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Ball Detection Based on Color and Shape Features Captured by Omni-Directional Camera

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Abstract – The ability to detect the ball on a soccer robot is the key to victory in a match. However, in reality, there are several things that can become a distraction in the detection process. These include the color and shape of the ball which often change. This study aims to create a system that can detect balls based on the color and shape of the ball by comparing the level of accuracy and computation time process. The research process was carried out by capturing real-time video on an Omni-Directional camera and through image processing, including image segmentation by taking HSV colors at a certain range, noise image restoration, feature extraction using contours with optimal roundness, and analysis of detection results. From the application of this method to video images of random balls, an accuracy value of 90,61 percent is obtained. This is obtained with an average computing time of 0,025 seconds.

Index Terms—Shape detection, Contour detection, Omni-Directional Camera, HSV Filtering, Optimal roundness.

I. INTRODUCTION

In one of the fields of the Indonesian Robot Competition (KRI), namely the Wheeled Indonesian Football Robot Contest (KRSBI Beroda), the robot's ability to detect the ball plays a vital role. According to the regulations set out in the KRI guidelines for the KRSBI Wheeled branch, it uses an orange ball. In addition, the sensor used is an omni-directional camera [1]. This is a challenge for robot system makers. Robot programmers must develop systems that can recognize balls with a high degree of accuracy. This must also be balanced with a short computation time process.

An object usually has unique characteristics including color. The color model commonly used in the image detection process is RGB (Red, Green, Blue), especially if the detected object has various color characteristics such as detecting human faces [2], types of fish [3], and moving objects [4]. If we focus on looking for changes in the basic color to other colors, for example, blue to red, we can use this color model. However, in this study, the object to be detected has only one color characteristic. The changes include the grayness and brightness of the object so that it sometimes resembles the surrounding objects. this is due to the light. An object far from the light source has a different color than a near one. Therefore it is necessary to have a setting that can recognize the color of things in a range of different levels of light intensity. The HSV (Hue, Saturation, Value) color model allows the user to adjust the brightness level of a color characteristic [5]. It can dismiss single-colored objects with dynamic levels of gray and brightness.

In the detection process using a one-way camera or directional camera, it may be enough to use the color parameter and we can get a fairly high accuracy [6], Many researchers use the Hough transform voting method, for the detection of circular objects such as detection of apples [7], droplet [8], Vascular area (Blood vessels) [9], and Ball [10],[11],[12]. The Hough transform utilizes the voting value on the accumulator in determining the center point of an object depending on the shape of the object to be detected [12]. This method has two weaknesses, namely, it requires a fairly heavy computational process if the image processing is not carried out optimally and cannot tolerate shapes other than circles, whereas in this study the shape of objects can change significantly due to the effect of an omni-directional camera.

The Omni-Directional Camera has a wide viewing angle compared to cameras with fish eye lenses and wide angle [13], but this camera has serious problems in the process of object shape detection. We can just use the Hough Transform method [10],[11],[12], but the level of accuracy certainly cannot match a one-way camera. This is because the further the ball is away from the center point of the camera, the more oval the shape tends to be.

The contour detection method has a degree of flexibility in detecting objects by adjusting the level of contour similarity to the shape to be detected [14]. As investigated by Xiaohu [15] in detecting the tip of a steel rod, the application of this method has the highest accuracy value compared to other image processing and even neural networks, in the context of images with limited color characteristics. Then the final step is to find the minimum roundness level that can be detected by the Omni camera so that the system can tolerate changes in the shape of the ball.

From the explanation of the various problems above, this research will discuss ball detection using an omni-directional camera that combines color range filtering and contour detection methods with optimal roundness levels to be able to detect changes in the color and shape of the ball.

II. RESEARCH METHOD

This research consists of two parts, namely pre-processing and feature extraction (Fig.1). Image pre-processing aims to make the video image provide the required information, and image feature extraction aims to detect the object's characteristics.

