Movement of Trolley Robot using Fuzzy Logic Control and Camshift Algorithms in Following Similar Object

Siti Sendari, Dyah Lestari, Anik Nur Handayani, Danang Arengga Wibowo, Ahmad Burhanudin Fahmi, Satrio Dwi Sanjaya and Hsien-I Lin

***Abstract*—An object follower robot could be implemented to a shopping trolley, which should move to follow the right customer, autonomously. Then, the movement of the robot should be developed properly, where differential actuators, a camera, and a processor are attached to the shopping trolley. Since the robot follows the customer behind, so identifying the right customer could be determined based on the cloth color captured by the camera. The robot should maintain the movement to follow the right customer among them who wearing similar color clothes. Here, the camera is connected to Jetson Nano to detect and measure the distance of the trolley toward the customer. Furthermore, DC motors are coupled to the trolley's wheels as actuators using the differential mechanism. The robot should move smoothly in following the right customer controlled using Fuzzy Logic Control. This robot was tested to observe whether the robot can move following the right customer successfully. The result show that the robot can work successfully. The efficiency of selecting object for moving can be observed furthermore.**

***Index Terms*—Object detection, Camshift algorithm, Fuzzy Logic Control, shopping trolley, robotic**

I. Introduction

A modern shopping mall provides trolleys to help customers to bring the goods. The customers have to push or pull the trolley from a rack to other racks according to items they need. The problems occur when they do several activities to compare and review some goods, while they also bring handbag. Then, the customers could have limited activities to use their hands to push the trolley. Then, an autonomous trolley, which is able to follow the right customer during shopping, could be an innovation to solve this problem. The advantage of developing an autonomous trolley, retailers can show the willingness to improve services for their customers [1] [2].

Some researchers focus on developing an autonomous trolley, which can be developed using a microcontroller, sensors and actuators [3] [4][5]. In the previous research, the robot used ultrasonic sensor to detect the environment, so it could only detect obstacles [4]. In the other research, line and radio frequency identification (RFID) sensors were used to guide the robot movement [6] [5] [7]. These methods cannot detect the right customer. The appropriate solution could use a computer vision to detect objects [8] [9]. There are some common approaches of object recognition system, such as [10] and [11], the task of the system is to detect the object based on predetermined color. However, in those previous researches, the robot must set the RGB value manually as the main color. It is difficult to select the appropriate object when there are some objects have a similar color. Therefore, we proposed a solution to determine the right object using Camshift algorithm [12] [13]. Using Camshift algorithm, the robot can determine the right customer among similar customers based on their color clothes.

Implementation of robot vision based on size and object position can also be used to determine the direction and pose of the robot movement. The trolley robot is expected to work autonomously regarding the position and distance of customers when they move in front of the robot. Differential wheels [14] [15] can be used as movement mechanism for the trolley robot, since it could move easily from left to right and vice versa. Furthermore, Fuzzy Logic Control (FLC) can be integrated and applied to this trolley to control the movement [16] [17], which can be embedded to the processor to determine an appropriate delay for DC motors. Then, the robot should move following the right customer, who walks in a maze environment represented by shopping track, using FLC.

This paper combines the Camshift algorithm and FLC to control the robot movement. This algorithm can be implemented to choose the right customer, so the robot has an ability to determine appropriately among several customers who wear similar color clothes captured by the camera. The return value of object position is controlled using FLC, so the trolley robot can move smoothly following the right customer. The architecture of the trolley robot is presented in Section 2. The proposed method of the trolley robot is to identify the right customer and determine how to follow the right customer behind as described in Section 3. The implementation results and the discussions are described in Section 4 and Section 5, respectively. Finally, the conclusion is presented in Section 6.

II. Architecture of Trolley Robot

Architecture of the trolley robot is described in two parts, i.e., Principles of Vision- Based and Hardware Design.

