Victim Retrieval System Based on Object Classification on a Hexapod Robot Using a 2-DoF Gripper

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Abstract. This study aims to develop the Barelang F1 hexapod robot for the 2024 Indonesian SAR Robot Contest (KRSRI), in compliance with new regulations requiring the distinction between real and dummy victims during rescue missions. The identified problem is the lack of a system in Barelang F1 capable of differentiating between real and dummy victims. The objective of this research is to implement a detection system using the Huskylens camera sensor, which combines two algorithms: color recognition and object classification, to detect and classify victims. Image processing is conducted without the need for an additional mini-PC, thereby reducing system complexity and hardware costs. The robot employs a two-degree-of-freedom (DoF) gripper as the output mechanism to retrieve victims during rescue missions. The results show that the system achieved a 95% success rate in identifying and retrieving real victims. However, the system's efficiency is constrained by the need to identify victims one by one, leaving room for improvements in time efficiency.

Keywords: Hexapod Robot, Victim Detection, Gripper 2-DoF.

1 Introduction

The Indonesian SAR Robot Contest (KRSRI) is part of the Indonesian Robot Contest division organized by the ministry in charge of universities [1]. KRSRI is a legged robot competition that aims to save victims after a natural disaster. This year, KRSRI raised the theme of the earthquake disaster in Cianjur Regency at the end of 2022 [2]. The Barelang F1 team is one of the participants in the KRSRI division, and it has competed consistently since 2018. The main mission of this contest is to evacuate victims to a safe zone, so several previous studies discuss victim detection and evacuation systems.

The mission for this year's SAR Robot competition was announced three months before the event, challenging participants to create a robot capable of navigating terrain damaged by an earthquake and evacuating victims to a safe zone, represented in the arena. Unlike previous years, the victims this year are categorized into two types: dummy victims and real victims, which are made using a 3D printer and colored orange. Dummy victims do not require evacuation and are designed to closely resemble real

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victims, and the two categories of victims were placed side by side. This change is intended to increase the difficulty level of the competition and challenge the intelligence of the robots.

Currently, the Barelang F1 robot is not equipped with a system capable of distinguishing between real and dummy victims, necessitating the development of an optimal system within a relatively short timeframe. Previous research utilized a mini PC with YOLO methods for victim detection [3]. However, this system was not designed to differentiate between the two categories of victims, as regulations requiring such differentiation were not in place at that time. Although the methods used in that research could be applied to distinguish between real and dummy victims, they involve complex image processing. Other research used microcontrollers and smart vision sensors based on color filtering but focused solely on color detection and could not differentiate between real and dummy victims [4].

Therefore, this study aims to develop a simpler victim retrieval system based on object classification to distinguish between real and dummy victims, utilizing the Huskylens camera without requiring an additional mini PC for image processing. This system is intended to support the development of the Barelang F1 hexapod robot and enhance its success in rescue missions for the 2024 Indonesian SAR Robot Contest (KRSRI).

2 Method

To deal with the problems faced. Huskylens camera sensor is used which has many algorithms in it including being able to classify objects without the need to use an additional mini-PC [5]. In this research, the two main algorithms used so that the robot can effectively recognize the location of the victim and distinguish between dummy victims and real victims are color recognition and object classification algorithms.

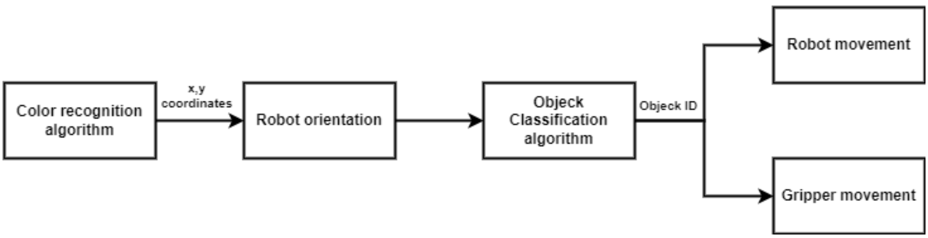


Fig. 1. Block diagram system

Based on the system block diagram in Figure 1. The color recognition algorithm is used to detect and obtain the x and y coordinate values of the detected object, with this algorithm allowing the robot to determine the position of the victim. This step is used for initial navigation and position adjustment of the robot to the victim.

