BGSW’s BOROSA

Bosch Road Safety Hackathon

(Two-Wheeler Surround Awareness)

MDS Riders’ Shield

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ABSTRACT

The vulnerability of two-wheeler riders on the road necessitates a technological solution to improve their awareness of surrounding objects. This system aims to bridge the information gap in a rider's blind spots, excluding the forward field of view. This project aims to develop an advanced two-wheeler surrounding awareness system to enhance rider safety by detecting nearby objects and vehicles within a 1.5-meter radius, excluding the front 60-degree zone. The system utilizes sensors to continuously scan the surroundings, processing sensor data to precisely determine the distance and angle of surrounding objects relative to the rider's position. The collected information is intelligently displayed on a radar interface, providing the rider with real-time awareness of their environment. Additionally, an integrated audio alert system is implemented to notify the rider discreetly when objects are within 1 meter distance. The integration of all system components undergoes rigorous testing across various scenarios, ensuring optimal functionality and reliability in diverse environmental conditions and driving scenarios. This project endeavors to significantly improve rider awareness and safety, contributing to the reduction of accidents in both urban and highway settings. By leveraging advancements in sensor technology, processing power, and user-centered design principles, this system has the potential to revolutionize rider awareness and contribute to a safer riding experience.

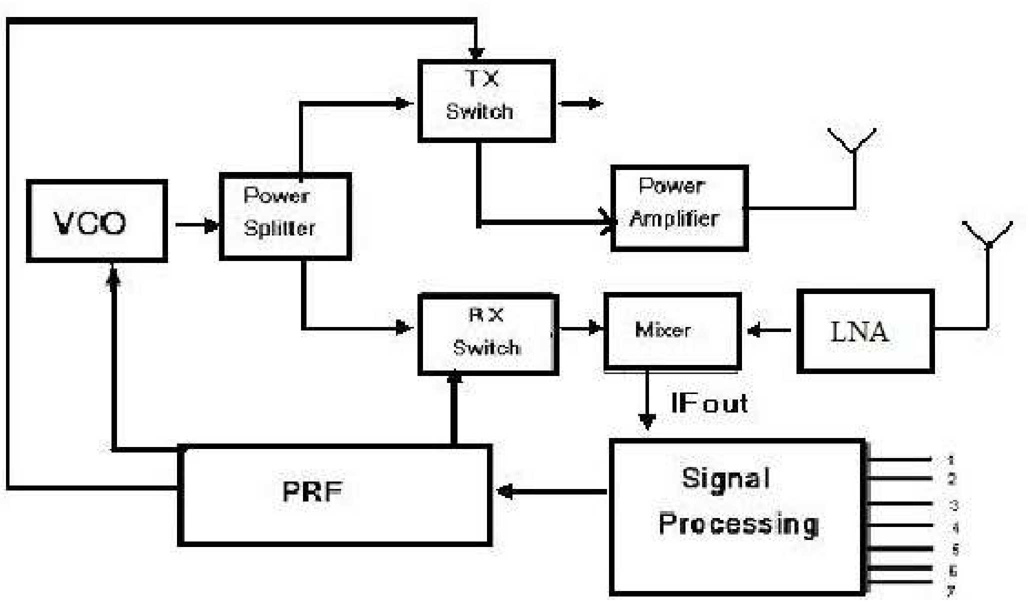
SYSTEM COMPONENTS

[I] RADAR SENSORS and their suitability for object detection on a two-wheeler

In our two-wheeler object detection system, we opted to utilize radar sensors as the primary means of detecting surrounding vehicles and objects. Radar sensors function by transmitting electromagnetic waves and analysing the reflected echoes. Here's a breakdown of radar technology and its advantages for this specific application:

1. Radar Sensor Working Principle

The working principle of a radar sensor is to compute the speed of an object along with its direction by detecting the change in frequency wave which is known as Doppler Effect. A radar sensor includes an antenna that emits a high-frequency (62 GHz) transmitted signal. This transmitted signal also includes a modulated signal with a lower frequency (10 MHz). This sensor gets the signal once it is returned back from an object. So, this sensor evaluates the phase shift between the two frequencies. Here, the difference in transmitting time & receiving time will determine the distance between the sensor & an object.



