Review on Sensor parameter analysis for forward collision detection system

Miss. Vaishali B.Gadekar[1], Mrs. Savita R, Pawar[2]

[1] M.E.Student, Department of Electronics and Telecommunication, MIT Academy of Engineering, Alandi, Pune.
[2]Asst. Professor, Department of Electronics and Telecommunication, MIT Academy of Engineering, Alandi, Pune.
Email:vaishaligadekar17@gmail.com, srpawar@etx.mae.ac.in

Abstract— Automobile crash safety is becoming one of the important criteria for customer vehicle selection. Today, passive safety systems like seat belts, airbags restraints systems have become very popular for occupant protection during collisions. Even the active safety systems like ABS, ESP, parking assist camera etc are becoming regular fitments on many vehicle models. Also many technologies are evolving for collision detection, warning & avoidance as well. Different sensors, which comprise of RADAR, LIDAR / LASER or Camera, are used in forward collision warning (FCW) to avoid the accidents. In this project scope, study is carried out on sensing parameters for different types of sensors on Indian road environment in context of collision avoidance systems to benefit the overall road safety in India. The analyses of the parameters will support towards selection of best sensing configuration, to achieve optimal system performance. Such a study would also provide insights into the functionality limitations of different types of sensing systems.

Keywords—Collision avoidance System, forward collision warning System, Radar Sensor, LiDAR sensor, Camera sensor, Azimuth – Elevation Field of View.

INTRODUCTION: When early automobiles were involved in accidents, there was very little or no protection available for the vehicles occupants. However, over a period of time automotive engineers designed safe vehicles to protect drivers and passengers. Advances such as improved structural design, seat belts and air bags systems helped decrease the number of injuries and deaths in road accidents. Recently collision avoidance systems (CAS) are evolving to avoid vehicle collisions or mitigate the severity of vehicle accident. These systems assist drivers in avoiding potential collisions [1]. In order for a CAS to provide a positive and beneficial influence towards the reduction of potential crashes, it is critical that the CAS system has the ability to correctly identify the vehicle, pedestrian & object targets in the Host vehicle's path [1]. The solution to this problem relies primarily on the CAS system's sensing system ability to estimate the detection range, relative speed, radius-of-curvature,etc. between the Host vehicle and all other appropriate targets (i.e.: roadside objects, pedestrians, vehicles, etc). The in-path target identification & discriminating them from out of path objects (deal with nuisance object) is technically very complex and challenging task in collision avoidance system [1].

The range, range rate, and angular information of other vehicles and/or objects around the host vehicle can be measured by sensors radar, lidar, and/or cameras in real time.CAS process all the information in real time to keep track of the most current vehicle-to-vehicle kinematic conditions. When a potential collision threat is identified by the system, appropriate warnings are issued to the driver to facilitate collision avoidance. If the driver fails to react in time to the warnings to avoid the imminent collision, an overriding system can take over control to avoid or mitigate the collision in an emergency situation. Therefore collision avoidance systems can assist drivers in two ways, warning and/or overriding, according to the dynamic situation. In such situations some of critical sensing parameters are: [2]

- *Azimuth field of view:* The required range for the field of view of sensor.

- *Elevation Field of View (FOV):* By determining a suitable value for the elevation FOV parameter helps sensor to keep track of objects which are within range and azimuth FOV and account for road tilt (5% grade), road variation, sensor misalignment, and vehicle pitch.
- *Operating Range:* Sensor is required to detect/track stopped objects at a range that provides time for driver reaction.
- *Range Rate:* Needs to be large to avoid aliasing or dropping target tracks.

FORWARD COLLISION DETECTION SENSORS:

1. **RADAR SENSOR:** RADAR which stands for Radio Detection and Ranging is a system that uses electromagnetic waves for detecting, locating, tracking and identifying moving and fixed objects at considerable distances. In this technology the distance from the object is calculated through the echoes that are sent back from the object. Radar transmitter transmits electro-magnetic waves through a directional antenna in any given direction in a focused manner. A part of the transmitted energy is absorbed by the atmosphere. Some of the energy travels further through the atmosphere and a fraction of it is scattered backward by the targets and is received by the radar receiver. The amount of received power depends upon radar parameters like transmitted power, radar wavelength, horizontal and vertical beam widths, scattering cross section of the target atmospheric characteristics etc.In the Forward Collision Warning System, Doppler Effect based radar transmits and detects electromagnetic waves and the time taken for detection after transmission helps to determine the distance from the lead vehicle or obstacle. Although the amount of signal returned is tiny, radio signals can easily be detected and amplified [5]. Radar radio waves can be easily generated at any desired strength, detected at even tiny powers, and then amplified many times. Thus radar is suited to detecting objects at very large ranges where other reflections, like sound or visible light, would be too weak to detect. The determination of the position of an object is done through the Time-of-flight and angle measurement. In process of Time-of-flight measurements, electromagnetic energy is sent toward objects and the returning echoes are observed. The measured time difference and the speed of the signal allow calculating the distance to the object. The Speed measurement is made through the "Doppler Effect". The base of Doppler Effect is change of wavelength due to the changing gap between waves. In the automobile industry there are two kinds of RADAR: short range and long range RADAR. Short range RADAR (24 GHz) reaches approximately a range of 0.2-20 m, while long range RADAR (76-77 GHz) reaches a distance between 1-200 m. The characteristics from RADAR change a lot depending on short range or long range [6].

