

CHAPTER 2 - LITERATURE REVIEW

2.1 Theoretical Concept

The integration of modern technologies has become crucial for enhancing road safety and predicting the collisions risk. The research proposes a theoretical concept that serves as the basis for developing the Driver Assistance Collision Warning System. This system aims to intelligently reduce collisions by integrating kinematics and perception algorithms. The theoretical concepts intend to explain the existing theories that are relevant to the study being conducted and how they are connected [8]. The theoretical concept will identify and define three essential concepts: Collision, Kinematics Algorithm, and Perception Algorithm.

2.1.1 Collision

A collision refers to the physical impact between two or more objects, especially vehicles in the context of road safety. Collisions can result in a range of outcomes, including damage to property as well as serious injuries or even death. Acquiring insight into the underlying cause and current efforts to reduce the impact is essential for developing efficient collision detection strategies.

Collisions may occur from various directions, such as the front, side, and rear, while each direction generates specific challenges in terms of vehicle safety. The various direction of collision is also confirmed by the safety tests conducted by the ASEAN New Car Assessment Program (ASEAN NCAP) through the ASEAN NCAP 2026-2030 roadmap, which assesses the performance of vehicles within front, side, and rear collision situations [9]. The focus of this research is on front collision, which are particularly concerning as these incidents can be prevented through driver actions, such as using the brakes. While side and rear crashes frequently affect by the actions of other drivers, it is important to emphasize the capabilities of collision detection systems to deal with front collision.

Ongoing efforts in the field of road safety are aimed at reducing the frequency and severity of collisions. Education campaigns aim to raise awareness about the dangers of distracted driving from Ministry of Transportation (Kemenhub RI) and the Law Article (Peraturan Pemerintah) plays a pivotal role in enforcing regulations and enforcing penalties for unsafe driving behaviors. Additionally, advancements in vehicle safety technologies, Advance Driving Assistance System, enhance the protective measures available to drivers. Collaborative efforts among government agencies, law enforcement, automotive manufacturers, and the public continue to drive innovation and progress in minimizing the impact of collisions on road safety.

2.1.2 Kinematics Algorithm

Kinematics algorithm involves an analysis of motion-related data, such as the relative speed of the vehicle and the distance to the vehicle in front, in order to make informed decisions. In the context of Driver Collision Warning System, kinematics data provide an essential part in determining emergency braking decisions associated with collision risks. Kinematics-based algorithm is a technique that utilizes sensor-read value as an input and integrates it to generate a decision output.

The sensor-read value is the distance to next vehicle (d) in centimeters. Then sensor is integrated with Microcontroller to generate the calculation of Relative Speed (v_r) which will be used to determine the Time-to-Collision (TTC). Relative Speed can be calculated by measure the distance at two different times (d_1 at t_1 and d_2 at t_2). Once the Relative Speed defined, Time-to-Collision notion denotes the time taken by the front end of the following vehicle to reach the rear end of the leading vehicle if both the vehicles proceed at their present speeds and on the same path [10]. The Equation 2.1 shows the calculation of Relative Speed and Equation 2.2 is the Time-to-Collision formula.

$$v_r = \frac{d_2 - d_1}{t_2 - t_1} \quad (2.1)$$

$$TTC = \frac{d}{v_r} \quad (2.2)$$

Comprehending the target value references is crucial for algorithm development, so that the target value derived from “3-second rule” that have educated by the Indonesian Ministry of Public Works and Public Housing (PUPR) through Toll Road Business Entities (BUJT) which mention, “apart from having to "Keep a Safe Distance" from other vehicles, there is also a time calculation formula to minimize and avoid the danger of accidents, known as the "3-second rule" [11]. The time interval between 1.5 and 2 seconds is the duration required for a driver's perception and reaction to the sudden application of brakes, enabling them to observe other vehicles ahead. Moreover, within a timeframe of 0.5 - 1 second, a driver promptly reacts to bring the car to a controlled stop, ensuring a safe distance is maintained to avoid colliding with the preceding vehicle that has suddenly applied its brakes.



Figure 2.1 3-second Rule Education Campaign from BUJT [11]

The 3-second rule, sometimes it is called 2-second rule. The traditional recommendation is a following distance of two seconds but, based on research by highway engineers, more recently states and traffic safety organizations favor a three-second rule [12]. The rule is not only applicable in Indonesia only, said by UK National Highways Head of Road Safety, Jeremy Phillips, “The closer you get, the less time you have to react and to stop safely. So, to avoid inadvertently getting too close to the vehicle in front, we would urge drivers to use the two-second rule and to always ‘stay safe, stay back’.” [13]. Also, in the Indian Training Manual for Drivers by Transport Department, Government of West Bengal, “While following a vehicle, always maintain a safe distance which can be covered in 2 second or more. This is called 2-second rule.” [14]. Considering the fact of 3-second rule significance, the target value is set to Time-to-Collision ≤ 3 second. The kinematics algorithm's decision will precisely match the specified target value as either true or false in a strict sense.

