Human Detection and Avoidance Control Systems of an Autonomous Vehicle

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Abstract. A long-range and short-range navigation systems of an autonomous vehicle are the most important thing to develop because it is very complex and related to safety in the driving of an automatic vehicle. The purpose of this research is to develop a short-range navigation system for autonomous vehicles focused to detect and avoid humans which implemented on an autonomous vehicle prototype. Image Processing and deep learning algorithm used for human detection and ultrasonic sensor used for distance calculation. Decision making for human avoidance system using the Fuzzy algorithm based on the position of detected human and human distance. The implemented system has a success rate of 85.71% to avoid human which ideal distance more than 2 meters. The implemented prototype of an autonomous vehicle can be implemented in the real vehicle with some adjustments in the sensor and hardware system, however, the systems are expected to reduce traffic accidents caused by human error.

1. Introduction
Autonomous vehicles or a self-driving vehicle is a computer-controlled car that can drive by itself, known surrounding environments, make decisions and operated without human. There are many major benefits in the implementation of an autonomous vehicle: Improving traffic conditions, Business Opportunities and Increasing Revenue, Ease of Use and Convenience, Consumer-Centric Experience, Autonomous parking and the most important benefit is improved safety and reduce traffic accidents especially caused by human error [1,2]. A traffic accident is a major source of disability and mortality, every year 50 million people injured by traffic accidents and 1.2 million dies [3].

Autonomous vehicle technology is one of the most important topics to be developed [4], however, automatic navigation systems in a dynamic environment is still a challenge to be implemented in the real world. One of the cases is a close-range navigation system where the vehicle must be able to navigate safely among around objects such as people or other vehicles that move with implicit uncertainty from around the environment and the perceptions of the system boundaries [5]. There are many research to develop autonomous vehicle including environments sensing [6-8], processing and decision making [9,10], and also controlling vehicle [11,12].

This research will develop a close-range navigation system on an autonomous vehicle focused to detect and avoid collision between vehicles and humans. One method of detect humans is using a Histogram of Oriented Gradient (HOG) and Support Vector Machines (SVM) [13]. However, in this
research the human detection system using image processing with You only look once (YOLO) deep learning algorithm and for the human avoidance decision-making systems using fuzzy algorithms based on human position data and distance data taken using an ultrasonic sensor.

2. Method
This research has two important points, the system to detect and recognize human and its position and the decision-making system to avoid collision with the human.

2.1. Human Detection Systems
Generally, the method of object detection algorithm in image processing is repeating the classifier or localizer systems and implemented the models to the image on any locations and scales, the area with the highest value is the detected object. However, the YOLO algorithm implementing a different method for object detection. Yolo uses a single neural network to an image. The networks divided into several regions and predicting the bounding box and calculating the probability of each region (Figure 1).

\[ s = \left( \frac{x_0}{t} \right) \times F \]  

(a) \hspace{2cm} (b)

**Figure 1.** Sample object detection, (a) Human detection, (b) Human Position

Error! Reference source not found.a is a sample of human detection using YOLO algorithm. The systems detect the human object with its accuracy, the algorithm can also detect the human object with the various pose. The position of the detected object to the center of the camera calculated by equation 1. The example of position in Error! Reference source not found.b.

2.2. Human Avoidance Decision systems
The Algorithm for human avoidance system using Fuzzy Tsukamoto. There is four input for the fuzzy system are: object degree (OD), object distance from left (ODL), object distance from right (ODR) and object distance from center (ODC). The fuzzy system has two outputs are: steering degrees (SD) and vehicle speed (VS). The simple fuzzy set described in Figure 2.
2.3. Vehicle Prototype
The system implemented to the autonomous vehicle prototype with size about 75 cm x 50 cm as described in Figure 3. the prototype using the Ackerman steering system, where the drive system separated from the steering system. This condition requires precision control because a small error of the control caused large odometry error. The control system uses the defuzzification data from fuzzy systems to control steering and vehicle speed.