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A. Principles of Vision-Based Trolley Robot

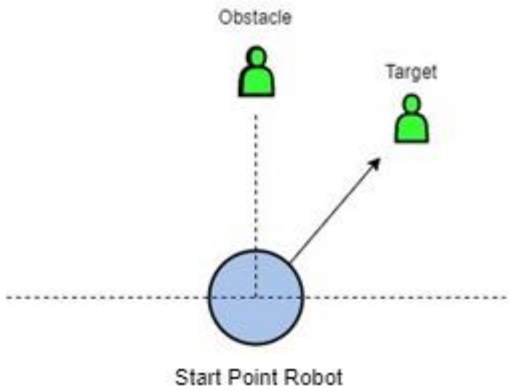


Fig. 1. Identification target and obstacle objects

In this paper, the trolley robot is a mobile robot, which uses two DC motors connected with differential wheel mechanism. The goal of robot movement is to follow the right target, as shown in Figure 1.

The robot needs some relevant information, such as color cloth and target position in order to move avoiding obstacles and following the target. A camera is used to detect specific objects (obstacles and target), which are detected based on the object's color. Regarding the configuration shown in Figure 1, the robot is developed with a single camera integrated with a processor shown in Figure 2. The camera works as a vision sensor to determine the angle of view in capturing objects. It is based on information of the maximum X-coordinate and maximum Y coordinate, i.e., 316 and 160 pixels, respectively. The detail information of selecting objects is explained in Section 3.

B. Hardware Design

The trolley robot is developed with Jetson Nano as the main processor for object detecting, while Arduino Nano is added to manage actuators for the robot movements. The additional components, i.e., Webcam Camera, LCD Touchscreen, Motor Driver, DC Motors and battery, are added as shown in Figure 2. This hardware is installed to the conventional shopping trolley as shown in Figure 2(a). The Arduino and the Jetson Nano were connected over USB which is commonly called serial communication (UART) by connecting them directly using the Jetson Nano's USB port. The microcontroller Arduino Nano, Jetson Nano, driver motor and battery are put on the robot base as shown in Figure 2(b), while Webcam Camera and LCD Touchscreen are installed on the upper side of trolley robot. The camera captures the object and send the image information to the processor for determining its position. This processing result is sent to the Arduino Nano to control the robot movements.

III. Proposed Method

A. Selecting Object of Trolley Robot

Figure 3 shows the process of selecting the right object. This method includes four procedures, i.e., (1) selecting object reference using LCD Touchscreen, (2) pre-processing the image captured by a camera, (3) processing Camshift algorithm to select and tracking the appropriate object, and (4) determining the output (X, Y) positions.

The first procedure is to select the reference object using LCD touchscreen. The reference object is used to determine the initial search window as the Region of Interest (RoI). This procedure is done using mechanisms, i.e., select the appropriate object, set an initial search window (Xc, Yc) to fit with the captured object, and determine the midpoint, as shown in (1-5).

$$M_0 = \sum_x \sum_y I(x, y) \quad (1)$$

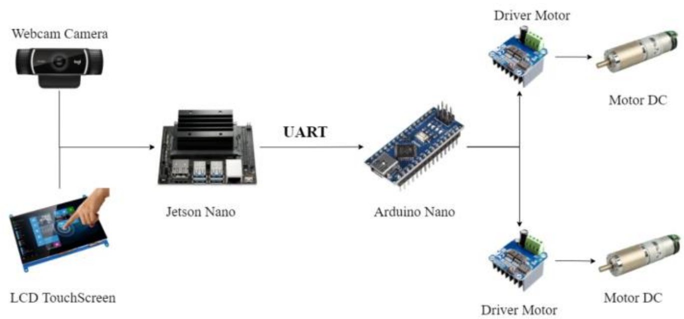
$$M_x = \sum_x \sum_y x.I(x, y) \quad (2)$$

$$M_y = \sum_x \sum_y y.I(x, y) \quad (3)$$

$$X_C = \frac{M_x}{M_0} \quad (4)$$

$$Y_C = \frac{M_y}{M_0} \quad (5)$$

M_0, M_x and M_y represent the zeroth moment, the first moment for x, and the first moment for y, respectively. X_C is the X-coordinate, while Y_C is the Y-coordinate of object.



(a)

(b)

Fig. 2. (a) General Architecture hardware, (b) The trolley with attached Hardware and Component.

