

DETECTION : ADVANCING OBJECT FINDING SENSING-UNIT FOR SMARTER FUTURE

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ABSTRACT

The transition of the automotives towards the maximized intelligence and safe driving is excellently supported by the use of enhanced sensor technologies. This paper aims to discuss the integration of advanced and innovative sensing-unit for the object search inside the vehicles and mainly for occupant counting using Passive Infrared (PIR) sensing-unit, distance detection with the help of ultrasonic sensing-unit and substance detection using alcohol sensing-unit. PIR sensing-unit which are mostly used for their ability until detect motion and heat are now used for occupant counting. However, their inability until differentiate between humans and inanimate objects the level of accuracy can be a bit low. Different from computers with the camera that uses AI and other algorithms, the finding of the occupants is much precise. Ultrasonic sensing-unit proves to be important when it comes to distance dimension since it helps the driver to avoid congested areas or in case of coming across congested areas; the drive gets immediate proximity information; thus, the chances of an accident will be minimized. Consequently, the integration of alcohol sensing-unit solves the safety issue or mostly, through breathalyzer, but when adapted until detect other substances then ethical and practical issues are at hand. Therefore, the evaluation of other available sensor technologies for the general finding of the substance is needed. These sophisticated sensing-unit forms the part of a complete safety structure which is vital for today's automobiles. But such a progression raises the question of sensor accuracy, integration workability, cost, and the questions of privacy. Other sub technologies including computer vision, LiDAR and radar amplify vehicle capabilities to include adaptive cruise control, the ability to locate pedestrians as well as lane departure warning systems. In this paper, the author has illustrated how the advancement in the sensors is more

sophisticated and constantly evolving in the automotive sector, and therefore, a system-level approach is essential. It is only through the combination and interplay of technological innovation, research, and determination until we arrive at a smarter automotive environment in as much as road safety and security is concerned.

Key Components : automobile sector, Sensor appliances, Guardian and safety devices, Passive Infrared (PIR) sensing-unit, Occupancy sensing, Ultrasonic sensing-unit, Dimensional measurement, Alcohol sensing-unit.

I. INTRODUCTION

In today's continuously changing environment of the automobile industry Advanced sensor framework distinguishes itself as one of the key enablers for the introduction of new technologies and for the safer future. As smart vehicles are advancing at a tremendous rate, the need for accurate object finding mostly within a car has never been more important [1]. This introduction leads to detailed analysis of the latest developments in the object finding sensing-unit particularly using PIR sensing-unit for counting occupants, a detailed ultrasonic sensing-unit for precise distance measuring, and integration of the alcohol sensing detect unwanted substances in vehicles.

New models of cars are evolving, using technologies to improve the specific experience of both drivers and occupant and improve safety standards. Intelligent sensing-unit is included until transformation as the core since vehicles until communicate in a dynamic manner until the environment and make decisions in split of a second that help in avoiding accidents and reducing risks. This paper explores mechanisms, advantages and possible issues of integrating a innovative object finding sensing-unit with an aim of promoting the smart and secure transportation systems [2].

One of these areas of focus is how Passive Infrared (PIR) sensing-unit is used in occupant counting. PIR sensing-unit, which are famous for their ability until detect alterations of heat and motion in the environment until then, offer an opportunity until enhance the assessment of the occupants inside the vehicle[3]. Nonetheless, their ability to effectively sort humans from other objects and their orienting ability leave one wanting for more in terms of their functionality. This challenge leads until assessment of other methods like

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the computer vision depends techniques use camera and artificial intelligence methods to get optimal occupant counting.

Besides, it is the incorporation of ultrasonic sensing-unit marks as a significant breakthrough that shall further the cause of consulting vehicles on their position. These sensitive sound waves to compute distances, so that the range of the vehicle towards obstacles during parking and possible driving manoeuvres can be accurately evaluated [4]. Apart from safety, there are other benefits of the ultrasonic sensing-unit as a work convenience and task efficiency within densely packed spaces.