2.1.3 Perception Algorithm

Perception-based algorithm refers to a computational approach that emulates human-like reasoning in handling uncertainty and imprecision. This algorithm involves utilizing Artificial Intelligence (AI) logic to process rule-based information from the fuzzy system. The primary purpose of the perception algorithm in the context of a collision prevention is to enhance the system's ability to navigate and respond to diverse and unpredictable driving conditions, such as a variative speed and distance to the front vehicle. Perception algorithm is expectedly allows for smoother transitions between different levels of risk and response based on AI logic.

Artificial intelligence (AI) is a collection of concepts and ideas that are related to the development of intelligent systems [15]. The tasks encompassed in this domain involve learning knowledge, logical thinking, finding solutions to difficulties, interpreting tactile data, and interpreting languages. Furthermore, these concepts and ideas can be built over in various fields and utilized in diverse domains. To comprehend the scope application of AI, it is necessary to examine a collection of domains that might be referred to as the AI family.

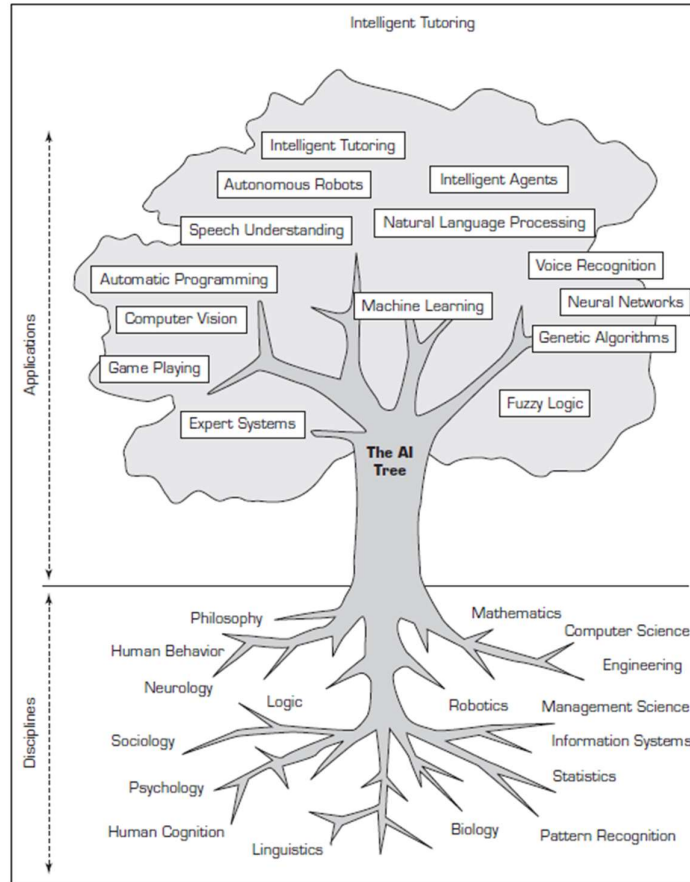


Figure 2.2 The AI Tree [15]

The AI Tree, shown in Figure 2.1, illustrates the progression of artificial intelligence (AI) from many academic disciplines to its practical applications. The roots represent distinct disciplines such as Philosophy, Mathematics, and Engineering, which are essential for constructing AI knowledge. The trunk is AI itself, demonstrating that it is a strong field based on these several disciplines. The branches represent distinct areas of AI, such as Machine Learning and Robotics, demonstrating the growth of AI into specialized domains. Eventually, the leaves serve as a representation of the practical implementation of AI, demonstrating its extensive utilization in our everyday existence. This diagram symbolizes the intricate nature of AI as a discipline deeply rooted in science and technology, extending its influence to several aspects of our contemporary society.

In this research, the AI Tree used to build a Driver Assistance Collision Warning system. The roots represent fundamental concepts gathered from disciplines such as mathematics and physics, which facilitate the comprehension of vehicle motion and direction, and also psychology, assisting in gaining an understanding of driver behavior. Engineering and computer science are responsible for constructing technical knowledge of the system, while knowledge gained from exploring human behavior and cognition ensures that these systems can effectively operate along with individuals.