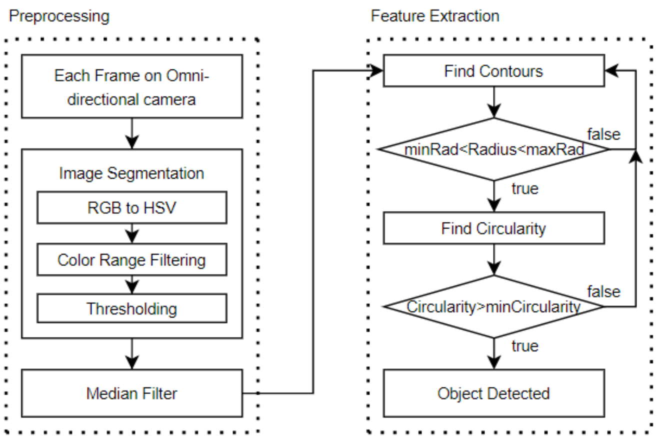


Fig. 1. Research Method

A. HSV Color Model

The most common method of determining color composition is based on the 3 basic color compositions, which are RGB (Red, Green, Blue).

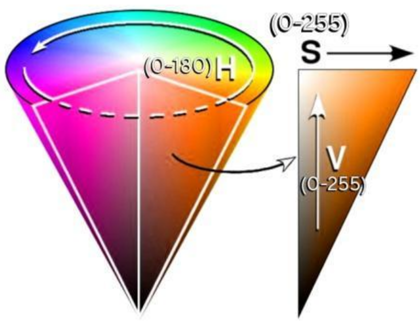


Fig. 2. HSV color model

But we as humans with limited reasoning will definitely find it difficult to imagine the composition of color using RGB composition. To overcome this HSV (Hue, Saturation, Value) is the solution because the HSV model has sequential color sequences and distinguishes only gray elements and the brightness of a color. The HSV color model uses degrees as a parameter for determining the order of a color identity (hue) starting from red to purple with added gray elements (saturation) and light levels (value).

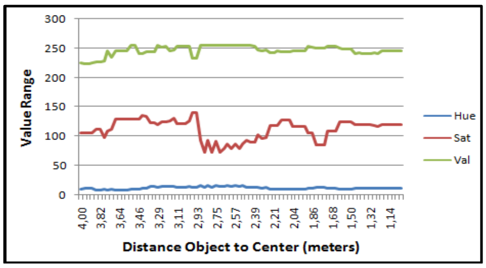


Fig. 3. HSV Value of Moving Object

This study uses the HSV color model to make it easier for the system to tolerate colors that change frequently during the detection process. Here are the steps for converting RGB to HSV:

Normalize RGB values to the range 0-1 :

$$R' = \frac{R}{255},\; G' = \frac{G}{255},\; B' = \frac{B}{255} \quad (1)$$

Find minimum and maximum values of RGB :

$$C_{max} = max\,(R', G', B') \qquad C_{min} = min\,(R', G', B') \quad (2)$$

Find the differences :

$$\Delta = C_{max} - C_{min} \quad (3)$$

Finaly, Find Values of H,S,V :

$$H = \begin{cases} 0 & ,\Delta = 0 \\ \left(30 \times \left(\frac{G' - B'}{\Delta}\right) + 180\right) mod\ 180 & ,\ C_{max} = R' \\ \left(30 \times \left(\frac{B' - R'}{\Delta}\right) + 60\right) mod\ 180 & ,\ C_{max} = G' \\ \left(30 \times \left(\frac{R' - G'}{\Delta}\right) + 120\right) mod\ 180 & ,\ C_{max} = B' \end{cases} \quad (4)$$

$$S = \begin{cases} 0 & ,\ C_{max} = 0 \\ \frac{\Delta}{C_{max}} & ,\ C_{max} \neq 0 \end{cases} \quad (5)$$

$$V = C_{max} \quad (6)$$

Pay attention to Fig. 3 regarding changes in the HSV value of a moving object center. So by using this color model the system can recognize the characteristic color of objects degraded by light.

B. Color Range Filtering

A digital image processing process usually requires a fairly heavy computational process, especially if the image to be processed is a video image consisting of various colors. However, if we can sort out what colors we want to process, it will certainly decrease the computational process. From Fig. 3 we can observe that the change in hue value is not too significant compared to the S and V values, so we can use it to define that the range of values is an object. In this paper, we used *InRange* in the *OpenCV* library to dismiss a range of colors, namely orange balls only. With a range of values for Hue (0-180), Saturation (0-255), and Value (0-255).

C. Thresholding

As seen in Fig. 1 the thresholding process is an integral process with color filtering in image segmentation. The difference is that in this process the output image is converted into a binary image with values of 0 (black) and 1 (white) for the results of color range filtering. As shown in Fig. 4.