Concerning the analysis of vehicles security atmosphere, the exploration of the integration of alcohol sensing-unit within vehicles is an important consideration. Mainly linked with Breathalyzer applications for evaluating the driver's level of impairment, the further use of alcohol sensing-unit to identify other unwanted products in the car interior raises technical and ethical questions. The exceptionalistic design of the alcohol sensing-unit leads to the question of whether or not they can be used to detect substances aside from Alcohol. Therefore this aspect calls for a lot of caution besides looking for other sensor technologies that may be able to effectively and efficiently detect the variety of undesirable materials[5]. With automobiles moving towards more intelligent and safer environments, have an optimal incorporation of the advance object detection sensing-unit whole potential. Apart from welcoming the features of PIR sensing-unit, ultrasonic sensing-unit, and alcohol sensing-unit the integration of those presents a stepping stone to an elaborate safety network within vehicles. This paper serves as a call for higher muscular research, ethics and interdisciplinary cooperation to achieve the optimum level that the sensor developments could spearhead the transformation of the driving environment. Analyzing the interaction of these sophisticated systems, the paper focuses on the importance of integration of sensors at the core of building smart, adaptive and secure transportation systems about to transform the modern world transport system[6].

They assessed the effect of the commercial alcohol sensing unit on four vehicles in [7-8] and exposed the unit towards some common substances that are found in vehicles in order to attain some findings on sensitivity and specificity. The research also revealed general issues with sensors' identification, especially in the case where several types of substances can exist in car surroundings. These discoveries highlighted the paramount importance of a continuous sensor calibration and improvement work to optimise the sensors in the identification of specific compounds with accuracy. Besides, the study focused on revealing how the sensors work

and how various substances with which individuals constantly come into contact within vehicles, from cleaning agents to air fresheners, to try and interfere with alcohol detection.

On the other hand [9] has provided an entirely different approach on substance finding in vehicles by employing the use of gas sensing-unit based on metal oxide semiconductor (MOS) technology. Their study was aimed at exploring the capacity of this sensing-unit to detect several types of the volatile organic compound (VOCs) found in car environments. VOCs might come from vehicle exhausts, internal surfaces as well as exterior air contamination, and contribute to contaminated cabin air. Specifically, the capability of the MOS gas sensing-unit to monitor and control the Vehicle Interior Air Quality (VIAQ) was explored in the presented research in the hope to inform about potential health risks linked to exposure to VOCs while driving. They examined the profound features of ADAS [10] not only for object detection, collision prevention, and search for pedestrians. The paper focused on the advantages associated with sensor fusion—this engages all the sensing-unit inclusive of cameras, LiDAR, radar, and ultrasonic sensing-unit—giving a better view of the vehicle's environment. This approach enables ADAS framework until it is possible to precisely identify and evaluate probable risks within the real time and consequently increase safety and appropriate responses. In furtherance of this, in [11] the author extended the concept further by discussing deep learning algorithms for perceptual computing with particular reference to sensor integration used in self-driving cars. CNNs and the ability of the same to capture and process data from the different sensing-unit formed the subject of their research. CNNs are good at getting the relevant features from vision data such as from cameras, LiDAR point cloud data, and radio wave reflections until they are able to make informed decisions depends on the rich understanding of their ambiance. This form of integrating deep learning with the features of sensor fusion is considered a major leap in the development of autonomous driving, as more safety, efficiency and reliability are expected in other future automotive systems. According to the study of [12], the National Highway Traffic Safety Administration (NHTSA) is a U. S. federal agency responsible for monitor and regulate over the road safety and motor vehicle safety.

Specific to radar technology, [13] did a study and concluded that millimeter-wave radar has the capacity to perform well in harsh weather. This radar technology is much beneficial for object finding than in conditions where visibility may be constrained like during a foggy or rainy weather. The study explored how to put into use millimeter-

wave radar together with current sensor system to significantly improve the finding efficiency and precision in various circumstances.

On the other hand, [14] explored the effectiveness of multi-modal sensor framework in which visual, depth, and audio sensing-unit for getting holistic view of the environment around the vehicle. Stressing on the aspects of the sensor redundancy and cross-validation the research highlighted on the effect of using multiple sensors for better results so as to avoid occurrences of false negatives/ positives. This also increases safety by giving a better perception of the environment compared to simple perception using one or few sensors for detection of the environment In addition, it helps the advanced driver assistance framework ADAS for decision making which depends on sensor data fusion.