2. Advantages of Radar Sensors for Two-Wheeler Object Detection:

There are several key reasons why radar sensors were chosen for our two-wheeler object detection system:

- **All-Weather Performance:** Unlike cameras or LiDAR sensors, which can be significantly affected by rain, fog, or low light conditions, radar sensors operate effectively in various weather scenarios.
- **Distance and Direction Information:** Radar sensors provide both distance and directional data for detected objects. This allows for a more accurate representation of surrounding vehicles on the display compared to sensors that only offer distance information.
- **Compact and Durable Design:** Modern radar sensors can be relatively compact and lightweight, making them suitable for integration on a two-wheeler without adding excessive weight or bulk. Additionally, they are generally robust and can withstand the vibrations and potential bumps encountered during operation.

3. Disadvantages

The **disadvantages of radar sensors** include the following.

- It cannot differentiate & resolve numerous targets which are extremely close like our eye.
- It cannot identify the color of the objects.
- It cannot observe objects which are too deep and in the water.

Radar sensors offer a compelling combination of all-weather performance, detailed object information (distance, direction, velocity), and a form factor suitable for two-wheeler integration. These advantages make them the ideal choice for our object detection system, ensuring reliable and accurate information for the rider in diverse environmental conditions

[II] The Kalman Filter: Efficient Object Tracking for Our Two-Wheeler System

Our two-wheeler object detection system employs the Kalman Filter algorithm to process data from the radar sensors and track the movement of surrounding vehicles. Let's delve into the concept of the Kalman Filter and its suitability for this task.

1. Working of Kalman Filter:

- <u>System Modeling:</u> The first step in applying the Kalman Filter is to model the system dynamics. This involves defining a mathematical model that describes how the system's state evolves over time.
- <u>State Estimation:</u> The goal of the Kalman Filter is to estimate the current state of the system based on a series of noisy measurements. The filter maintains two main estimates:
    - *Predicted State:* This estimate is obtained by using the system model to predict the state of the system at the current time step based on the previous state estimate and the system dynamics.
    - *Corrected State:* This estimate is obtained by combining the predicted state with a new measurement. The Kalman Filter uses a weighted average of the predicted state and the measurement, with the weights.
- <u>Update Process:</u> The Kalman Filter consists of two main update steps: the prediction step and the correction step.
    - *Prediction Step:* In this step, the filter predicts the current state of the system based on the previous state estimate and the system dynamics.
    - *Correction Step:* In this step, the filter updates the predicted state estimate based on a new measurement.
- <u>Iterative Process:</u> The Kalman Filter is applied iteratively, with each iteration consisting of a prediction step followed by a correction step. As new measurements become available, they are used to refine the state estimate, leading to increasingly accurate estimates over time.
- <u>Optimality:</u> One of the key properties of the Kalman Filter is that it provides the optimal estimate of the system state in the presence of Gaussian noise, under the assumption that the system dynamics and measurement models are linear.

2. Advantages of Kalman Filter for Object Tracking with Radar Data:

The Kalman Filter presents several advantages for object tracking on our two-wheeler system using radar sensors:

- Efficient Processing: The algorithm is computationally efficient, making it suitable for implementation on a microcontroller with limited processing power.
- Handling Noisy Data: Radar data can be inherently noisy due to environmental factors. The Kalman Filter effectively handles this noise by incorporating it into the state estimation process, providing a smoother and more accurate representation of object movement.
- Object Tracking: The Kalman Filter excels at tracking objects over time. This is crucial for our application, as we need to maintain a stable representation of nearby vehicles on the display as they move around the two-wheeler.

3. Conclusion:

The Kalman Filter's efficiency, ability to handle noisy sensor data, and object tracking capabilities make it a perfect choice for our two-wheeler system. It allows us to process radar information in real-time and provide the rider with a clear understanding of the surrounding environment.