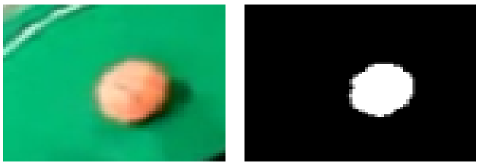


Fig. 4. Segmented image

D. Median filter

The Median Filter here can remove black and white dot noise or commonly called salt and pepper noise as a result of the shooting process. This noise is not exposed to perfect light or caused by dust/dirt around the lens. However, in this study, this filter removes spots around the ball from the reflection of a mirror whose color resembles the color range of the ball. It also smooths out the image of the ball in segmentation results. The working process of the Median filter is to find the middle value of a pixel matrix against neighboring pixels [16] which are odd in size (3x3, 5x5, 7x7... Etc.).

E. Omni Directional Camera.

Not long ago, several camera lens technologies emerged with a wider viewing angle than directional cameras. These technologies include wide angle and fish eye lens technologies, which are believed to capture an image angle of up to 200° using a convex lens. There are drawbacks to these two lens technologies, including the presence of interference from the resulting image [13], which results in objects being wider at wider angles as a result.

This study uses an Omni-Directional camera with a 360° horizontal viewing angle so that it can take pictures of the entire area. By relying on the Omni-directional camera as the main sensor, it is very possible for the robot to see in all directions at the same time without rotating the robot and also without moving the camera angle [17].

F. Color Contour

In detecting the contour of an object, it certainly has a close relationship to the color of the object itself. In order to get the expected shape of the object, it is necessary to intervene in image processing, including removing a color. This was done by [15].

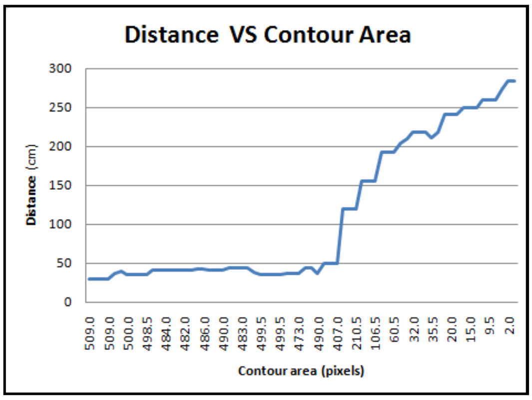


Fig. 5. Effect of distance on contour area

HSV color-thinning images can be used to define orange spherical objects with a variety of contour shapes, as shown in Fig. 5. The area of contour detection becomes smaller at increasing distances. By applying this color contour the system can detect spherical objects with all their shape changes due to the influence of the omni-directional camera.

G. Degree of Roundness

When detecting a color contour, sometimes other objects fall into the color range we detect. For example, orange spectator t-shirts. Then spontaneously the system will detect this as an object of detection as well, resulting in a disturbance in the detection process As a result, it is necessary to adjust the shape of a contour obtained, specifically the Circle, in order to overcome this problem.

OpenCV provides a minEnclosingCircle function or commonly called MEC in finding the circularity level of a contour by predicting the area of the smallest circle that can cover all areas on a contour [14].

Calculate moments of contour :

$$m_{ij} = \sum_x \sum_y x^i y^j contour(x, y) \tag{7}$$

Then look for contour coordinates (x,y) in the image, with i,j In the form of moments to be calculated. Namely moments m_{10} to m_{00} and m_{01} to m_{00}, because this moment is used to find the center point of an object.

Find the coordinates of the contour center:

$$Contour_X = \frac{m_{10}}{m_{00}} \text{ and } Contour_Y = \frac{m_{01}}{m_{00}} \tag{8}$$

From the contour center coordinates, the area of the contour and the area of the minimum circle that covers all contours can be calculated. This is done by calculating the minimum distance between points using the Euclidean approach [18].

Calculate *Circularity* :

$$Circularity = \frac{contour\ area}{minimum\ circle\ area} \tag{9}$$

In this study, circularity was utilized as a determinant of object detection by looking for the smallest circularity value from the measurement results of an object in several video images.