2. **LIDAR SENSOR:** LIDAR (Light Detection and Ranging; or Laser Imaging Detection and Ranging) is a technology that determines distance to an object or surface using laser pulses. As in the similar radar technology, which uses radio wave instead of light, determination of the range to an object is done by measuring the time delay between transmission of a pulse and detection of the reflected signal. The main difference between lidar and radar is that much shorter wavelengths of the electromagnetic spectrum are used, usually in the ultraviolet, visible, or near infrared. Lidars provide range, range rate, azimuth and elevation measurements. Laser based ranging is a time-of-flight measurement of a light beam from a light source to a target and back. In these systems, the laser scanner device encompasses a transmitter and receiver. When the beam hits an object, part of the incident beam energy is reflected, indicated by the red arrows representing a hemispherical radiation pattern. The receiver is located near the laser; it is an optical system that captures the energy radiated back from the target object. The received signal is further processed to compute the distance from the Lidar to the object. In the path from the transmitter to the target object, the beam is spreading with a small angle .This spreading causes a decrease in intensity as the distance increases and is referred to as geometric loss. The medium through which the light travels might absorb or scatter the light which introduces a path loss that increases with the distance to the target[6].

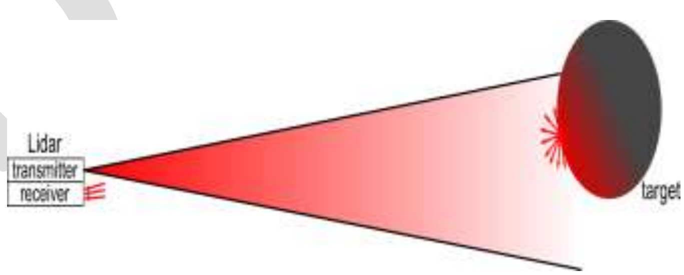

Figure 1 : Operating principle of Lidar

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3. **CAMERA SENSOR:** Vision systems use one or several cameras together with a microprocessor to perform image processing. Since they operate in the visible light region, their capabilities are similar to that of our own eyes. In this type of FCWS, a camera based sensor is used to detect car/obstacle in front of the host vehicle. Camera based FCWS are typically used for medium range, medium field of view detection. The camera system can be charge coupled device (CCD) based or Complementary Metal Oxide Semiconductor (CMOS) based [5].

The two main types of system are:

- *Single camera systems* **-** using either a monochrome or a color camera. One use in automotive applications for single camera systems is to monitor the lane markings in lane-keeping aid systems.
- *Stereo camera systems* **-** A stereo camera system provides a 3D image by combining the images from two (or more) cameras. In such a system, range can be measured through triangulation. Because of the 3D information obstacle detection is easier. Generally, shape or pattern recognition is not needed to the same extent as for a single camera system.

The performance of a vision system depends on among other thing the optics, the size of the sensor, number of pixels, and the dynamic range. The update frequency of many vision sensors is 25 Hz

The most important measurements provided by the automotive sensor are range, range rate, azimuth angle, and elevation angle as shown in following figure 2.

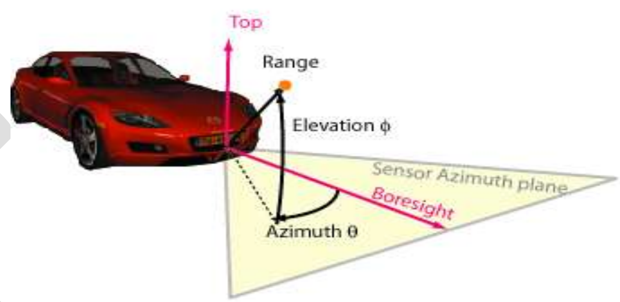

Figure 2: Measurements provided by the radar sensor are range, elevation angle and azimuth angle.

