Object detection for autonomous search and rescue quadrotor application

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Abstract. Indonesia is located in the ring of fire zone. It causes a high risk of disaster threats. Volcanoes and earthquakes are unpredictable sources of natural disaster in a massive size, which many times caused an inaccessible area. We need to prepare how to overcome this situation. Quadrotor is an aerial vehicle that can access the disaster location easily and passing through many obstacles. Its autonomous ability can increase searching efficiency. Object detection will be a primary parameter which responsible to move the quadrotor. In this paper, we proposed to use cascaded Canny Edge with SURF clarified with SIFT to get more robust detection in real-time application. Our method is using image detection in guiding the quadrotor movements. First, we detect the object by cascaded Canny Edge with SURF and ORB, both of them checks whether the target is true or not. When both methods approved that target have been detected, then the process uses only the cascaded Canny Edge with SURF methods to locate the victims and to decrease the image processing time. Output of this image detection method applies into our quadrotor control movements, by using simple Proportional Integral Derivative (PID) control. This visual feedback control guides the quadrotor flies to the target and note the victim position and reported in its log. This paper will also provide data comparison between our method with the only SURF and the only ORB method to do the same task.

1. Introduction
Autonomous SAR Quadrotor is an excellent disaster response tool. Choosing the sensors involved gives it an upgrade capability as a SAR tool to become an important help in SAR operations. The capability of sensors needs to be added to increase effectiveness in finding victims of natural disaster [1]. A standard camera on a SAR Quadrotor is only able to retrieve the picture of disaster area, furthermore SAR team needs more information. In added to its capability in increasing the effective use of a quadrotor, a method is implemented in the detection. Another challenge to have a good detection from a quite distance to the target is accuracy and precision. Also in a disaster conditions where the victims and its surroundings have a similar colour and many dimensions of items to be analyse, we propose an improvements of objects detection by using cascaded canny edges with SURF in parallel with ORB.

The implementation of cascaded canny edge with SURF method to identify victims at the affected areas helps SAR teams in reducing response times. To get more accuracy and precision in the first detection, we also report the use of ORB method on the result of using canny edge with SURF. Experiments show us the improvement, accuracy and process time in implementing our propose method in image detections.
2. Quadrotor system
We built a system to search the victims of natural disasters by using a camera which embedded in the quadrotor. The camera has resolution of 720p that gives us an image dimensions of 25 x 60 pixels from a human size 45 x 165 cm with a 12 meters distance. The quadrotor has a 30 cm length of each rotor arm which attached to the main board of a 10 cm radius. The battery uses 4-cell lithium polymer with 5200 mAh with its weight of 460 grams. Camera calibrated using the Rodriguez equations and gives relation between pixels and metric measurements. Quadrotor flies and takes videos of the affected area and then image detection algorithm looking for the disaster victims in every frame of the video. The location of victims becomes input parameter to move the quadrotor and the movements will be visually feedback to give correction of target position.

3. Image detection
Object detection is currently being discussed by many people. There are many methods of object detection. Nowadays, SURF is one of a good detection method. Speeded Up Robust Feature (SURF) is a detection scheme by finding unique features from a given image [4-6]. The detected feature can be verified even though the image provided has a different angle from the initial reference image. This is one of the strengths of the SURF election. in natural disaster conditions, we cannot determine whether the drones that we make come from the same direction or from other direction orientations, so that disaster victims caught by the camera become undetected due to differences in orientation angles [7-9], but the use of SURF can still be increased again in terms of accuracy and time of image processing. In addition to the increased processing time, the very complicated impacted area become the background of the need to improve the accuracy of victim tracking.

4. Feature matching
Speeded up Robust Feature is a feature detector, descriptor and matcher. It find some feature of an image, to be checked. Then the feature will be evaluated whether it has a same feature to the target image or not. The feature taken from the image are unique to their neighbourhood feature. If it there are no any other similar pixel so it is stated as a feature. SURF is a good Feature extractor because its capability to check in every degree of orientation. So we can use the SURF to detect image from every orientation image.

Orientated FAST and Rotated BRIEF (ORB) is another method that serve a feature extractor and matching that also scale invariant [12-13]. ORB can detect rotated image same like SURF and SIFT. The ORB detection is also a fast detection. In normal condition the ORB gives 15% faster time of process than the SURF does. But the ORB limits only 500 feature that can be extracted, so we cannot gain more than 500 feature from the ORB in any condition. Previous research has try to improve the ORB with SURF method [11], it shows that it has better time response from SURF and has better accuracy. But the improved ORB by using SURF method is only an image detection. They have not develop it for a video detection.