Fig. 2. Color recognition algorithm

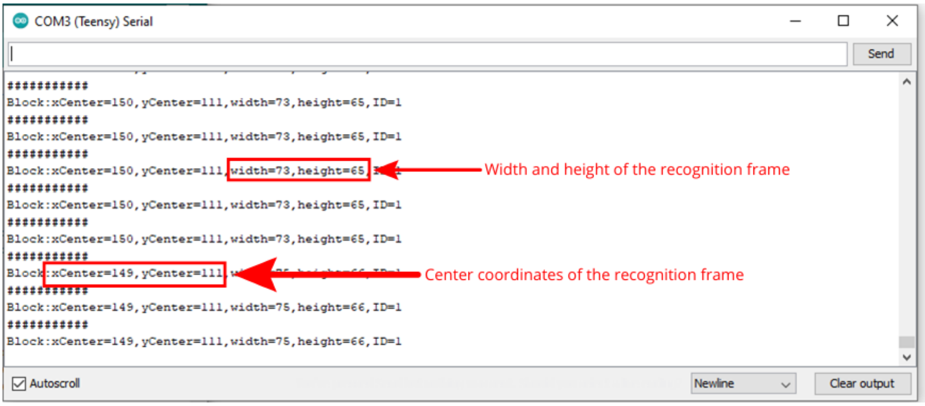


Fig. 3. Result data of detected objects

Meanwhile, the object classification algorithm plays an important role in the victim identification process, where it allows the robot to distinguish between the real victim and the dummy victim based on the visual differences that the two victims have. The combination of these two algorithms ensures that the robot can not only locate the victim but can also make the right decision in executing the rescue mission.

4a. 4b.

Fig. 4. (a) Real victim, (b) Dummy Victim

Based on Figure 4, the differences between the dummy victim and the real victim are evident. The dummy victim is smaller in size compared to the real victim. Additionally, the real victim has distinguishable features such as hands and a head, which the dummy victim lacks. Once the robot successfully identifies the real victim, it proceeds to use the gripper to pick up the victim. In this research, the gripper is designed with two degrees of freedom, utilizing Dynamixel AX-18A and HS5085 MG servos. This design enables the gripper to effectively pick up and lift the victim.

2.1 Gripper Design

In the mechanical design of the robot, the design is adjusted to the regulations of the Indonesian SAR Robot Contest in 2024. The regulation prioritizes the ability of the robot to pass through various obstacles and the robot has at least two legs and a gripper so that it can take victims [2]. The design of the gripper and hexapod robot can be seen in Figure 5.

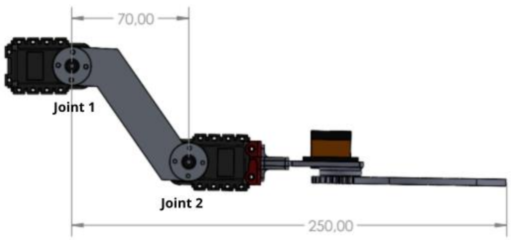


Fig. 5. Gripper design

The gripper design has two degrees of freedom with a gripper link length of 70 mm. The length is a size that has been considered with the overall dimensions of the robot, thus ensuring that the robot still fits in the contest arena. A Huskylens camera will also be placed on the gripper to detect the victim. The servo at joint 1 and joint 2 uses an AX-18A servo, while the HS5085 MG servo is used for gripping the victim.

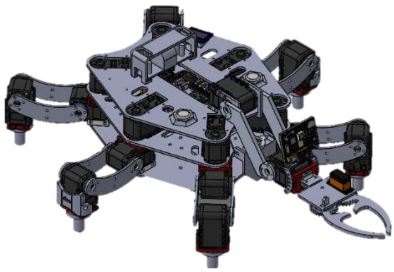


Fig. 6. Design of hexapod robot with gripper

Figure 6 is a hexapod robot design that has been installed with a gripper. The gripper is placed on the front side of the robot to allow the robot to easily access and grasp the victim while executing the rescue mission.

2.2 Design Hardware

Hardware design is carried out to determine the components that will be used by the plan so that the entire system can work properly. Figure 7 is a hardware block diagram of the hexapod robot system used in this research.