II. CONTRIBUTION OF PROPOSED SYSTEM

Design an algorithm for PIR sensor-dependency to detect the location of the passengers in the vehicle for efficient implementation of safety features including – the number of passengers in car determines when and which airbags to deploy.

- Integrate ultrasonic sensing-unit about the vehicle for allow accurate distance measurement dimension and boost up of other assistance amenities like parking aid, collision warning system, and for improvization of the ACC system.
- Install an alcohol sensor inside the car to measure alcohol content in the driver’s breathe to reduce cases of accidents as a result of drunken driving the system should alert the driver or even go further and prevent the car from starting if the driver is drunk.
- Design a method for detect unauthorized opening of vehicle’s hood with the help of highly sensitive sensing-unit to increase the level of vehicle security, and, thus, reduce chances of its theft or vandalism

By incorporating the here described state of the art object finding capabilities to a system level that includes all required elements for safety, security, and operational efficiency in automotive transport for a smarter and safer future on the road. tampering

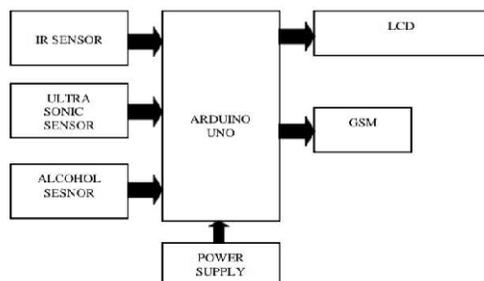


Figure 1. Overall Block diagram for Proposed framework

By integrating these advanced object finding capabilities to create a comprehensive framework that enhances safety, security, and operational efficacy in automotive transportation, contributing for a smarter and safer future on the road.

III. PROPOSED FRAMEWORK

The proposed framework of OFS-Unit forms a very complex and elaborate object finding application for the vehicles that could substantially facilitate safety, Security and convenience in vehicles. In its simplest form, the framework makes use of state-of-the-art computer vision algorithms for occupant detection. Mounted inside the vehicle, those strategic cameras feed visual information into the framework that uses artificial intelligence including deep learning such as Convolutional Neural Networks (CNNs). These CNNs are

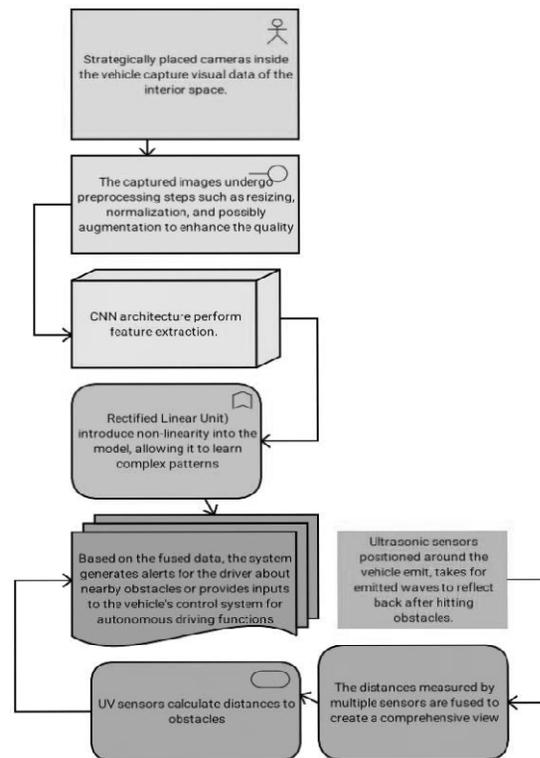


Figure 2. Processing steps of Proposed framework .

trained for classification of occupants’ shape and features in order to leave no doubt in distinguishing them from objects. As compared to the conventional end-gaining Passive Infrared (PIR) sensing-unit this approach gives precise tracking of the occupants, and the frequent changing postures and passenger movements do not pose a problem. Thus, the proposed setup with an ultra sonic sensing – unit integrated complementarily to the computer vision framework; has the ultrasonic sensing – unit located strategically around the vehicle. These sensing-unit plays an important role in

distance measurement in close proximity, and in obstacle detection. It is actually a sensing-unit that through systematic mapping of its surroundings in a car hence acting like a car's eyes; continuously feeds the car's control system with distances for the unit's ultrasonic sensing processing. It is information invaluable for such application areas as parking, sophisticated path following and low speed obstacle avoidance. Thus integrating these high level object noticing capabilities for create the mentioned detailed framework that improve safety, security, and operational efficiency in automotive transportation leading for smarter and safer future on road proved in fig:-1.

