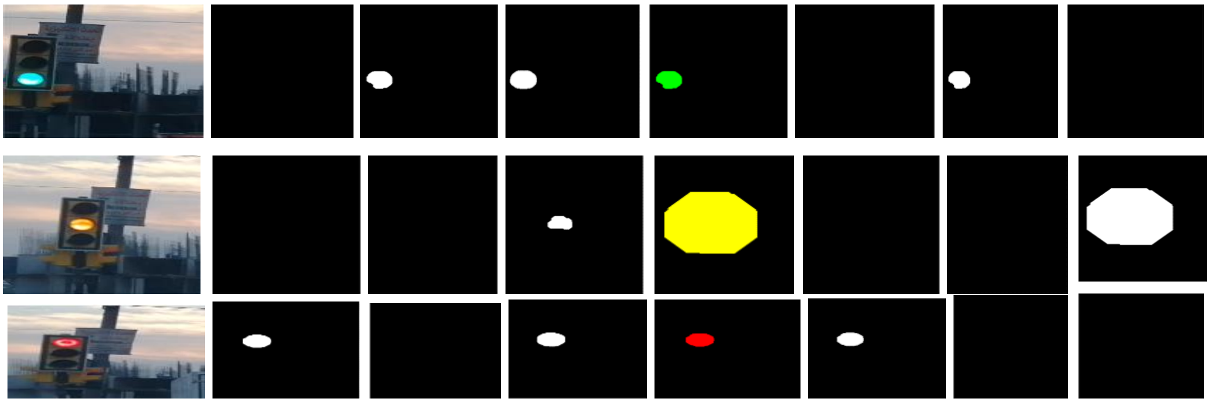


(a) (b)

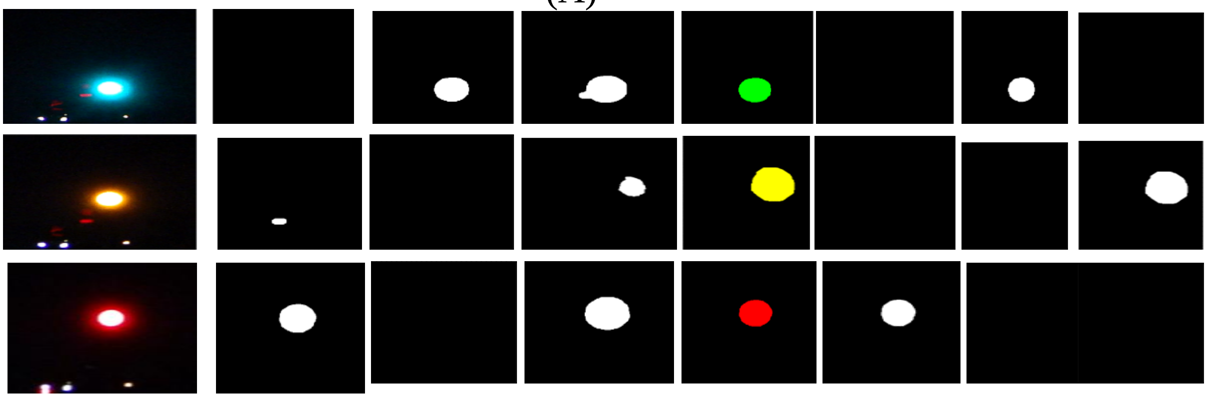
FIGURE 6. The relationship between the bright traffic light with the number of frame .where (a) First video (b) Second video

From Figure 5, make a decision for the state of the illuminated traffic light by drawing the relationship between the state of the bright signal (red, green, yellow), which represents the peak (1) and the state of the dark signal (0) by the number of frames, which represents the time period for making each color, which helps in determining the time. Actual traffic signal and reduce traffic congestion.

- Detection of color circles using morphological methods according to the proposed algorithm, where the luminous signals determined in each frame. The area of the largest object determined using a function *regionprob* . Then on the basis of which the decision was taken to detect the illuminated color circle (Illuminated color traffic signal circle) and delete the rest of the light objects less than the largest area, as shown in Figure 7.



(a) (b) (c) (d) (e) (f) (h) (g)
(A)

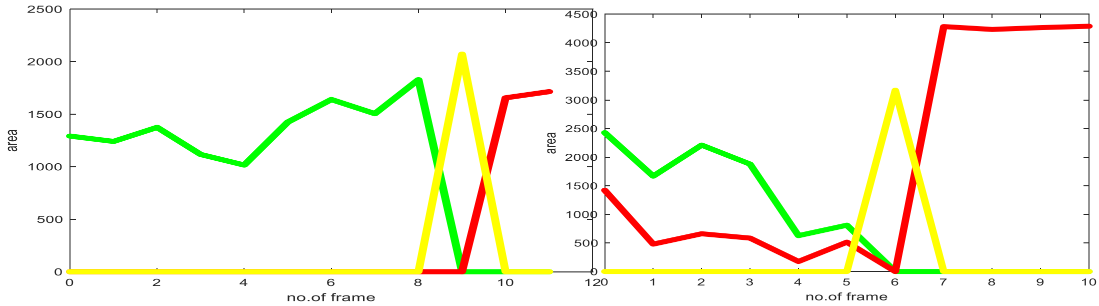


(a) (b) (c) (d) (e) (f) (h) (g)
(B)