Algorithm 1. Flow of method

1 : **Begin**
2 : Define **minRad** and **maxRad** of the circle
3 : Define **minCircularity** of the circle
4 : **For** each contour that is formed :
    if minRad < $R_{Contour}$ < maxRad. **then :**
5 :   find ***Circularity*** with (9) **;**
        if ***Circularity*** > minCircularity, **then** :
            Mark this Contour as Detection object,
6 :   Find the midpoint of the Contour, as
            center object (x,y) use : (8)
        end if
    end if
7 :   Draw circle with $R_{Contour}$ and Center(x,y)
  End for
8 : **Finish**

H. Circular Hough Transform

As previously explained, this method is often used in detecting circles, but because the use of the omni-camera sensor in this study can make circular objects change shape, the use of this method will have a smaller accuracy value.

The Hough transform method uses a shape voting technique to detect the candidate which can be called a circle, apart from the color accuracy of this method it also depends on the edge detection process, therefore canny is included in the process in OpenCV. Each pixel point generated by Canny will be voted in a circle using the polarization equation. And as a final step, the pixel point that has the most circle tangents is the center point of the circle to be detected. This research will also try the detection process with this method as a comparison.

III. RESULTS AND DISCUSSION

The initial stages of the research were carried out by collecting image data in the form of video recordings with various conditions including a video of the ball moving away from the center point, and several videos of ball movements where in the video the ball is moved randomly over the green field and the size match the real conditions on KRI [1].

The RGB component of each image pixel is converted to the HSV color model with (1-6). This results in H values in the range 0-180, S in the range 0-255, and V in the range 0-255. Then segment the color of the orange ball by a range of values:

TABLE I. Range HSV values of Several Colors.

Ball Color	Lower Hue	Upper Hue	Lower Sat	Upper Sat	Lower Value	Upper Value
Orange	0	15	50	255	50	255
Red	101	255	50	255	50	255
Yellow	20	55	100	255	150	255
Blue	85	110	100	255	100	255

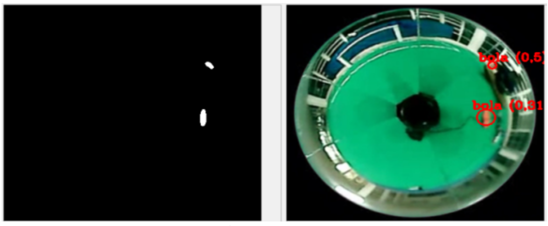
This values was obtained through by experiment technique in Fig. 3. After that, the image improvement process was carried out using a median filter to remove unwanted distortions in the image. This was so it would not be detected as an object.

The next stage is the feature extraction process by utilizing the color contours obtained in the image segmentation process. Then use (7-9) to find the circularity of the existing contour to define its spherical contour. But before that, a limit was needed in determining the circularity value to avoid unwanted objects being detected.

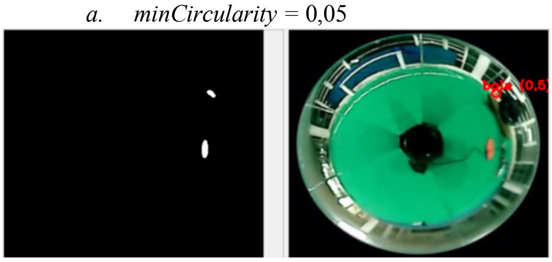
TABLE II. Minimum Circularity Ball

File_name	*Total Frame*	*Ball Count*	*Minimum Circularity*
sample1b.avi	78	1	0.4774
sample2b.avi	77	1	0.5209
sample3b.avi	**77**	**1**	**0.3389**
sample4b.avi	77	1	0.4379
sample5b.avi	77	1	0.3464

In Table 2 above, a search for the minimum circularity of detected spherical objects was carried out 0,3389. This was provided that no other objects were detected, only 1, namely a ball. This aims to prevent interference as shown in Fig. 6 below:



a. *minCircularity* = 0,05



b. *minCircularity* = 0,43

Fig. 6. Circularity of contours

The following are the results of testing a spherical object with a minimum circularity value obtained through contour detection (Table. 2) on a video of random ball movements with some of them having distortions in the form of red paper objects with shapes other than balls.

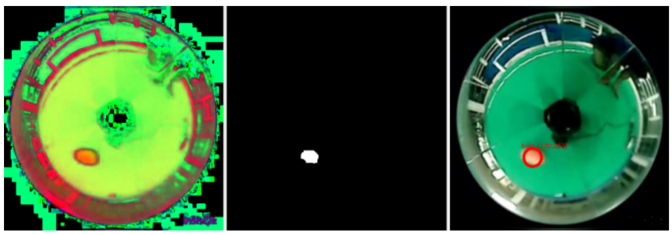


Fig. 7. Ball detected by system

Because in this research the brightness of the light also affects the detection process, the table below will describe the effect of varying light conditions and colors on the application of the contour method.