Commonly used Sensor Performance Comparison Matrix:

Performance Factor's		**Sensor**		
		Radar	Lidar	Vision based
Environmental	Rain			
	Snow			
	Fog			
	Hail			

influence	Dust			
	Day-night operation			
Object Type	Metallic object			
	Non-Metallic object			
Object Discrimination capability				
Range		120-200 m	50-150 m	50-70m

	Good Performance
	Degradation with condition
	Poor Performance

Table 1: Sensor Performance Comparison Matrix

METHODOLOGY

The following methodology has been used to analysis the performance of the sensing parameter**.** The following flow diagram describes the steps of analysis which is described in the methodology.

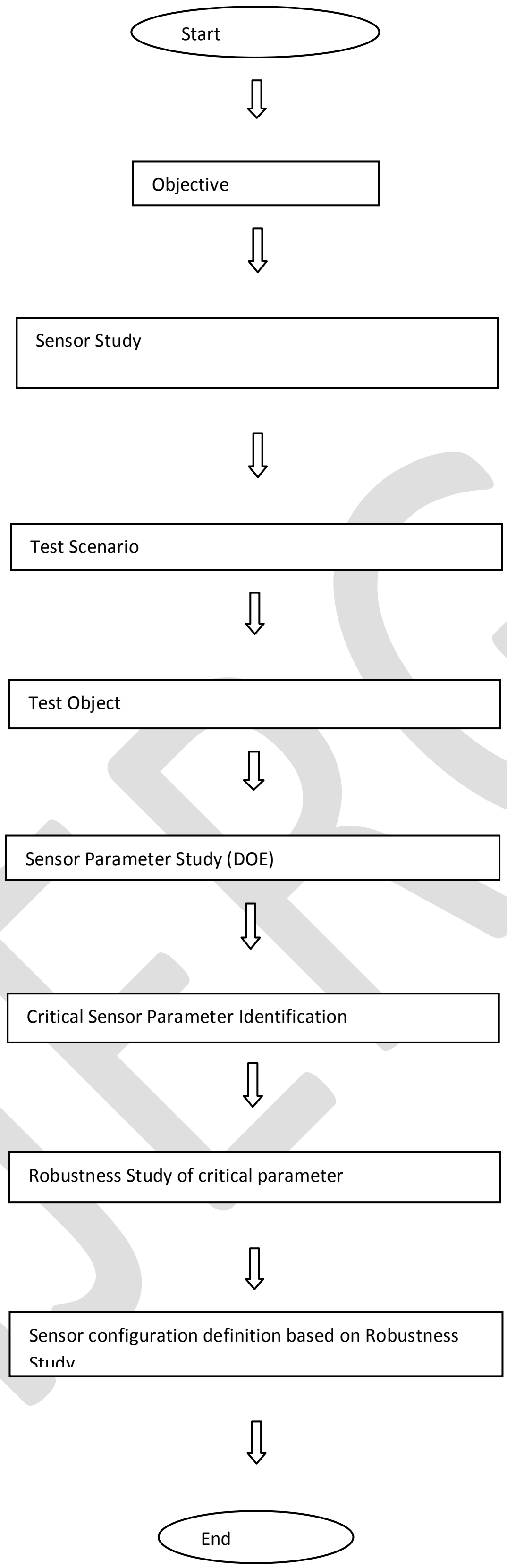

Figure 3: Flow chart -Project flow diagram

Study of different sensor types:
The first task of this study is to get the knowledge about the different types of sensor i.e. RADAR, LiDAR and Camera/ Vision sensor. Hence studied has been carried out by considering key performance of sensing parameter with respect to different Lighting Condition, Environmental condition i.e. weather factor affect and also with respect to different Road types like concrete , asphalt, gravel , sand etc… by considering different infrastructure types (like curve road, straight road ,U-turn, gradient type)

Selection criteria with possible combination:
The selection criteria is based on the range rate ,object discrimination capability of the sensor under different weather condition (like dense fog, heavy rain, snow, sensitivity to light condition) and operating range.

CAE assessment using software tool: Evaluation of the different objects / vehicles detection data received from CAE or testing for different types of sensor performance study: For CAE study the software will be used in which it will create different type of load cases (traffic scenario) and by considering the typical traffic / accident scenario and object detection in different environment conditions, it will be Identify the risks where sensing systems can fail to meet the performance requirements and also Derive the specification for sensing configurations for forward collision avoidance systems.
Selection of sensing system configuration and design parameter based on CAE assessment.
Robustness Study of design parameter of chosen sensing system for parameter robustness.

CONCLUSION

[1] During this study different automotive sensors are studied with their advantages – disadvantages and limitations.
[2] Performance assessment criteria for sensor configuration have been established in this study.
[3] CAE simulation has been carried out for doing assessment of sensor performance under different environment and working condition..
[4] CAE simulation will be finalize for define application.
[5] For define sensor configuration robustness study will be carried out for various sensor parameter.

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