![Image](image1.png)

**Figure 2.** Fuzzy Set

![Image](image2.png)

**Figure 3.** Vehicle prototype (a) 3D view, (b) Ackerman systems

3. Results and Discussion
Based on the implementation of the system and algorithm, the following result is obtained.

3.1. Human Detection systems Result
The human detection system tested to detect human objects with distance from 1 to 7 meters adjusted by vehicle prototype and camera specification. The result described in Table 1. At 1 meter of the distance, the detection accuracy is very low because the object captured incomplete by the camera. The complete object captured with the distance from 2 to 7 meters. In this area, the accuracy of the detected image is high.
Table 1. Human detection result

| Distance (m) | Detected | Accuracy (%) |
|--------------|----------|--------------|
| 1            | yes      | 42           |
| 2            | yes      | 87           |
| 3            | yes      | 95           |
| 4            | yes      | 99           |
| 5            | yes      | 98           |
| 6            | yes      | 97           |
| 7            | yes      | 85           |

Success average 74.14

The accuracies level of the detected object affected by the distance of the object. Closer or farther an object caused the accuracies level is smaller. The highest accuracies level at 2 meters of distance with a value of 99%.

3.2. Object Position
The possible object position based on camera specification is 39° to left and right from centre of the camera, the testing value for the position between 0° to 30° as described in Table 2, the position of the detected object has an error rate 2.44°.

Table 2. Object position result

| Position (°) | Detected position (°) | Error (°) |
|--------------|------------------------|-----------|
| 0            | 1.82                   | 1.82      |
| 10           | 8.165                  | 1.84      |
| 20           | 18.281                 | 1.72      |
| 30           | 34.368                 | 4.37      |

Error average 2.44

The error value caused by inaccuracy on real object position and by tolerance value of the field-of-view of the camera.

3.3. Human Avoidance Decision Result.
Human avoidance systems using a fuzzy algorithm, there are 4 input OD, ODL, ODC, ODR, and two output SD and VS. output system testing compared to manual output Steering Direction manual (SDM) and vehicle speed manual (VSM) with manual calculation. The result there is an error rate of 0.0240 for the steer direction and 0.032 for the vehicle speed. The data described in Table 3.

Table 3. The human avoidance decision result

| No | Input | System Output | Manual output | Error |
|----|-------|---------------|---------------|-------|
|    | OD    | ODL | ODC | ODR | SD | VS | SDM | VSM | ESD | EVS |
| 1  | 80    | 40  | 100 | 50  | 8.29 | 117.14 | 8.26 | 117.1 | 0.03 | 0.03 |
| 2  | 125   | 125 | 125 | 125 | 10.14 | 63.57 | 10.16 | 63.6 | 0.02 | 0.03 |
| 3  | 110   | 120 | 105 | 100 | 12.29 | 67.14 | 12.26 | 67.1 | 0.03 | 0.04 |
| 4  | 99    | 33  | 103 | 213 | 8.92 | 118.2 | 8.90 | 118.17 | 0.02 | 0.03 |
| 5  | 130   | 53  | 75  | 125 | 7.5 | 65.83 | 7.48 | 65.8 | 0.02 | 0.03 |

Error average 0.024 0.032
3.4. System Result
The detection system and decision system are combined and tested to find the success rate of the system to avoid humans from the collision. The testing based on the distance between humans and the vehicle from 1 to 7 meters. Every point of distance tested 5 times. The result described in Table 4. The success criteria are if the vehicle no collision with the human.

Table 4. System testing result

| Distance (m) | Success rate (%) |
|-------------|------------------|
| 1           | 20               |
| 2           | 80               |
| 3           | 100              |
| 4           | 100              |
| 5           | 100              |
| 6           | 100              |
| 7           | 100              |

Success average 85.71%

Based on Table 4 with using the model and weight configuration for yolo algorithm, the success rate for the avoidance systems is 85.71% with ideal avoidance distance more than 2 meters.

4. Conclusion
The implemented yolo algorithm can detect and recognize the human or pedestrian with a success rate of 100% with accuracies average 74.14%. The fuzzy system with the rule and data above success to avoid collision with the human with error only 0.024° for steering degree and 0.032 for vehicle speed. The whole system with implemented to the vehicle prototype success to detect human and avoid collision with success rate 85.71%

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