TABLE III. Testing of purposed method on Varying Light and colors with *minCircularity* = 0,3389.

Ball Colors	36 – 65 *Lux*			70 – 86 *Lux*			105 – 133 *Lux*		
	frames	Ball frames	Accuracy (%)	frames	Ball frames	Accuracy (%)	frames	Ball frames	Accuracy (%)
Orange	697	673	92,55	686	638	77,72	628	493	70,58
Red	660	578	79,12	638	488	67,13	620	391	59,09
Yellow	677	654	89,67	700	547	67,18	613	326	39,57
Blue	690	654	85,23	670	520	73,77	776	613	76,96

Calculate the Accuracy :

$$Accuracy = \frac{frames\ ball - frame\ error}{Number\ of\ Frames}\ x\ 100\% \qquad (10)$$

Where :
frame ball : Amount of frames where balls were detected.
frame error : Amount of frames where balls were detected > 1.
number of frame : Amount of frames in a video

The (Table. III) above is generated from the results of applying the contour method with a roundness level of 0,3398 to videos with a variety of frames and object movements at varying colors (Table.1) and lighting. The table also concludes that the most ideal light in the detection process is at the level of 36-65 lux.

TABLE IV. Testing of purposed method in Several Random Videos

Filename	***random1.avi***	***random2.avi***	***random3.avi***	***random4.avi***	***AVERAGE***
Durations(s)	22	6	9	6	-
Frames	440	126	186	123	-
Frame Ball Detected	384	112	170	120	-
Avg Circularity	0,58	0.57	0.68	0.64	**0,58**
Double Ball detected	2	0	0	0	
Avg Execute time @frame (s)	0.025	0.027	0.025	0.026	**0,02575**
Accuracy (%)	86.62	88.18	90.90	96.77	**90,61**

A comparison method was also tested in this study, namely using the hough circle transform method on images and the same segmentation process.

TABLE V. Testing of Hough Circle Transform method.

Filename	***random1.avi***	***random2.avi***	***random3.avi***	***random4.avi***	***AVERAGE***
Durations(s)	22	6	9	6	-
Frames	441	127	187	124	-
Frame Ball Detected	364	89	147	100	-
Avg Execute time @frame (s)	0.036	0.041	0.042	0.043	**0,0405**
Accuracy (%)	82.53	70.07	78.60	80.64	**77,96**

IV. CONCLUSION

This study uses video images from omni-directional camera. In order to detect spherical objects and not objects with similar shapes and colors, a search for the minimum circularity of the contours is carried out through image processing. The minimum circularity of 5 random video images is 0.3389. This study also shows the effect of different lighting conditions and the color of the balls on the detection process.

With ideal light conditions and Minimum Circularity value for orange ball, testing was carried out on 4 video images containing random ball movements with different positions and durations. Testing obtained an average accuracy value of 90,61% and an average execution time of the method for each frame an average of 0.025 seconds.

V. REFERENCES

[1] B. Kusumoputro, “Panduan Kontes Robot Indonesia (KRI) Tahun 2022,” p. 146, 2022.

[2] W. Pebrianto, P. Mudjirahardjo, and S. H. Pramono, “YOLO Method Analysis and Comparison for Real-Time Human Face Detection,” *Proc. - 11th Electr. Power, Electron. Commun. Control. Informatics Semin. EECCIS 2022*, pp. 333–338, 2022, doi: 10.1109/EECCIS54468.2022.9902919.

[3] A. Bhateja, B. Lall, P. K. Kalra, and M. Karnani, “Multi Fish Detection and Tracking Using RGB-D Vector,” pp. 1–6, 2023, doi: 10.1109/iccubea54992.2022.10011033.

[4] P. Mudjirahardjo and H. Suyono, “Real Time Boundary Density Based Moving Object Extraction,” *TIMES-iCON 2018 - 3rd Technol. Innov. Manag. Eng. Sci. Int. Conf.*, pp. 17–20, 2019, doi: 10.1109/TIMES-iCON.2018.8621754.