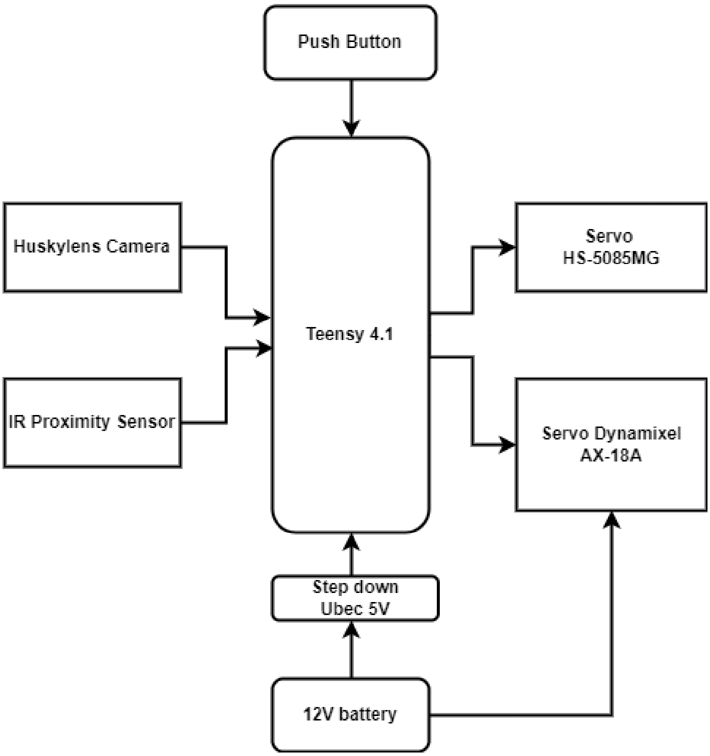


Fig. 7. Research hardware design

Figure 7 illustrates the block diagram of the hardware design used in this research. the microcontroller used is Teensy 4.1. Huskylens camera is used to detect the victim using I2C communication. The IR proximity sensor serves as a validation tool to indicate when the victim is within the gripper range to be grasped. In addition, AX-18A servos and HS5085 MG servos are used as robot actuators, moving the legs and gripper to perform various tasks such as walking, lifting, and moving objects but communication between the Teensy 4.1 and the Dynamixel AX-18A Servos, the 74LS241 IC is required to differentiate between the data transmitted and received from the microcontroller [6].

2.3 Victim Retrieval System Design

The system design has been adapted to meet these requirements. The color recognition algorithm was chosen because it can provide the positional coordinates of detected objects, whereas the object classification algorithm does not offer this capability [5]. In this camera implementation, the x coordinate can be divided into three possible situations, of which the center point of the camera is considered the center of the system [7]. X >= 0 && X <= 146 indicates the object is on the left, X >= 176 && X <= 320 indicates the object is on the right, and X >= 146 && X <= 176 indicates the object is in front of the robot. The flowchart of the designed victim retrieval system can be seen in Figure 8.