[III] STM32R37 Microcontroller: The Brains of Our Two-Wheeler Object Detection System:

The STM32R37 microcontroller serves as the central processing unit (CPU) for our two-wheeler object detection system. This section explores the features of the STM32R37 and its role in coordinating various components.

1. Capabilities of the STM32R37:

The STM32R37 is a powerful microcontroller from STMicroelectronics, well-suited for real-time embedded applications like ours. Here are some key features relevant to our project:

- Processing Power: The STM32R37 boasts a powerful ARM Cortex-M processor core, providing the necessary processing muscle to run the Kalman Filter algorithm, handle sensor data communication, and update the display in real-time.
- Communication Interfaces: This microcontroller integrates various communication interfaces like SPI and I2C, enabling seamless interaction with the radar sensors and the display unit. These interfaces allow for efficient data transfer between different components of the system.
- Power Efficiency: While offering ample processing power, the STM32R37 is designed for low-power operation, a crucial consideration for battery life on a two-wheeler.
- Timers: High-resolution timers can be used for precise timing and synchronization tasks within the system

2. The Role of the STM32R37 in the System:

The STM32R37 acts as the central processing unit, overseeing various functionalities within the system:

- Sensor Interfacing: The microcontroller communicates with the radar sensors using appropriate protocols (SPI/I2C) to receive raw data about detected objects.
- Kalman Filter Implementation: The STM32R37 runs the Kalman Filter algorithm, processing the radar data to estimate the position, direction, and velocity of surrounding vehicles.

- Display Control: The microcontroller updates the display unit (e.g., PPI display) with the processed information from the Kalman Filter, providing the rider with a real-time representation of the environment.

3. Conclusion:

Overall, the combination of the STM32R37 microcontroller with advanced object detection models and radar sensors presents a powerful solution for creating intelligent two-wheeler systems capable of detecting and responding to objects in their environment effectively.

SCENARIOS

1. Low Speed Driving(e.g., urban areas or residential)

This scenario is considering the low speed of vehicles which is usually in urban areas and residential areas. The rider is navigating through a crowded city street where speeds are typically low due to the traffic congestion which involves the frequent interaction between vehicles, and there are numerous pedestrians, cyclists, and parked cars which can be the cause of the accidents.

System Response:- The system should provide accurate and timely alerts for objects near it to prevent collisions in crowded areas. Focus on precise detection and clear visual/audio feedback to assist the rider in navigating through tight spaces safely.

2. High-speed Driving (e.g., highways or open roads)

The rider is travelling at higher speeds on a highway or open road where there may be fewer obstacles directly surrounding the vehicle but the risk arises due to the fast traffic flow and the surroundings are generally more open as compared to urban areas. On open roads, one reason for the accidents is the sudden lane changes.

System Response:-The system should provide early detection and warnings for objects approaching from the sides or rear to give the rider ample time to react. Ensure that the display interface is designed for quick glanceability without distracting the rider from the road ahead.

3. City Driving(e.g., congested traffic,interactions)

The rider is navigating through dense city traffic with frequent stops, starts, and intersections, where there's a mix of vehicles, pedestrians, and potential hazards. In congested city traffic, where there's limited visibility and numerous potential hazards, the awareness system provides crucial assistance to the rider.

System Response:- The system should prioritize detecting stationary objects such as parked cars or obstacles on the road, which can pose immediate hazards to the rider. Implement intelligent filtering algorithms to differentiate between static and moving objects to reduce false alarms.

4. Highway Driving (e.g., long stretches of highway, high-speed travel)

In this scenario, the rider is travelling on a highway with long, straight stretches where speeds are typically higher, and traffic patterns are more predictable compared to urban driving.

<u>System Response</u>:- The system should focus on detecting fast-moving objects approaching from blind spots and adjacent lanes. Provide clear and distinct alerts for objects within critical distances to prompt immediate evasive action from the rider.