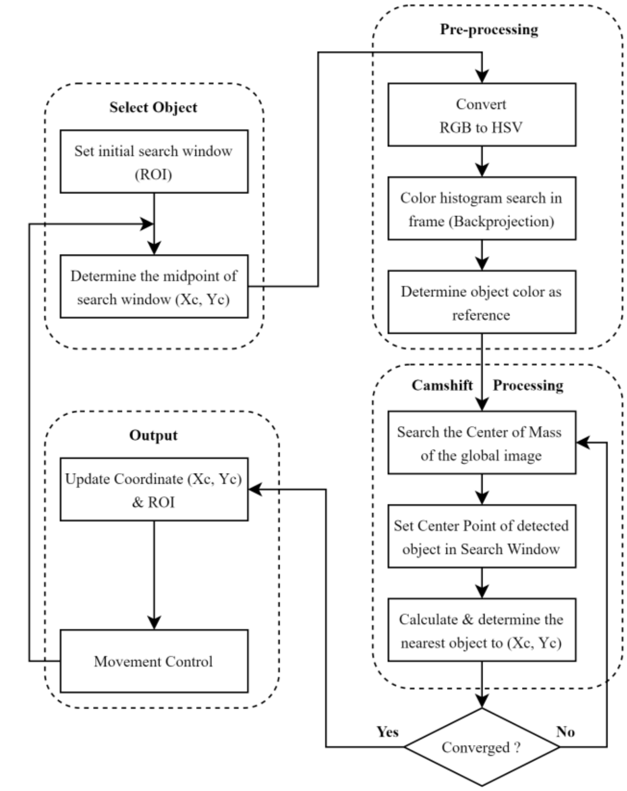


Fig. 3. Flowchart of procedure to detect the object

The second procedure is the pre-processing. The captured image, which has RGB values, is converted in to HSV color. Regarding the ROI, the color histogram of the object is determined based on the backprojection function [18][19][20]. Then, this detected object is converted to binary values [15] [16] [17] to be set as the target reference.

The third procedure is to select and tracking the appropriate object using camshift algorithm [10]. The advantage of the camshift algorithm is able to select and track the objects based on the color even though there are similar objects around the selected object. However, the camshift algorithm tracking is susceptible to interference when a tracking object is occluded or when its hue is similar to the background. The global image is observed using the same steps as explained in Procedure 2. The objects, which have similar values with the target object, are calculated to find the center mass of the objects. The nearest center mass to coordinate (Xc,Yc) is determined as the new midpoint. This midpoint determines the selected object as shown in Fig. 3, which is used to update the object position (Xc,Yc). Then, the movement of the robot is processed using FLC.

B. Movement Control of Trolley Robot using Fuzzy Logic Controller

Some research study about implementing FLC method as a solution to control mobile robots [21][22]. This paper studies FLC, which is developed to control the velocity and navigate the trolley robot. Figure 4 shows the structure of FLC that used in this research.

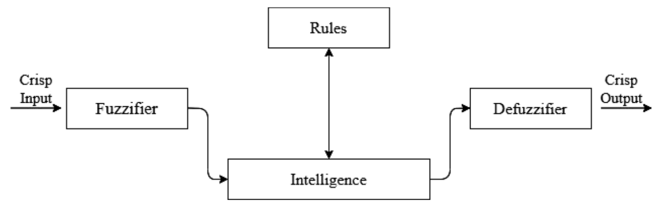


Fig. 4. Method of tracking FLC system

For navigating tasks, the FLC uses two inputs, i.e., distance and position of the captured object, while outputs of FLC are direction and speed of the wheels. The position has values between 0 to 316, which can be defined by five triangular membership functions shown in Figure 5, while the distance has values 50 to 160, which can be defined also by five triangular membership functions, shown in Figure 6.

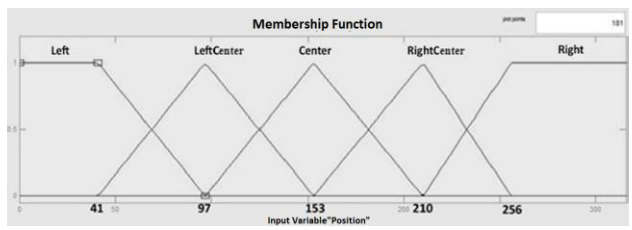


Fig. 5. Membership Function of Position

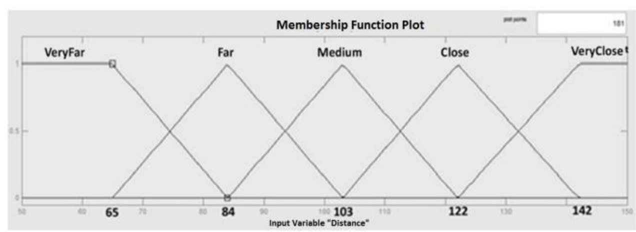


Fig. 6. Membership Function of Distance

The crucial objective of designing FLC is to determine rules regarding the inputs (position and distance) and an output (speed) of the mobile robot [23]. After determining membership function, 25 fuzzy rules are determined based on IF-THEN rules as represented in Table I.