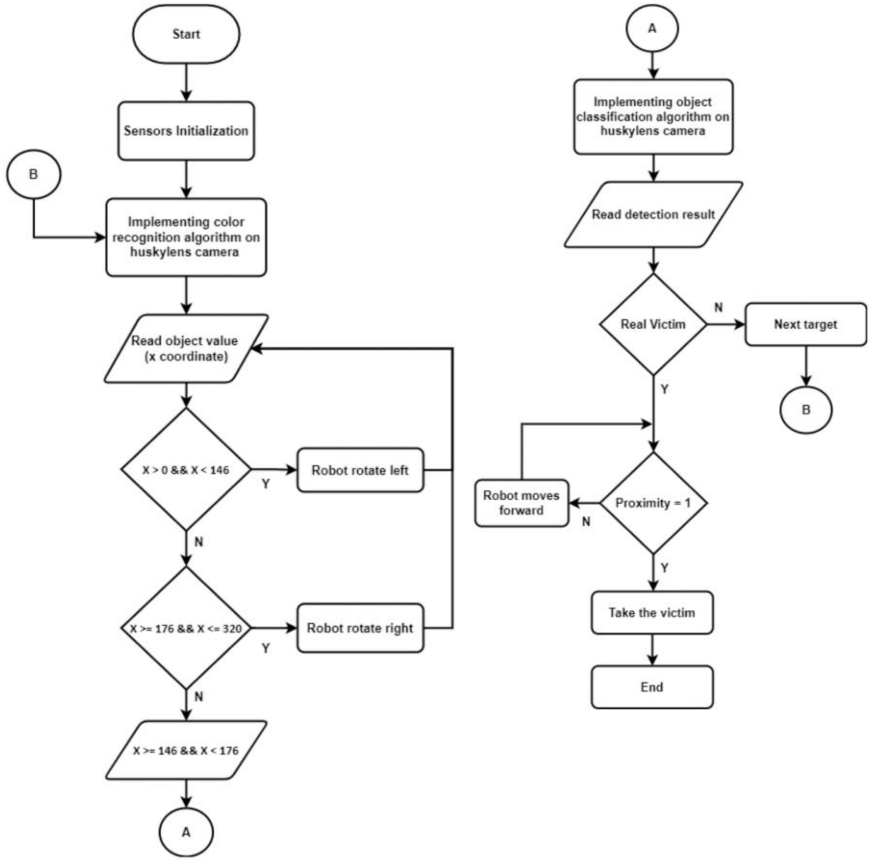


Fig. 8. Flowchart of victim retrieval system design

Here is an explanation based on the flowchart of the object retrieval system design:

1. The robot initializes the sensors.
2. The camera applies color recognition algorithms as an initial step to recognize objects.
3. The camera detects the color orange and sends the coordinates of the detected object's position.
4. The robot adjusts its position to be precisely centered on the object.
5. The camera applies the object classification algorithm to determine whether the detected object is a real victim or a dummy victim.
6. If a dummy victim is detected, the robot will move to the next target object and reapply the color recognition algorithm to adjust its position to be centered on the object.
7. If a real victim is detected, the next step is to read the proximity sensor value.

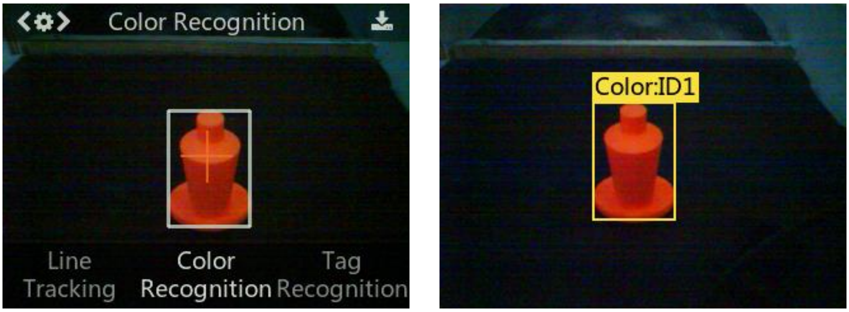
8. If the proximity sensor value is 1, the robot will grasp the object.
9. If the proximity sensor value is 0, the robot will advance until the proximity sensor value is 1, and then it will grasp the object.

3 Result And Discussion

3.1 Huskylens Camera Testing

Testing of the Huskylens camera will be conducted using two algorithms: color recognition and object classification. This evaluation aims to determine the accuracy and performance of the Huskylens camera in detecting and identifying objects. The results will help assess whether the camera is suitable for use in the designed system.

Color Recognition Algorithm. Color recognition is a method in digital image processing used to identify specific colors. This color recognition operates based on color models [8]. In the color recognition algorithm on the Huskylens, initial learning is required for accurate color detection. To initiate learning, position the "+" symbol over the target as shown in Figure 9, then press and hold the learning button on the Huskylens. Release the button to complete the learning process. The results of the learning phase are illustrated in the figure below.



a. b.

Fig. 9. (a) Learning process on color recognition algorithm, (b) Learning result on color recognition algorithm

Testing the color recognition algorithm involves evaluating its performance against both detection distance and light intensity. The distance between the object and the Huskylens camera is measured using a rolling meter. To assess the algorithm's performance with varying light intensities, a BH1750 sensor is placed next to the object to measure the ambient light level [9]. The test results indicate that the Huskylens camera can detect colors at a maximum distance of up to 2.5 meters. Optimal detection occurs when the light intensity falls within the range of more than 30 lux and less than 600 lux.

Object Classification Algorithm. Classification is an algorithm that uses a set of features describing an object to determine the category or class of each object [10]. An initial learning process is required to use the object classification algorithm on the Huskylens. This process involves recognizing the features of each type of victim so that the algorithm can accurately distinguish between real and dummy victims. To perform object learning, point the bounding box at the targeted object, then press and hold the learning button until the display shows "Learning XX/30 ID:1," as illustrated in Figure 10. This indicates that the HuskyLens is learning the object. Table 1 presents the test results of the object classification algorithm in recognizing victims, where the real victim is marked as "ID1" and the dummy victim as "ID2."