5. Night Driving

Night driving poses unique challenges due to reduced visibility, varying light conditions, and potential hazards that may be less visible in the dark. The rider is navigating through roads illuminated by streetlights, vehicle headlights, and occasional darkness.

<u>System Response:</u>- The system should ensure the visibility of the vehicles or obstacles without causing distraction.

ASSUMPTIONS

1) **Sensor Accuracy**: The sensors used in the system are assumed to have a high level of accuracy in detecting objects within the specified range and angle.

2) **Environmental Conditions**: The system is designed to function effectively in extreme weather conditions such as heavy rain or intense sunlight.

3) **Power Supply**: It is assumed that the system is powered by a reliable and stable power source compatible with the requirements of the components used. Power management strategies are implemented to optimize energy consumption and ensure uninterrupted operation during the ride.

4) **Market availability**: The solution assumes the necessary hardware components (sensors, display unit, etc.) are readily available and commercially viable for integration into the system.

5) **Rider Responsiveness**: The effectiveness of the audio alert system relies on the rider's ability to perceive and respond to the alerts without causing distraction or compromising safety. Therefore, it is assumed that riders will appropriately react to the alerts while maintaining focus on the road.

SOLUTION

This document outlines a solution for a two-wheeler surrounding awareness system designed to enhance rider safety by providing real-time information about nearby objects.

System Components:

- **Sensors:** Three short-range radar sensors:
  - Two positioned on either side of the two-wheeler, covering the blind spots.
  - One positioned at the back, covering the rear area.
- **Microcontroller:** STMicroelectronics S32R37: This microcontroller provides the processing power to handle sensor data and run the Kalman Filter algorithm.
- **Kalman Filter Algorithm:** This algorithm will process the raw data from the radar sensors, accounting for noise and inaccuracies, to determine the distance and angle of surrounding objects within a 1.5-meter radius (excluding the front 60-degree zone).
- **Display Unit:** A dedicated Circular Plan Position Indicator (PPI) display positioned on the dashboard near the speedometer for easy visibility. This display will visually represent the detected objects around the rider.
- **Audio Alert System:** A non-intrusive audio beep will notify the rider when an object enters the 1.5-meter radius (excluding the front 60 degrees).
- **Voice Assistance:** To minimize the need for the rider to look away from the road, voice assistance will be provided whenever a vehicle enters the 1m radius to alert the rider of the vehicles presence.

System Functionality:

1. The radar sensors continuously scan the surroundings, sending data to the S32R37 microcontroller.
2. The Kalman Filter algorithm processes the raw sensor data, estimating the distance and angle of nearby objects, excluding the pre-defined front 60-degree zone.

3. The processed information is then sent to the PPI display, where objects are represented as visual indicators on the circular map.

4. When an object enters the designated 1.5-meter radius (excluding the front 60 degrees), a non-distracting audio beep alerts the rider accompanied with a voice command.

Benefits:

- **Increased Rider Awareness:** The system provides real-time information about surrounding vehicles and objects, improving the rider's situational awareness, especially in blind spots.

- **Reduced Accidents:** By enhancing awareness, this system can potentially help riders avoid collisions with nearby objects.

- **Customizable Excluded Zone:** The system focuses on areas not readily visible to the rider (excluding the front 60 degrees).

- **Non-Intrusive Alerts:** The audio beep serves as a subtle reminder without distracting the rider from their primary focus of controlling the two-wheeler.

Implementation:

- The system will require careful integration of the radar sensors, microcontroller, PPI display, and audio system.

- Software development will focus on implementing the Kalman Filter algorithm and processing sensor data for visualization on the PPI display.

- Extensive testing in various scenarios (different objects, weather conditions) is crucial to ensure accuracy and reliability.

Conclusion:

This surrounding awareness system for two-wheelers utilizes radar sensors, a Kalman filter, and a dedicated display to provide riders with valuable information about their surroundings. By enhancing rider awareness, this system has the potential to significantly improve safety on the road.