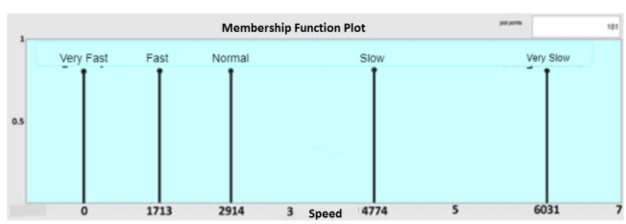


Fig. 7.Membership function for speeds

For speed, five singleton membership functions are determined, i.e., Very fast, Fast, Normal, Slow, very slow as shown in Figure 7.

TABLE I
RULES OF FUZZY LOGIC CONTROL

If	Position	And	Distance	Then	Output
If	Left	*And*	VeryClose	*Then*	Left VerySlow
If	LeftC	*And*	VeryClose	*Then*	Left Slow
If	Center	*And*	VeryClose	*Then*	Stop Delay
If	RightC	*And*	VeryClose	*Then*	Right Slow
If	Right	*And*	VeryClose	*Then*	Right VerySlow
If	Left	*And*	Close	*Then*	Left VerySlow
If	LeftC	*And*	Close	*Then*	Left Slow
If	Center	*And*	Close	*Then*	Forward VeryFast
If	RightC	*And*	Close	*Then*	Right Slow
If	Right	*And*	Close	*Then*	Right VerySlow
If	Left	*And*	Medium	*Then*	Left Slow
If	LeftC	*And*	Medium	*Then*	Left MediumSpeed
If	Center	*And*	Medium	*Then*	Forward VeryFast
If	RightC	*And*	Medium	*Then*	Right MediumSpeed
If	Right	*And*	Medium	*Then*	Right Slow
If	Left	*And*	Far	*Then*	Left MediumSpeed
If	LeftC	*And*	Far	*Then*	Left Fast
If	Center	*And*	Far	*Then*	Forward VeryFast
If	RightC	*And*	Far	*Then*	Right Fast
If	Right	*And*	Far	*Then*	Right MediumSpeed
If	Left	*And*	VeryVar	*Then*	Left MediumSpeed
If	LeftC	*And*	VeryVar	*Then*	Left Fast
If	Center	*And*	VeryVar	*Then*	Forward VeryFast
If	RightC	*And*	VeryVar	*Then*	Right Fast
If	Right	*And*	VeryVar	*Then*	Right MediumSpeed

IV. EXPERIMENT RESULTS

The detected object could be one of two people wearing similar color clothes, as shown in figure 8(c). The person on the left side is labeled as person 1, and that on the right side is labeled as person 2. Table II shows the experimental results of detecting two similar people wearing blue jackets (BJ), i.e., person 1 and person 2. Here, person 1 is the target object. Various distances are determined from 160 cm to 380 cm. Here, person 1 and person 2 walked away simultaneously, the results show that the system can identify the target object (Person 1) appropriately until 360cm. Table III shows the results of calculation and real distance between the trolley robot and the selected person. Table IV shows the result of the trolley movement uses Fuzzy Logic Control. Figure 9 shows the final result of the trolley to follow the user when there is other user with the same clothes.