Fig. 10. Learning process on object classification algorithm

Table 1. Object classification algorithm testing

Actual object	Detected	Detection Result
Real victim "ID1"	Real victim "ID1"	

Actual object	Detected	Detection Result
Dummy victim “ID2”	Dummy victim “ID2”	

3.2 Gripper

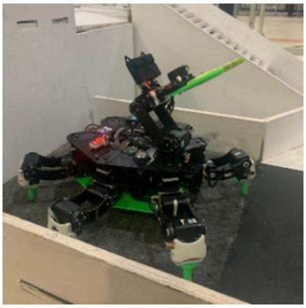
The gripper is a critical robot component designed to function as an object holder [11]. Its structure can be adapted to the shape of the object, ensuring successful object retrieval. In this study, the gripper design has been tailored to effectively grip the victim. The number of joints in the robot manipulator determines its degrees of freedom (DoF), with more joints allowing for greater movement versatility [12]. The gripper in this research has two degrees of freedom, as it includes two joints that enable it not only to grip but also to lift the victim. The servo positions and the corresponding gripper control table used in the victim lifting process are illustrated below.

Fig. 11. Position of the servos on the gripper

Table 2. Servo controlling value

Position	Servo 1	Servo 2	Servo 3
Ready	820	1023	50
Scanning	540	1000	80
Retrieving victim	208	590	80
Lifting victim	680	470	50

Servo 1 and Servo 2 utilize AX-18A servos, which require position values within a range of 0 to 1023 to set their positions, differing from Servo 3, which uses degree values for positioning. The gripper positions based on the values listed in Table 2 are illustrated in Figure 12.


a.


b.


c.


d.

Fig. 12. a.Ready position, b.Scanning position, c.Retrieving victim position, d.Lifting victim position

The "ready position" refers to the state of the robot when it is first powered on. The "scanning position" is when the robot is actively trying to recognize a victim, with the gripper facing downward to align the Huskylens camera for detection. The "victim retrieval position" is when the gripper is lowered to pick up the victim. Finally, the "victim lifting position" occurs when the gripper is raised to lift the victim.

3.3 Victim Retrieval System

There are several victim rescue points in the Indonesian SAR Robot Contest in 2024. In the regional contest, there are two points of victim rescue where there are dummy victims so it requires the robot's ability to identify the original victim in the rescue. The following is a picture of the regional contest arena.

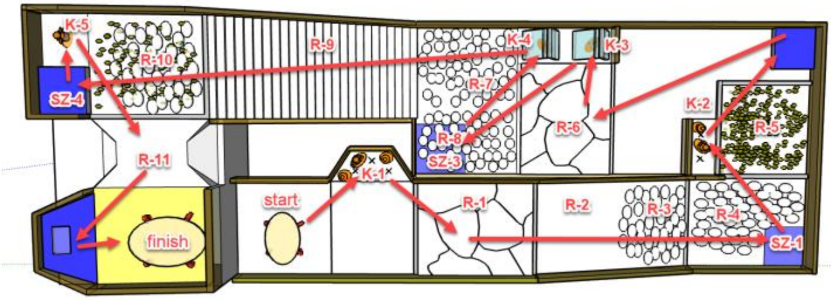


Fig. 13. KRSRI 2024 regional contest arena

The illustration of the arena in the contest area above shows that the KRSRI arena in 2024 includes obstacles that must be navigated, areas where victims need to be rescued, and safe zones designated for placing victims, each marked with specific codes. The code "K" is used for victim location areas. The arena indicates that five victim location areas require rescue, with dummy victims placed in areas K-1 and K-2. Tests were conducted in both of these locations. The system test results for location area K-1 are presented in Table 3.