DESIGN

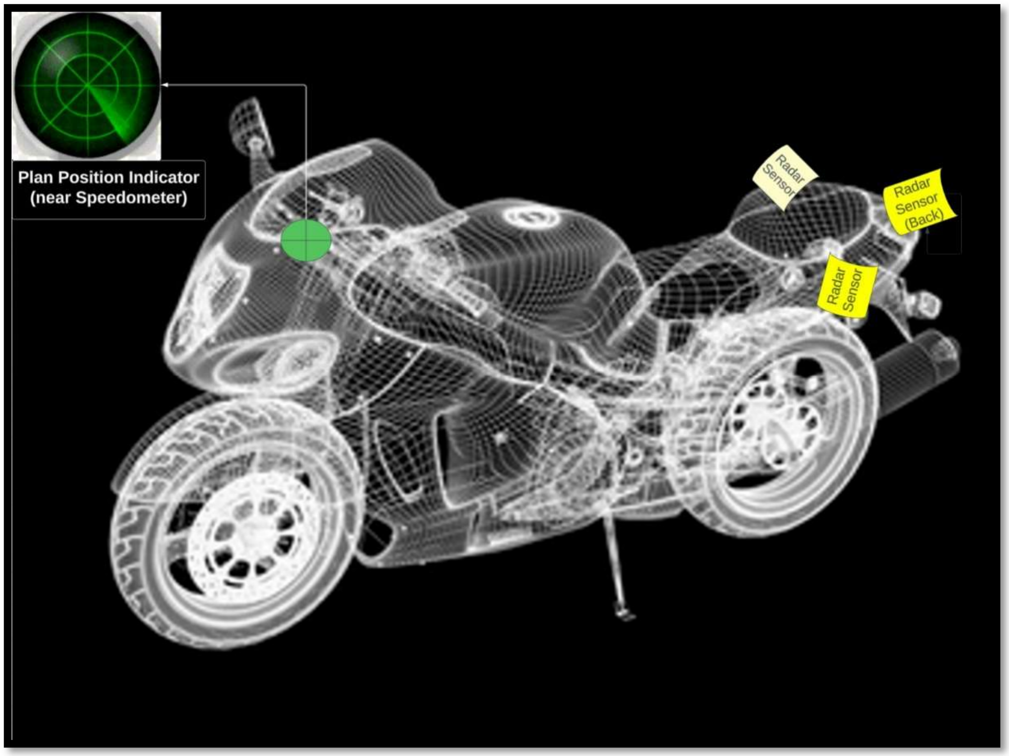


Fig. 1 Position of Components on the Motorcycle

This image depicts the placement of key components within the motorcycle object detection system.

- **Plan Position Indicator (PPI Display):** The PPI display will be positioned near the speedometer within the rider's line of sight. This location ensures the rider can easily view critical information about detected objects without compromising focus on the road ahead.
- **Radar Sensor Locations:** Three radar sensors are strategically placed to maximize object detection coverage around the motorcycle:
    - **Two side radars:** These are positioned on either side of the motorcycle, likely on the handlebars or fairing, facing outwards. Their coverage spans 120 degrees each, encompassing areas from the rider's blind spots towards the rear.
    - **Rear radar:** This sensor is positioned at the rear of the motorcycle, likely near the license plate or tail light. It covers the 120 degrees directly behind the vehicle.

By combining the visual representation on the PPI display with the comprehensive radar coverage, this system aims to provide the rider with enhanced awareness of surrounding objects and potential hazards on the road.