TABLE II
THE DETECTING RESULTS OF TWO OBJECTS WITH A SIMILAR COLOR

Person 1	Person 2	Selected Person	Camera Distance (cm)	Distance between Person 1 and Person 2 (cm)	Selecting Result
BJ	BJ	Person 1	**160**	60	ok
BJ	BJ	Person 1	**180**	60	ok
BJ	BJ	Person 1	**200**	60	ok
BJ	BJ	Person 1	**240**	60	ok
BJ	BJ	Person 1	**280**	60	ok
BJ	BJ	Person 1	**300**	60	ok
BJ	BJ	Person 1	**320**	60	ok
BJ	BJ	Person 1	**340**	60	ok
BJ	BJ	Person 1	**360**	60	ok
BJ	BJ	Person 2	**380**	60	Failed

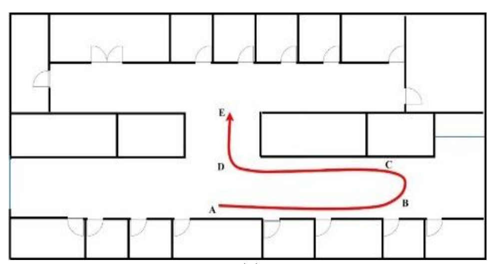
(a) (b) (c)
Fig. 8. (a) HSV Frame; (b) Binary Frame, (c) Real Frame with bounding box

TABLE III
THE RESULTS OF COMPARISON OF REAL DISTANCE AND CALCULATION DISTANCE FROM THE OBJECT SIZE

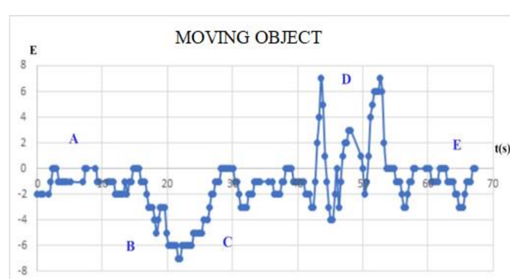
	Pixels		Distance		Error
Selected Person	Height	Width	Calculated	Real	
Person 1	64	47	158.3	160	1.06%
Person 1	73	52	139.7	140	0.20%
Person 1	76	59	118.6	120	1.16%
Person 1	80	66	100.4	100	0.40%
Person 1	88	68	79.5	80	0.60%

TABLE IV
THE FINAL RESULT OF THE TROLLEY TO FOLLOW THE RIGHT PERSON

Selecting	Distance Object from Camera (cm)	Position Object (Angle)	Time (s)	Result
Person 1	240	**-70**	7.14	Ok
Person 1	240	**-65**	7.12	Ok
Person 1	240	**-60**	5.67	Ok
Person 1	240	**-40**	6.71	Ok
Person 1	240	**-30**	6.03	Ok
Person 1	240	**0**	5.89	Ok
Person 1	240	**30**	5.56	Ok
Person 1	240	**40**	6.09	Ok
Person 1	240	**60**	7.37	Ok
Person 1	240	**70**	7.45	Ok



(a)



(b)

Fig. 9. The trolley follows the user in motion (a) Movement plan (b) Graphic of response robot to object

V. Discussion

Generally, selecting and detecting objects have been successfully implemented, and the results show good performances in selecting the right object when two similar objects moves away concurrently, as shown in Table II. The results show that, from 10 attempts with various distances, 9 attempts have detected object appropriately with accuracy 90%. Error occurs when the object distance is more than 360 cm.

The pre-processing image is shown in Figure 8, where the appropriate color of target object is needed to get the true (white) value through the HSV value. The true (white) value is a similar color as the target object, as shown in Figure 8(a) and 8(b). The right target is selected using the camshaft algorithm. The system locks the target position and convert the position and distance of the right object. Figure 8 (c) shows that the system detects the target object correctly, even there is another object wearing a similar color cloth in front of the camera.

The method used is applied in a processor, Jetson Nano, with a python application, which is one of the programming languages that is closest to human language, compared to C# and C++ [24]. The DC motors are connected to the Jetson Nano using Arduino microcontroller to communicate with DC motors [25][26]. Thus, it needs to transfer data from Jetson Nano to microcontroller Arduino. Jetson Nano sends X-coordinate and distance data of the object detected. The data are processed to determine the direction and speed of the robot using FLC. The data from X-coordinate is integrated with the membership function of Position, whereas the data from distance integrated with membership function of Distance. The output of the fuzzy rules is used to control DC motors to determine the trolley movements. Table III shows the results of calculation and real distance between the trolley robot and the selected target (Person 1).