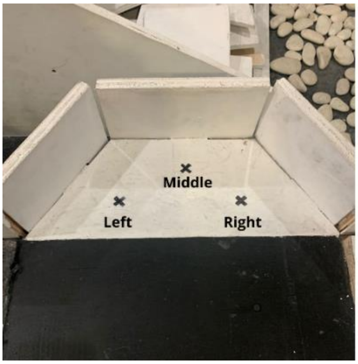


Fig. 14. Victim positions in the K-1 location area

Table 3. System testing in the K-1 location area

Real victim position	The success of the system		Time used (s)	
	Real victim detection	Real victim retrieval	Real victim detection	Overall time
Left	Success	Success	19	24
Middle	Success	Success	7	12
Right	Success	Success	6	11

Real victim position	The success of the system		Time used (s)	
	Real victim detection	Real victim retrieval	Real victim detection	Overall time
Left	Success	Success	18	23
Left	Success	Success	9	15
Right	Success	Success	6	12
Right	Success	Success	5	10
Middle	Success	Success	6	11
Middle	Success	Success	4	10
Right	Success	Success	6	12
Middle	Failed	Failed	9	14
Right	Success	Success	5	12
Left	Success	Success	12	18
Left	Success	Success	10	16
Right	Success	Success	6	12
Right	Success	Success	4	9
Right	Success	Success	4	10
Middle	Success	Success	7	14
Left	Success	Success	10	15
Left	Success	Success	12	18

From the table of test results conducted at location area K-1, the system successfully retrieved the real victim 19 times out of 20 trials, showing a high success rate in detecting and evacuating victims. Next, testing was carried out on location area K-2, with the results shown in Table 4.

Fig. 15. Victim positions in the K-2 location area

Table 4. System testing in the K-2 location area

Real victim position	The success of the system		Time used (s)	
	Real victim detection	Real victim retrieval	Real victim detection	Overall time
Left	Success	Success	11	18
Right	Success	Success	5	13
Right	Success	Success	6	14
Left	Success	Success	13	19
Left	Success	Success	10	16
Right	Success	Success	5	11
Left	Success	Success	9	15
Left	Success	Success	15	22
Right	Success	Success	6	12
Left	Success	Success	8	15
Right	Success	Success	6	12
Left	Success	`Success	11	18
Right	Success	Success	4	11
Right	Success	Success	5	11
Left	Failed	Failed	6	12
Left	Success	Success	9	16
Right	Success	Success	7	13
Left	Success	Success	9	15

Real victim position	The success of the system		Time used (s)	
	Real victim detection	Real victim retrieval	Real victim detection	Overall time
Right	Success	Success	4	10
Right	Success	Success	6	13

From the table of test results conducted in the K-2 location area, the system successfully detected real victims 19 times out of 20 trials. This demonstrates that the system maintained a high success rate in detecting and evacuating victims in that area, consistent with its performance in the K-1 area. Overall, the data shows that the system successfully detected real victims 38 times out of 40 trials. Detection failures in several trials occurred due to errors in the Huskylens camera, which identified dummy victims as real ones. This issue is most likely due to an incomplete training process, leading to errors in distinguishing between victim types. The system's success rate can be calculated using the following equation:

$$Success\ percentage = \frac{Total\ success}{Total\ number\ of\ tests} x100\%$$

$$Success\ percentage = \frac{38}{40} x100\% \tag{1}$$

Based on the results of system testing conducted in the K-1 and K-2 location areas, the system demonstrated good performance with a success rate of 95%. This indicates that the system can be relied upon for victim rescue in the Indonesian SAR Robot Contest in 2024. The 5% failure rate in the system was due to the Huskylens camera misidentifying objects, which resulted in victims not being detected correctly. However, this relatively small error percentage shows that even without the use of an additional mini-PC, the system is already quite effective and reliable in executing rescue missions. A demonstration of the system can be seen in the following video link: https://youtu.be/BHCsXiocwu0?si=5Ro9Cx-OlDpFk1Jy.

4 Conclusion

Based on the results of this research, the Barelang F1 hexapod robot is capable of identifying both dummy and real victims without the need for an additional mini PC in the system. This not only makes the system more lightweight but also reduces the complexity and cost of the required hardware. Additionally, the Barelang F1 robot can retrieve victims using its two degrees of freedom (DoF) gripper. The combination of these features results in a system that can detect and retrieve victims with a 95% success rate. However, one drawback is that the robot must identify victims one by one, which slightly increases the time required for the process.

In the future, the Barelang F1 robot is planned to be equipped with a mini-PC to achieve better efficiency. The expected outcome is that the robot will be able to detect and identify victims more quickly, saving time and enhancing the overall effectiveness of the system in rescue missions.

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