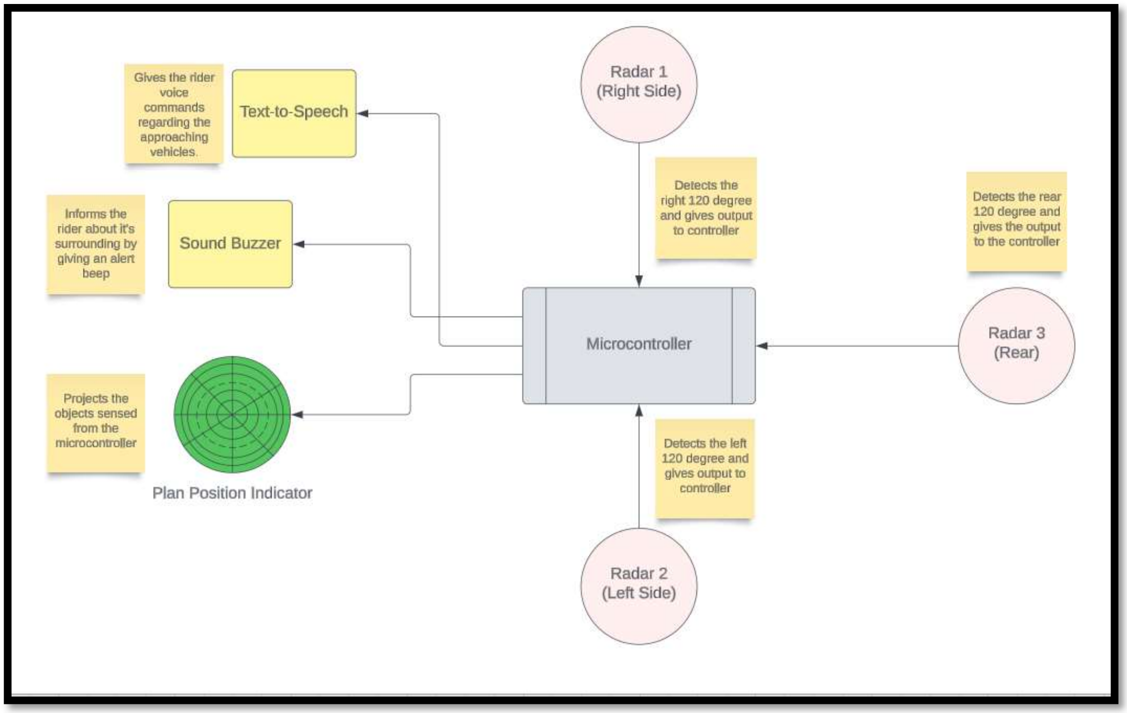


Fig. 2 System Architecture

This block diagram illustrates the system's core components and their interconnectivity:

- **Radar Sensors:** The three radar sensors are represented. These sensors detect the presence, direction, and distance of surrounding objects.
- **Microcontroller (STM32R37):** The microcontroller serves as the central processing unit, receiving raw data from the radar sensors. It likely performs the following functions:
  - Processes radar data to identify and estimate the position of surrounding objects.
  - Implements algorithms like the Kalman Filter (if applicable) to refine object position and trajectory data.
  - Controls the visual display on the PPI unit.
  - Potentially triggers audio alerts through the beeper or voice messaging system.
- **Plan Position Indicator (PPI Display):** The PPI display visually represents the detected objects and their relative positions around the motorcycle. Riders can use this information to gain awareness of potential hazards.
- **Beeper and Voice Messager (Optional):** An audio alert system (beeper or voice messaging) might be integrated to provide audible warnings in addition to the visual

PPI display. This can further enhance rider awareness, particularly for critical situations.

Data Flow and Signal Processing:

1. Radar sensors constantly scan the surroundings and transmit raw data about detected objects to the microcontroller.
2. The microcontroller processes this data to extract relevant information about object position, direction, and distance.
3. The processed data is then formatted and sent to the PPI display for visual representation.
4. If an audio alert system is implemented, the microcontroller might trigger beeps or voice messages based on the object's proximity or potential danger level.

This block diagram provides a foundational understanding of how the various components within the motorcycle object detection system work together to enhance rider awareness and safety on the road.