As shown in Table IV shows the result of the trolley moving to the user in different positions. The field-of-view of the camera in the robot is 70 degree. It means the maximum position of the user in the right position is 70 degree and the left position is -70 degree. In this experiment, the robot performs well if the position of the object is 0 degree in front of the robot. When the position of the object is -70 degree or right 70 degree, the robot will take longer to move to the object, as shown in Table IV. Then, the robot was tested to follow a moving object. The movement was evaluated based on the robot trajectory. When following the object in hallways, the robot could move straight, left and right. The object's movement plan from point A to point E is shown in Figure 9(a). The response of the robot when detecting the position of a moving object as shown in Figure 9(b). As shown in Figure 9(b), if the detection result is close to 0 then the robot will move forward, if the detection result is close to -8 then the robot is turning to the left, if the detection result is close to 8 then the robot is turning to the right. The adjustments of control angle and speed of the robot could be very smooth because Fuzzy Logic Control works well with high tolerance, as shown in Figure 5, Figure 6 and Table I.

VI. Conclusion

The design of the Trolley Robot uses Camshift Algorithm to select and detect object has been applied to Mini PC Jetson Nano, Webcam Camera, and LCD touchscreen has a percentage of success of 90%. The trolley robot has also been tested and works effectively to be implemented in Hallways with a width of approximately 1.5 m with straight, left and right movements. In this research, Users can enjoy shopping without pushing the shopping trolley themselves. Fuzzy logic control can be applied to control robot movement based on the results of the image detection. The closer the object is from the center position, the faster the robot moves towards the object. Conversely, the farther the position of the object from the center point, the longer time the robot moves towards the object.

In the future works, the efficiency of selecting the right object for moving can be observed to improve the performance of Fuzzy logic Control and Camshift Algorithm.

References

[1] A. A. S. Gunawan *et al.*, “Development of smart trolley system based on android smartphone sensors,” *Procedia Comput. Sci.*, vol. 157, pp. 629–637, 2019.

[2] H. Bello-Salau, A. J. Onumanyi, D. Michael, R. Isa, C. O. Alenoghena, and H. Ohize, “A new automated smart cart system for modern shopping centres,” *Bull. Electr. Eng. Informatics*, vol. 10, no. 4, pp. 2028–2036, 2021.

[3] K. Ingole and S. R. Khedkar, “Automatic Human Following Trolley Using Raspberry Pi,” *Int. Res. J. Eng. Technol.*, vol. 08, no. 07, pp. 1558–1563, 2021.

[4] E. D. Suryanto, H. Siagian, and D. Perangin-angin, “Design of automatic mobile trolley using ultrasonic sensors,” in *The International Conference on Mechanical, Electronics, Computer, and Industrial Technology (MECnIT) 2017*, 2018.

[5] A. Anil and A. Corresponding, “RFID Based Automatic Shopping Cart,” *Int. J. Adv. Sci. Res. Eng.*, vol. 1, no. 1, pp. 39–45, 2018.

[6] Y. L. Ng, C. S. Lim, K. A. Danapalasingam, M. Loong, P. Tan, and C. W. Tan, “Automatic Human Guided Shopping Trolley with Smart Shopping System,” *J. Teknol.*, vol. 73, no. 3, pp. 49–56, 2015.

[7] S. Sendari, M. S. Hadi, A. N. Handayani, Y. R. Wahyudi, and H. I. Lin, *Implementation of PD (Proportional Derivative) Control System on Six-Legged Wall Follower Robot*, no. cm. IEEE, 2019, pp. 1–6.

[8] W. Li, X. He, and F. Jiao, “Skin region segmentation based on the average preprocessed image of multicolor face image sequence,” *J. Eng. Technol. Sci.*, vol. 46, no. 4, pp. 381–393, Dec. 2014.

[9] W. Budiharto, A. Santoso, D. Purwanto, and A. Jazidie, “A New Obstacle Avoidance Method for Service Robots in Indoor Environments,” *J. Eng. Technol. Sci.*, vol. 44, no. 2, pp. 149–168, 2012.

[10] M. Muladi, D. Lestari, D. T. Prasetyo, A. P. Wibawa, T. Widiyaningtiyas, and U. Pujianto, “Classification of Locally Grown Apple Based On Its Decent Consuming Using Backpropagation Artificial Neural Network,” in *2019 International Conference on Electrical, Electronics and Information Engineering (ICEEIE)*, 2019, vol. 6, pp. 96–100.