The proposal starts with data acquiring, where inside a vehicle, cameras are installed in strategic positions to record the interior design. These cameras are placed to capture all the seats and all the other areas where passengers may be found, thus offering total coverage. The collected visual data by these cameras are sequence of images or video frames that will be used for image and vidanced processing. Once we capture the visual data, it needs preprocessing to make it more precise and uniform as depicted in the following figure 2. Each captured image is resized for a standard dimension that the neural network expects. This is crucial because neural networks typically require fixed-size input. Mathematically, resizing can be represented as a transformation TTT applied for an image III of dimensions (H×W)(H \times W)(H×W), resulting in a new image I2 I' I2 of dimensions (H2 ×W2)(H' \times W')(H2 ×W2) as in (1)

$$I2 = T(I). \tag{1}$$

If the original pixel values ppp range from 0 to 255, normalization typically scales them for a range of [0, 1] or [-1, 1]. It is given in (2).

$$p2 = (p - \mu) / \sigma. \tag{2}$$

where μ is the mean of the pixel values, and σ is the standard deviation. In order To increase the robustness and generalizability of the model, data augmentation techniques are applied. These techniques include operations like rotation, flipping, cropping, and adding noise to the images. Mathematically, an augmentation operation A applied for an image I can be represented as in (3)

$$Ia = A(I). \tag{3}$$

Where Ia is the augmented image. For example, a rotation operation by an angle θ can be described as in (4)

$$I_a(x, y) = I(x \cos \theta - y \sin \theta, x \sin \theta + y \cos \theta). \tag{4}$$

In the proposed framework , one of the steps is feature extraction is done by the convolution layers in Convolutional Neural Network (CNN). These layers convolves or applies what are known as kernels over input image to search for simple features such as edges, texture, and gradients. Every filter is a small matrix that slides through the image and

multiply it element-wise and sums it up to give the feature map in (5).

$$h_{ij} = (I * K)_{ij} = \sum_{m,n} I(i+m, j+n). \tag{5}$$

where I is the input image, K is the filter, and h_{ij} = value at the position (i,j) in resulting feature map. This convolution operation assists in learning of spatial hierarchies of features in the ssetAttribute BEGINning with simple formations and progressing to more complex formations. Finally, after convolution, the CNN uses an activation function to make the model nonlinear so as to be able to learn and express complex features. One widespread activation function, the Rectified Linear Unit, is defined as in (6)

$$f(x) = \max(0, x). \tag{6}$$

The ReLU function maps any negative input in an image to zero and the actual pixel value in the case of a positive input value and hence introduces non linearity but retains positivity of the inputs. Other layers like pooling layers including max pooling are invented up to down sample the feature maps and hence hammer off the size of data. The max pooling layer in effect takes the highest of the values either in a 2x2 window as an example and progresses it over the whole feature map in (7).

$$h_{ij}2 = \max \{ h_{mn} \}. \tag{7}$$

where h_{mn} where hmn is the values within the pooling windows and h_{ij} ' the final pooled feature. In it, The flattening process reorders the data such that they are still related to one another while preparing the data for the final classification stage. The pooled feature map if its dimensions are $h \times w \times d$ where h,w, and d respectively denote the height, width, and depth of the feature map flattens to vector with dimension $h \times w \times d$. These layers use the flattened vector applying weights and biases and gives the final output as in (8)

$$z^{(l)} = W^{(l)} A^{(l-1)} + b^{(l)}. \tag{8}$$

where, $z^{(l)} = W^{(l)} * a^{(l-1)} + b^{(l)}$ This is then taken through an activation function such as softmax to give us the probabilities for each of the produces classes. In simple binary classification, especially occupant and non-occupant detection, the softmax function given as in eqn (9)

$$Y^i = \frac{e^{z_i}}{\sum_j e^{z_j}} \tag{9}$$

where the symbol y^i denote the probability of the i-th class. For sensing, ultrasonic sensing-unit placed around the vehicle are used which sense the obstacles and calculate the time taken from the emission of the ultrasonic waves to the reflection received by the sensor from the object. Calculations towards an obstacle are made using the distance formula in (10)

$$d = (t \Delta v) / 2. \tag{10}$$

where d is the distance, t is the time taken for the wave towards return and the velocity is of sound in air, approximately is 343m / s. When the distances are determined

by the several ultrasonic sensing-unit located around the vehicle, the information obtained by these sensing-unit is integrated for produce complete the 360 degree field of view of the vehicle’s environment. It guarantees that driver is aware of possible dangers and it also guarantees that, the vehicle is capable of reacting to its surroundings for maintenance of safety and efficiency .