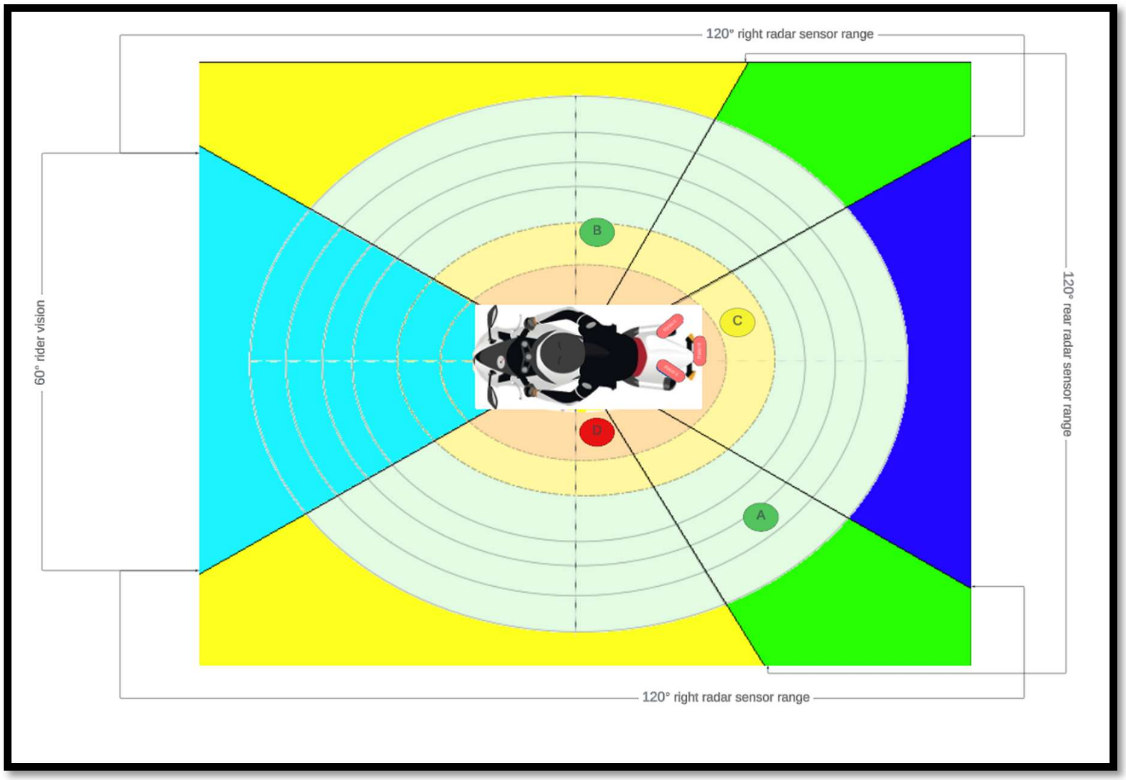


Fig. 3 Radar Range Distribution and Vehicle Detection

This illustration depicts a motorcycle object detection system utilizing multiple radar sensors to provide comprehensive coverage around the vehicle, enhancing rider awareness.

The rider's forward view of 60 degrees(sky-blue region) is designated as unsupervised due to direct visual access.

Sensor Coverage:

Two side radars cover 120 degrees each(yellow region) , encompassing areas from the rider's blind spots to the rear of the motorcycle. A 30-degree overlap zone between these side radars and the rear radar(green region) improves accuracy in these critical regions.

The rear radar covers the 120 degrees behind the motorcycle(dark blue region).

Visual Representation of Object Distance:

Concentric circles centered on the motorcycle represent the distance of detected objects.

Colours indicate proximity:

- Yellow: 1.5 meters from the motorcycle
- Red: 1 meter from the motorcycle

This color-coded system provides the rider with a clear and immediate understanding of surrounding objects and potential hazards.

SYSTEM MODULES

[I] Object Distance Detection:- In this module, we are focusing on the distance measurement of each vehicle from the motorcycle. This will then be displayed on the PPI. So, here for multiple vehicle detection at the same time the following things will be done:-

1. Vehicle Display on PPI:- Multiple vehicles will be displayed on the PPI using various colors. Vehicles within the range of 1m and 1.5m, will be shown using yellow color, if the vehicle is closer than 1m then it will be shown using the red color and will be blinking so as to alert the rider. If two vehicles are at the same range then on the basis of their speed or sound frequency the nearer vehicle will blink.