The tree's trunk represents the fundamental AI technologies, which utilize algorithms to process and analyze data from a variety of sensors in order to enable the vehicle to perceive and interpret its surroundings. Branching out, machine learning enables the car to acquire knowledge from extensive data in order to enhance its ability to predict collision. By integrating all of these factors, the system is able to quickly predict the best brake decisions, so enhancing safety for both the driver and other road users.

2.2 Existing Research Search Strategy

In recent years, the field of Advance Driver Assistance System (ADAS) went through fast growth and transformation, encouraged by advances in collision prevention algorithm. As researchers and practitioners navigate this developing landscape, understanding the consequences and challenges related with system decision making algorithm has become crucial. This study will use Systematic Literature Review (SLR) to provide an in-depth review of the existing studies on collision prevention ADAS decision-making algorithm, providing significant insights that could inform future research and guide decision-making.

There are 5 main points used for an SLR method literature review [16]:

- 1) Defining the research questions
- 2) Identification of search string
- 3) Source selection
- 4) Study selection criteria
- 5) Data mapping

2.3 Research Question on Systematic Literature Review

The research questions identified for the Systematic Literature Review (SLR) are as follows:

- 1) Which actuators are used in the driver assistance collision warning system design?
- 2) What techniques or algorithms are used in the decision-making process of the driver assistance collision warning system design?

2.4 Search String and Research Database

The efficient of search strategies and an in-depth search of appropriate research databases are critical components in conducting a comprehensive literature review. The databases that are utilized to support the exploration for related existing research are Google Scholar, Scopus, IEEE, and researcher's personal database. The keywords used for searching related works on driver assistance collision warning system with kinematics and perception algorithms are "driver assistance" AND "collision" AND "perception" OR "kinematics".

2.5 Study Selection Criteria

The study selection criteria in a Systematic Literature Review (SLR) approach refer to established standards and regulations that researchers establish to determine the inclusion or exclusion of research papers or articles in their review. The standards for selection criteria are as follows:

- 1) Publication conducted within the past 5 years, from 2019 to 2024.
- 2) Publication had written in English.
- 3) Publication in the form of a journal or proceedings.
- 4) Completely written published article that available for downloaded completely (full text).

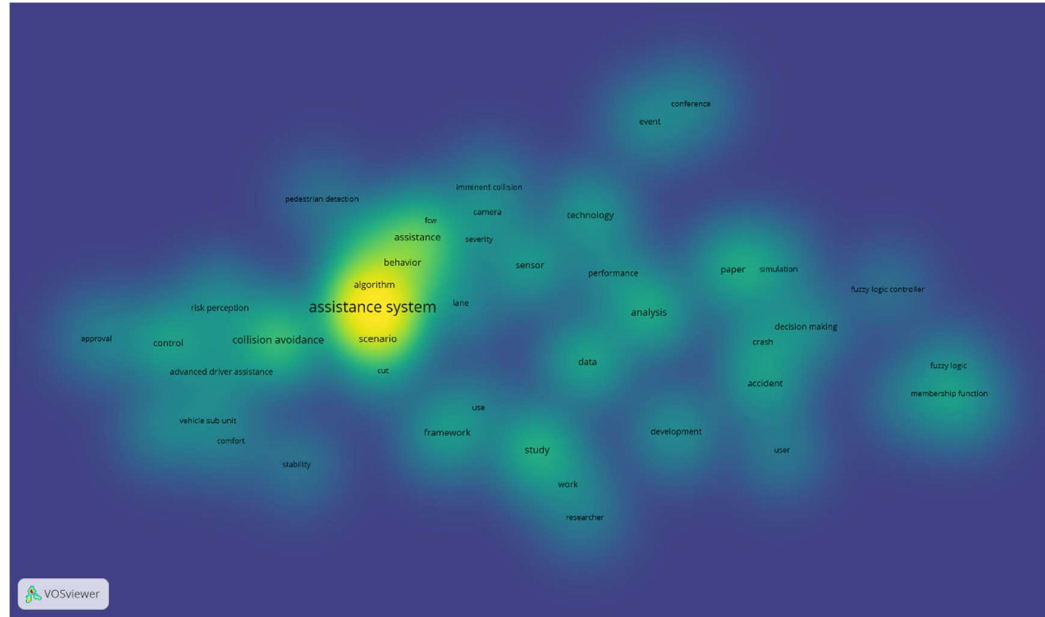


Figure 2.4 Density Visualization of Driver Assistance Collision Warning System

2.7 Existing Research

The objectives of the proposed system are to build a driver assistance collision warning system in order to prevent road accidents. In other words, when there is a collision possibility is detected, the system will act as driver assistance by providing a warning to the driver as a preventive action against a collision. Therefore, related works on collision detection are introduced and discussed in this section.