Canny Edge Feature is an edge detector that evaluates every pixel in the image. Canny edge feature compare every pixel to its neighbour pixels [2-3]. When it is stated as a unique pixel, and there are any sudden change of the pixel colour, so it is stated as an edge. This counted edge is then transformed into white line. The other the other pixel that is not an edge, then transformed into black pixel. So the final image from the canny edge feature is a black and white picture.

The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used.

4.1. ORB and Cascaded Canny edge with SURF
An upgrade detection process is needed to handle the detection process. The invariant detection from SURF used in this built system. But the original SURF image does not provide much detected feature and matched. Canny edge then take over the difficult image to be simplified into simple image. Our
previous research shows that cascaded canny edge with SURF algorithm could serves a better object detection method to the only SURF, and SIFT algorithm. But we want to try to make sure that the image detection detect a true object. We place ORB detection to detect the object to make sure that the image is true, so it also checked by the ORB detection method. The ORB is a fast object detection, but sometimes it fails to detect image, so we decide to use the ORB to be combined with our previous method. Our system calculated the ORB as long as the canny edge with SURF method calculated the image. By this way, it can reduces the calculation time. Although we can reduce the time process, but it evaluated through the ORB method. In a short way it will be better because of the double checking method in one time.

5. Quadrotor
The detected object from the image is an input to move drone to the target. When the target is found then the Proportional Integral Derivative control system implemented from the quadrotor to make sure that the detected object is a victim not any other image. The quadrotor speed is set to 0.5 m/s to reach the target.

6. Result
We use Intel® core™ i3-2340M CPU @2.30GHz, and 4096MB RAM to run the algorithm. We checked all of the algorithm through at least 200 times. We count the average data for every method included the comparing method kit.

We calculate the image accuracy by calculating the true matched feature from every matched feature. The accuracy is counted as the following equation:

\[
\text{accuracy} = \frac{\text{correct feature matched}}{\text{total feature matched}}
\]  

The ORB and cascaded canny edge with SURF shown in figure 3 gives a higher accuracy compared to the cascaded canny with SURF as shown in figure 2 and also the only SURF as shown in figure 1. This higher accuracy obtained from the feature extracted from the ORB and Cascaded canny edge with SURF gives more feature than the cascaded canny with SURF. In line with more feature extracted, so it has more option to be matched from the image.

We also checked the success detection rate from the image. From 200 frame, we count how many frame get lost of detection. The success rate is successful detection compare with all of 200 frame that counted in our test. The successful detection rate is counted as the following equation:

\[
\text{Success detection} = \frac{\text{detected frame}}{\text{total frame}}
\]  

The ORB with cascaded canny edge with SURF gives the same success detection rate with the cascaded canny edge with SURF algorithm. But our proposed method has more success detection rate compare with the only ORB detection algorithm.

Figure 1. SURF detection algorithm
The ORB and cascaded canny edge with SURF evaluation parameter is shown in this following table 1

| Method                        | Accuracy | Avg. feature matched | Success detection rate | Execution time |
|-------------------------------|----------|----------------------|------------------------|----------------|
| SIFT                          | 50 %     | 4                    | 85 %                   | 233 ms         |
| SURF                          | 46 %     | 15                   | 90 %                   | 300 ms         |
| ORB                           | 48 %     | 100                  | 65 %                   | 230 ms         |
| Cascaded Canny Edge with SURF | 52 %     | 45                   | 90 %                   | 280 ms         |
| Serial ORB and Cascaded       | 64 %     | 150                  | 90 %                   | 550 ms         |
| Canny Edge With SURF          | 64 %     | 150                  | 90 %                   | 282 ms         |

The table shows that the ORB can increase the cascaded canny edge with SURF detection algorithm. It increase the matched feature from the parameter image. A higher matched feature parameter make more precise detection compared to the less feature parameter. Although there are some feature that mismatch, but more feature gives more accurate location object.

But the ORB usage takes much more time than the cascaded canny edge with SURF, but by using the multiprocessing we can eliminate the time process by processing the ORB parallel with the cascaded canny edge with SURF. So it reduce much time by using two cores of our environment.