2. Beep Frequency:- When multiple vehicles are detected, the beep frequency will indicate the proximity of the closest vehicle. As vehicles near the motorcycle, the frequency of the beep will increase to alert the rider about their increasing proximity and potential danger. Conversely, the frequency of the beep will decrease when the distance between the motorcycle and vehicles increases, indicating a safe distance.

[II] Overlap Handling:- Handling overlap in coverage areas caused by multiple radar sensors on a motorcycle involves carefully managing the data from each sensor and integrating it to obtain a comprehensive and accurate representation of the surrounding environment. So, for handling it consider the following steps:-

1. Data collecting and processing:- Set up radar sensors on the motorcycle in such a way, that they cover the desired field of view with minimal overlap. Configure each radar sensor to continuously collect data about nearby objects, including their distance, angle, and relative velocity. Implement data processing algorithms on the microcontroller to receive and analyze the data from each radar sensor.

2. Overlap Detection:- Define the coverage areas of each radar sensor, taking into account their field of view and any overlapping regions. Develop algorithms to detect and identify overlapping regions based on the data from multiple sensors.

3. Data Fusion and Integration:- For this we are using the Kalman Filter. It can be used for the fusion or merging of data; if in the overlapping region there are more vehicles, then it finds the average of it and gives the accuracy in the merged data.

4. Boundary Handling:-Implement logic to handle boundary cases within the overlapping regions, such as resolving conflicts between sensor measurements or filling gaps in the data. Define rules or algorithms to prioritize or interpolate sensor data at the boundaries to maintain continuity and accuracy in the merged data.

FUTURE SCOPE

Future Scope: Expanding the Horizons of Rider Safety

This project has laid a strong foundation for a motorcycle object detection system with the potential to significantly improve rider safety. As we move forward, here are some exciting possibilities to explore and integrate into future iterations:

Enhanced Situational Awareness through Sensor Fusion:

- Integration with additional sensors like cameras could enable object classification (cars, motorcycles, pedestrians) alongside detection. By fusing data from radar and cameras, the system can provide a richer picture of the surroundings, offering the rider a more comprehensive understanding of potential hazards.

Predictive Hazard Detection and Alerts:

- The system can evolve beyond reacting to present dangers. By analyzing object movement and traffic patterns, it could anticipate potential threats. Imagine warnings for vehicles cutting lanes, sudden braking ahead, or even hidden hazards around blind corners (through V2X communication, if applicable).

V2X Communication: Leveraging the Power of Connected Vehicles:

- Future advancements in Vehicle-to-Everything (V2X) communication could allow your system to exchange information with other vehicles and infrastructure. This real-time data exchange could provide invaluable alerts about accidents, road closures, or even hidden dangers, fostering a more connected and safer riding environment.

User Interface Advancements: Minimizing Distraction, Maximizing Awareness:

- The PPI display can transform into a more intuitive interface. Imagine an augmented reality overlay that highlights detected objects directly on the rider's field of vision. This would minimize distraction while keeping the rider informed about their surroundings.

Advanced Threat Detection: A Comprehensive Safety Net:

- The system's capabilities can be extended beyond stationary object detection. Features like blind spot monitoring for overtaking vehicles, or alerts for approaching motorcycles in the same lane, could be integrated for a more comprehensive safety net.

Personalization and Rider Preferences:

- The system can be designed to adapt to individual rider preferences. Riders could personalize alert settings based on their comfort level. For example, the system could prioritize warnings for high-speed approaching objects or adjust audio alerts based on riding conditions (highway vs. city).

By continually innovating and incorporating these advancements, this motorcycle object detection system has the potential to become an invaluable safety companion for riders. It can play a pivotal role in shaping a future where motorcycle journeys are safer, more informed, and ultimately, more enjoyable.