FIGURE 7. Make the decision for which color was illuminated of traffic light detecting of Video (A) in morning.(B) in night . (a) Frame cropped from video (b)Detection red object (c)Detection green object (d) Detection yellow object, (e)the decision: illuminated traffic light (f)Detection red traffic light (h) Detection green traffic light (g)Detection yellow traffic light

- The relationship between the areas (S) of larger circle traffic light at y axis (red r, green g and yellow y) is plotted with the number of frames in x axis for distance 15m, as shown in figure 5.

  The behavior of the light ON and OFF for the traffic can be described according to the relationship of the light area and number of the video frame as shown in figure 8. The high number in area means the that color is ON otherwise it is OFF.

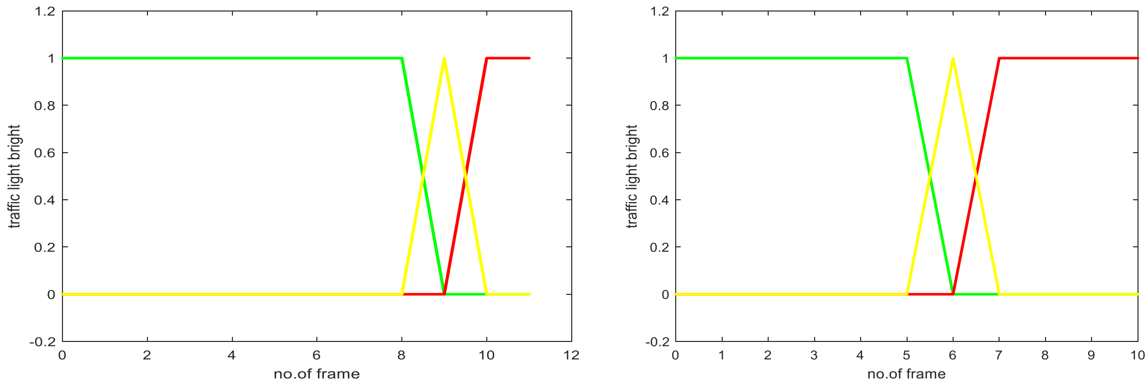


(a) (b)

FIGURE8. Relationship between the larger areas of traffic light with the number of frames.(a) first video (b) second video.

From Figure (8), we notice the area fluctuation with the number of frames, as it was shown in Figure (8a) that the area fluctuated with the number of frames more in proportion to the area fluctuation with the number of frames in Figure (8b).

- The relationship between bright light signal(V) is plotted with the number of frames for each distance, and from both the left and right sides as shown in figure (9).



(a) (b)

FIGURE 9. Relationship between the bright light signal with the number of frames for each distance (a). First video (b). Second video

From Figure 9, Decision-making for the state of the illuminated traffic signal by drawing the relationship between the state of the bright signal (red, green, yellow), which represents the peak (1) and the state of the dark signal (0) with number of frames it is possible by knowing the time duration of each color and thus knowing the time taken for the signal, not only in the area of autonomous driving, but this is what makes controlling the traffic lights more easy and smooth at road intersections in coordination and in conjunction with each other in order to prevent traffic congestion.

Conclusion:

Designing traffic lights detection and recognition systems to solve the problem of recognizing traffic lights in autonomous driving and other applications. These systems work at different times, different weather conditions, and different distances. The results were highly accurate and efficient in recognizing traffic lights and distinguishing their shapes and colors. Efficiency of the adopted image processing techniques (image subtraction and segmentation based threshold techniques) in identifying and distinguishing the color of traffic lights.

The efficiency of (CHT) method in detecting traffic lights in different environmental conditions, at times (night and day) and at different distances, where the results indicated the efficiency of this method at night time more than during the day, and that noted that the accuracy of discrimination increases as the distance of the camera from the object (traffic light) increase .The efficiency of (Morphology operations) method in detecting traffic lights in different environmental conditions, at times (night and day) and at different distances, where the results indicated the efficiency of this method in the daytime is more from the night, that observed that the accuracy of discrimination increases as the distance of the camera from the object (traffic light) increases. As well as increasing the area of the traffic light with the number of frames more than the area of the measured signal according to the detection method (CHT), can be conclude that the method (morphology operations) is better than the method (CHT) in terms of choosing one threshold for each color (red, green, yellow) and applying it to the videos approved in the work, making the decision to recognize the traffic light, making the decision to determine the actual time in operating the traffic light As well as the regularity of the shape of the detected traffic light.