In the past few years, vehicle safety system has been a major area of research, and many proposals for approach have been suggested. Many studies have been conducted on this topic, here are some studies were obtained that were in accordance with the topic.

1. Swiss German University graduated Master student, Himawan Kunto D. A. conducted a study in his thesis titled “Design and Develop Vehicle Anti-Collision Warning System” focusing on the vehicle anti-collision system that uses Arduino Uno to proceed object detection sensor (ultrasonic and laser range finder) as an input into the warning system output (buzzer and LED). The implementation of the system was successfully providing a detection object in the rear and front of the vehicle based on the parameter set. The testing result showed the accuracy of object distance detection.

2. The paper titled “Vehicle Collision Detection using IoT” by Poornachandra Prakash, Pavan Kalyan, Manoj Kumar, Diwakar Reddy, and Pavithra had a study on the vehicle collision detection with a system applied in IoT. The system is using radar to get the relative distance, relative speed, and direction angle as an input. IoT here has the main role of collecting all radar data from different vehicles before the system predicts the chance of collision. The system prediction triggered the automatic braking system on the vehicle.

3. Dewant Katore and Mohamed El-Sharkawy wrote an IEEE paper called “Embedded System Enabled Vehicle Collision Detection: An ANN Classifier” that focused on the forward collision warning system that uses the radar parameter (velocity, acceleration, and separation distance) to give supervised learning (Artificial Neural Network) in order to predict the collision or non-collision warning range. The system uses radar from the RTMaps component to acquire the real-time radar-sensed values

4. The other IEEE paper titled “An IoT Based Vehicle Accident Detection and Classification System using Sensor Fusion” by Nikhil Kumar, Debopam Acharya, and Divya Lohani focused on emergency notification in case there is a road accident in purpose to give information to predefined emergency services and family, in order to take the quick action. The system builds on the smartphone that gets input from Sensordrone and Radio-Controlled cars to define and classify road accidents.

5. The paper titled “Adaptive Forward Vehicle Collision Warning based on Driving Behavior” by Yuan, Yuwei Lu, and Qi Wang study on vehicle driving assistance that prevents vehicle collision based on driving behavior. The driving behavior is based on the face position of the driver, the system builds by the researcher’s data set for around 17 thousand images in six classifications of facial states: yawn, sleep, phone, head down, glance right, glance left, and normal. The system proposes a vision-based adaptive forward collision warning based on abnormal driver behavior detection

Here is the summary of the table of the above major studies, including the thesis and paper, related to the collision detection topics.

Table 2.1 Previous & Current Related Studies Comparison

Researcher	Year	Technology Aspect	Algorithm	Summary
Himawan [17]	2022	Sensor ultrasonic & laser range finder	Kinematics-based	Vehicle anti-collision warning system that uses sensor ultrasonic and laser range finder on front and side of the vehicle to provide object detection that triggered buzzer and LED as a collision warning indication.
Prakash, Kalyan, Kumar, Reddy, & Pavithra [18]	2020	Radar, IoT	Perception-based	Vehicle collision detection system that uses radar to get the relative distance, relative speed, and direction angle with IoT based, to predict the chance of collision which triggered the vehicle's automatic braking system.
Katare & El-Sharkawy [19]	2019	Artificial Neural Network (ANN)	Perception-based	Front Collision Avoidance system that uses radar parameters such as velocity, acceleration, and separation distance to predict the collision or non-collision warning range based on ANN supervised learning.
Nikhil Kumar, Debopam Acharya, & Divya Lohani [20]	2021	Sensordrone & Radio-Controlled Car	Kinematics-based	Vehicle accident detection with classify the road accident type before the system sends the emergency notification.
Yuan, Yuwei Lu, and Qi Wang [21]	2020	Camera	Perception-based	Vehicle collision warning based on the driver's behavior that detected by the vehicle camera. The system studies by data set to decide the driver behavior.

Collision detection research might be a common thing nowadays with the simple and complex features applied on the vehicle. The existing warning algorithm can be divided into two categories, kinematics-based and perception-based. The kinematics-based algorithm uses the sensor detection output to give a collision or non-collision warning. Whereas the perception algorithm depends on the factor variables such as relative speed, acceleration, and direction to calculate the collision risk. In order to give an effective system, the proposed system will provide collision detection with an integrated kinematics-based and perception-based algorithm to give the warning output.