[11] S. Saravanakumar, A. Vadivel, and C. G. S. Ahmed, “Multiple object tracking using HSV color space,” in *Proceedings of the 2011 International Conference on Communication, Computing & Security*, 2011, pp. 247–252.

[12] A. Salhi and A. Y. Jammoussi, “Object tracking system using Camshift, Meanshift and Kalman filter Modeling from an Object and Multi-object Tracking System View project Tuni-Shamballa View project Object tracking system using Camshift, Meanshift and

Kalman filter."

[13] D. Lestari, S. Sendari, S. D. Sanjaya, A. N. Handayani, H.-I. Lin, and A. B. Fahmi, "Locking Object Position using Camshift Algorithm for Automatic Trolley," in *2019 International Conference on Electrical, Electronics and Information Engineering (ICEEIE)*, 2019, vol. 6, pp. 90–95.

[14] M. Begnini, D. W. Bertol, and N. A. Martins, "A robust adaptive fuzzy variable structure tracking control for the wheeled mobile robot: Simulation and experimental results," *Control Eng. Pract.*, vol. 64, pp. 27–43, 2017.

[15] Y. Kim and B. K. Kim, "Time-optimal trajectory planning based on dynamics for differential-wheeled mobile robots with a geometric corridor," *IEEE Trans. Ind. Electron.*, vol. 64, no. 7, pp. 5502–5512, 2017.

[16] D. K. Tiep, K. Lee, D. Y. Im, B. Kwak, and Y. J. Ryoo, "Design of fuzzy-PID controller for path tracking of mobile robot with differential drive," *Int. J. Fuzzy Log. Intell. Syst.*, vol. 18, no. 3, pp. 220–228, 2018.

[17] S. Rajwade, A. K. Tiwari, and A. Pandey, "Type-1 Fuzzy Pulse Width Modulation Controlled Motion Planning of Differential Drive 4-Wheeled Power Robot," in *Lecture Notes in Mechanical Engineering*, 2020, pp. 1487–1496.

[18] A. Moscariello *et al.*, "Coronary CT angiography: Image quality, diagnostic accuracy, and potential for radiation dose reduction using a novel iterative image reconstruction technique-comparison with traditional filtered back projection," *Eur. Radiol.*, vol. 21, no. 10, pp. 2130–2138, Oct. 2011.

[19] S. Sendari, D. Lestari, C. U. Kusumohadi, F. S. Wibowo, and K. Anam, "Integrating embedded color vision to Bioloid robot for playing soccer," in *2017 International Conference on Signals and Systems (ICSigSys)*, 2017, pp. 297–302.

[20] I. A. E. Zaeni, S. Sendari, D. Lestari, Y. D. Mahandi, M. Jiono, and M. Syaifuddin, "An Implementation of Multi-object Tracking Using Omnidirectional Camera for Trash Picking Robot," in *2018 Electrical Power, Electronics, Communications, Controls and Informatics Seminar, EECCIS 2018*, 2018, pp. 154–158.

[21] N. I. A. Apandi and A. Martin, "The Integration of Fuzzy Logic System for Obstacle Avoidance Behavior of Mobile Robot," *Int. J. Electr. Eng. Appl. Sci.*, vol. 2, no. 1, pp. 31–38, 2019.

[22] M. R. H. Al-Dahhan and M. M. Ali, "Path tracking control of a mobile robot using fuzzy logic," in *2016 13th International Multi-Conference on Systems, Signals & Devices (SSD)*, 2016, pp. 82–88.

[23] R. Hartono and T. N. Nizar, "Speed Control of a Mobile Robot Using Fuzzy Logic Controller," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 662, no. 2, pp. 58–63, 2019.

[24] "C++ vs C# vs Python | What are the differences?" .

[25] W. Vijitkunsawat and P. Chantngarm, "Comparison of Machine Learning Algorithm's on Self-Driving Car Navigation using Nvidia Jetson Nano," 2020, pp. 201–204.

[26] E. Oneil and I. Sugiarto, "Omni-Directional Mobile Robot Control using Raspberry Pi and Jetson Nano," *Int. J. Ind. Res. Appl. Eng.*, vol. 4, no. 2, pp. 57–62, Aug. 2020.

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