We checked the detection object process in 100 frame. We evaluated their detection capability. The accuracy calculated through our test to find whether the feature is correct or not. It shows that the parallel ORB and cascaded canny edge with SURF provides a better accuracy. As we proposed that the double check system makes the detection method more robust. But by using the parallel form, it
doesn’t make the execution time to be very long, but it only takes as long as the normal cascaded canny edge with SURF works.

We apply our image processing in our quadrotor to find the object and approach the object. Our test shows that by using ORB and Cascaded Canny Edge with SURF, gives a smooth movement response. The quadrotor moves through the x axis after it found the target. It detect the target continuously so the quadrotor moves stable with constant velocity to the target. The Inertial Measurement Unit(IMU) data shows the quadrotor movement autonomously. Figure 4 shows the quadrotor position in x, y, z axis. It moves constantly through the x axis.

![Figure 4. IMU data in x, y, z position](image)

The graphic shows the movement of our quadrotor. It shows that the quadrotor can move by using our algorithm. The algorithm has been implemented in the quadrotor and succeed to do the task. The line in the graphic above shows that the quadrotor moves from initial point to the final point.

7. Conclusion and Future Works
Our proposed method Parallel ORB and Cascaded Canny Edge with SURF gives 12% more accuracy from our recent tested algorithm accuracy. The average feature matched is also increase by 50% to the ORB algorithm, and 300% higher than the cascaded canny edge with SURF method.

The success detection rate is stable at 90% comparing with the cascaded canny edge with SURF. But it still 25% better than the ORB algorithm 5% better than the SIF algorithm method.

The Parallel ORB and Cascaded Canny Edge with SURF can detect the victim and can be implemented in quadrotor to find the victim.

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References
[1] A. Rivera, A.D.D.Villalobos, J.C.N.Monje, J.A.G.Marinas and C.M.Oppus, "Post-disaster Rescue Facility: Human Detection and Geolocation Using Aerial Drones," 2016.
[2] Xu, Zhao, "Canny Edge Detection Based On Open CV," 2017 IEEE 13th International Conference on Electronic Measurement and Instrument, pp. 53-56, 2017.
[3] H. Bay, A. Ess, T. Tuytelaars and L. V. Gool, "Speeded-Up Robust Features (SURF)," Science Direct, pp. 346-359, 2007.
[4] J. T. Pedersen, "Study Group SURF: Feature Detection and Description," SURF: Feature
Detection and Description, pp. 1-12, 2011.

[5] An, Shan, "Face Detection and Recognition with SURF for Human-Robot Interaction," Internal Journal of Advances in Science Engineering and Technology, pp. 1946-1951, 2009.

[6] B. U. Umar, A. James, A. Aliyu, J. G. Kolo and O. S. O. O. M. Owolabi, "Human detection using speeded-up robust features and support vector machine from aerial images," in 2017 IEEE 3rd International Conference on Electro-Technology for National Development (NIGERCON), 2017.

[7] E. Oyallon and J. Rabin, "An Analysis of the SURF Method," Image Processing On Line, pp. 176-218, 2015.

[8] A. M. Gupta, B. S. Gupta, C. S. Kumar and D. L. Behera, "An on-line visual human tracking algorithm using SURF-based dynamic object model," in 2013 20th IEEE International Conference on Image Processing (ICIP), Melbourne, Australia, 2013.

[9] J. Li, J. Zhang, Z. Zhou, W. Guo, B. Wang and Q. Zhao, "Object tracking using improved Camshift with SURF method," in 2011 IEEE International Workshop on Open-source Software for Scientific Computation (OSSC), Beijing, 2011.

[10] L. Yuan and X. Xu, "Adaptive Image Edge Detection Algorithm Based on Canny Operator," IEEE Xplore, pp. 28-31, 2015.

[11] Z. J. S. D. Wang Xu, "An Improved ORB Image Feature Matching Algorithm Based on SURF," in 2018 3rd International Conference on Robotics and Automation Engineering (ICRAE), November 2018.

[12] X. X.-Z. Shu Cai-Wei, "ORB-Oriented Mismatching Feature Points Elimination," in 2018 IEEE International Conference on Progress in Informatics and Computing (PIC), December 2018.

[13] X. H. C. H. Qin Yanyan, "Image feature points matching via improved ORB," in 2014 IEEE International Conference on Progress in Informatics and Computing, May 2014.