[5] C. Purnama Yanti and I. G. Andika, “HSV image classification of ancient script on copper Kintamani inscriptions using GLRCM and SVM,” *J. Teknol. dan Sist. Komput.*, vol. 8, no. 2, pp. 94–99, 2020, doi: 10.14710/jtsiskom.8.2.2020.94-99.

[6] H. Mandala and E. Rudiawan, “Sistem Deteksi Bola Berdasarkan Warna Bola Dan Background Warna Lapangan Pada Robot Barelang FC,” *4th Indones. Symp. Robot Soccer Compet. 2016*, vol. 2016, no. snati, pp. 14–20, 2016.

[7] K. Firdausy and U. C. Purwa, “Pengolahan Citra menggunakan Metode Otsu dan Hough Circle Transform untuk Prototipe Alat Sortir Buah Apel Cahya,” *Semin. Nas. Apl. Teknol. Inf.*, pp. 1–7, 2019.

[8] S. Zhu, C. Li, J. Rogers, M. Gianni, and I. Howard, “A Real-time Double Emulsion Droplets Detection System using Hough Circle Transform and Color Detection,” *2021 27th Int. Conf. Mechatronics Mach. Vis. Pract. M2VIP 2021*, pp. 36–41, 2021, doi: 10.1109/M2VIP49856.2021.9665023.

[9] I. M. G. Sunarya *et al.*, “Deteksi Arteri Karotis pada Citra Ultrasound B-Mode Berbasis Convolution

Neural Network Single Shot Multibox Detector," *J. Teknol. dan Sist. Komput.*, vol. 7, no. 2, pp. 56–63, 2019, doi: 10.14710/jtsiskom.7.2.2019.56-63.

[10] N. Tofik, "Sistem Pengenalan Bola Dan Gawang Pada Robot Sepakbola Beroda Berbasis Mesin Visi," no. October 2020, pp. 30–31, 2018.

[11] A. Suheryadi, W. P. Putra, M. L. Sifa, and D. Fathin, "Deteksi Bola Menggunakan Kombinasi Metode," vol. 19, no. 3, 2021.

[12] B. C. Wibowo, F. Nugraha, and A. P. Utomo, "Uji Deteksi Objek Bentuk Bola Dengan Menerapkan Metode Circular Hough Transform," *J. Inform. Upgris*, vol. 7, no. 1, 2021, doi: 10.26877/jiu.v7i1.8309.

[13] V. Kakani and H. Kim, "Adaptive Self-Calibration of Fisheye and Wide-Angle Cameras," *IEEE Reg. 10 Annu. Int. Conf. Proceedings/TENCON*, vol. 2019-Octob, pp. 976–981, 2019, doi: 10.1109/TENCON.2019.8929339.

[14] A. Cornelia and I. Setyawan, "Ball detection algorithm for robot soccer based on contour and gradient hough circle transform," *Proc. - 2017 4th Int. Conf. Inf. Technol. Comput. Electr. Eng. ICITACEE 2017*, vol. 2018-Janua, pp. 136–141, 2017, doi: 10.1109/ICITACEE.2017.8257691.

[15] L. Xiaohu and O. Jineng, "Research on steel bar detection and counting method based on contours," *2018 Int. Conf. Electron. Technol. ICET 2018*, no. 3, pp. 294–297, 2018, doi: 10.1109/ELTECH.2018.8401470.

[16] D. Zanuar, E. Prastya, D. P. Pamungkas, and R. K. Niswatin, "Implementasi Metode Gaussian Filter Dan Median Filter Untuk Penghalusan Gambar," *Semin. Nas. Inov. Teknol.*, pp. 178–187, 2022.

[17] M. Herlius, I. Bustami, and D. Kisbianty, "Optimalisasi Kamera Directional Menjadi Kamera Omnidirectional Sebagai Sistem Navigasi Pada Robot Sepak Bola Beroda," *J. Ilm. Mhs. Tek. Inform.*, vol. 1, no. 2, pp. 111–120, 2019.

[18] Di. K. Kotary and S. J. Nandal, "A point symmetry distance based k-means algorithm for distributed clustering in peer to peer networks," *Conf. Proc. - IEEE Int. Conf. Syst. Man Cybern.*, vol. 2019-Octob, pp. 3573–3579, 2019, dPoi: 10.1109/SMC.2019.8913956.