The economic feasibility of using the proposed detection systems in terms of design and cost, through which it is possible to detect violations, traffic jams and other applications at different distances while the car is in motion by placing a card that works with the proposed systems in the driver's car.

References:

[1] Faisal, A., Kamruzzaman, M., Yigitcanlar, T., & Currie, G. (2019). Understanding autonomous vehicles. Journal of transport and land use, 12(1), 45-72.

[2] Yurtsever, E., Lambert, J., Carballo, A., & Takeda, K. (2020). A survey of autonomous driving: Common practices and emerging technologies. IEEE Access, 8, 58443-58469.

[3] Rosenzweig, J., & Bartl, M. (2015). A review and analysis of literature on autonomous driving. E-Journal Making-of Innovation, 1-57.

[4] Shah, A. S., Adhikary, D. D., & Maheta, A. (2017). Automated driving car using image processing. International Journal of Recent Trends in Engineering and Research, 3, 160-164.

[5] Kim, J., Cho, H., Hwangbo, M., Choi, J., Canny, J., & Kwon, Y. P. (2018, November). Deep traffic light detection for self-driving cars from a large-scale dataset. In 2018 21st International Conference on Intelligent Transportation Systems (ITSC) (pp. 280-285). IEEE.

[6] Rosique, F., Navarro, P. J., Fernández, C., & Padilla, A. (2019). A systematic review of perception system and simulators for autonomous vehicles research. Sensors, 19(3), 648.

[7] Omar, W., Lee, I., Lee, G., & Park, K. M. (2020). Detection and Localization of Traffic Lights Using YOLOV3 and Stereo Vision. The

International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 43, 1247-1252.

[8] Chinju Poulose , Saeeda K S , Arya P B , Bisty Buenest Babu , Midhun M V.(2021). Autonomous Vehicle Using Machine Learning. IJARCCE, 10, 2278-1021.

[9] Yadav, V. K., Batham, S., Acharya, A. K., & Paul, R. (2014, February). Approach to accurate circle detection: Circular Hough Transform and Local Maxima concept. In *2014 International Conference on Electronics and Communication Systems (ICECS)* (pp. 1-5). IEEE.

[10] K.A ., W.A.T. and Zainol A., “Hough Transform Method For Track Finding In Center Drift Chamber”,) Advancing Nuclear Science and Engineering for Sustainable Nuclear Energy Infrastructure ,AIP Conf. Proc. 1704, 030014-1–030014-7; DOI: 10.1063/1.4940083; 2016.

[11] Umer, S., & Dhara, B. C. (2015, January). A fast iris localization using inversion transform and restricted circular Hough transform. In 2015 Eighth International Conference on Advances in Pattern Recognition (ICAPR) (pp. 1-6). IEEE.

[12] Fatoumata D., “Object Detection using Circular Hough Transform”, American Journal of Applied Sciences, 2 (12), 1606-1609, 2005.

[13] Aksın, D. Y., Aras, S., & Göknar, İ. C. (2000, June). CMOS realization of user programmable, single-level, double-threshold generalized perceptron. In *Proceedings of Turkish Artificial Intelligence and Neural Networks Conference* (pp. 21-23).

[14] Oliva, D., Cuevas, E., Pajares, G., Zaldivar, D., & Osuna, V. (2014). A multilevel thresholding algorithm using electromagnetism optimization. *Neurocomputing*, *139*, 357-381.

[15] Heba Kh., Ali A., “A Study of Digital Image Fusion Techniques Based on Contrast and Correlation Measures”, PhD. thesis AL-Mustansiriyah Univ, 2013.

[16] http://www.digitalcamerareview.com/camerareview/sony-cyber-shot-dsc-hx1-review/

الخلاصة:
على الرغم من التطور الكبير الذي حققته الصناعة في مجال السيارات ذاتية القيادة ، الا ان هنالك صعوبات تواجهها في الكشف عن اشارات المرور حيث تم في هذا البحث تصميم نظام ذكي للتعرف على إشارات المرور في الأوقات والظروف المختلفة (ليلا ونهارا). يعتمد النظام على تقنيات معالجة الصور الرقمية ، والتي تتكون من ثلاث مراحل رئيسية: طرح الصورة ، وتجزئة إشارة المرور ، وتمييز إشارات المرور باستخدام طريقتين هما Circular Hough Transform (CH) والعمليات الصرفية واالمقارنة بينهما.دلت النتائج على كفاءة ودقة النظام المقترح في كلتا الطرقتين حيث تم الكشف عن إشارات المرور وتحديد منطقة كل إشارة بمرور الوقت واتخاذ القرار في الكشف عن حالة الإشارة سواء كانت ساطعة أو مظلمة مع مرور الوقت.