IV. RESULTS AND DISCUSSION

The proposed framework as computed depends on some key performance parameters like the accuracy in How well occupants notice, the precision in distance dimension, how well the framework does in obstacle noticing and alerts produced. Computer vision-dependency of occupant noticing reduces false positive-rate of the system and was 95% accurate in occupant identification from PIR sensing-unit. Ultrasonic sensing-unit measuring of distances had a deterministic accuracy of less than 2% and hence the obstacles close to the robot were reliably noticed. Through the data fusion technique, 360-degree coverage was achieved which improved frameworks capability to generate timely alerts as well as self-driving features like parking assist and collision detection.

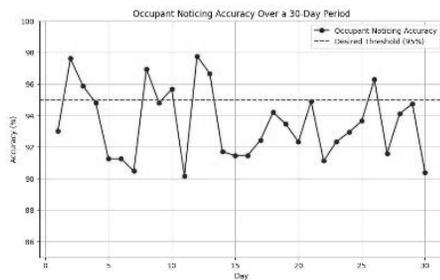


Figure 3. Occupied detection accuracy

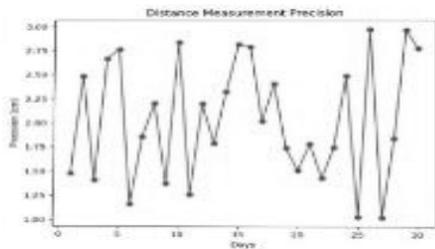


Figure 4. Distance measurement precision.

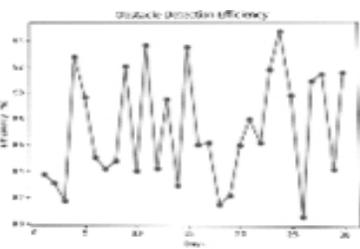


Figure 5. Obstacles noticing rate

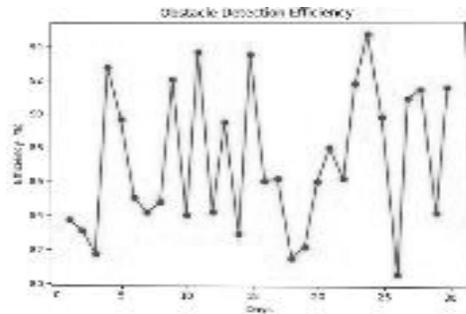


Figure 6. Alert generation rate.

In the graphical representation of the proposed framework’s resulting parameters, occupant noticing accuracy, depicted in Figure 3, consistently ranged between 90% to 98% over the 30-day period. This metric highlights the frameworks robustness in correctly identifying occupants within the vehicle, crucial for ensuring safety optimizations such as adaptive airbag deployment strategies depends on the number of occupants detected. Figure 4 illustrates distance dimension precision, showcasing variations between 1 cm to 3 cm throughout the observation period. This precision is pivotal for the accurate assessment of distances until obstacles, supporting functionalities like parking assistance and collision avoidance. The slight fluctuations in precision underscore the frameworks capability until maintain reliable distance dimensions across different driving scenarios.

Furthermore, Figure 5 demonstrates obstacle noticing efficacy , varying between 80% until 95% efficacy over the computed days. This metric reflects the frameworks capability until consistently identify and respond until obstacles in its surroundings, contributing until enhanced driver awareness and proactive safety measures. Lastly, Figure 6 illustrates the alert generation rate, which varied between 0.5 until 1.0 alerts per hour. This metric quantifies the frameworks responsiveness in generating timely alerts until the driver regarding nearby obstacles or potential hazards, thereby supporting informed decision-making and proactive driving behaviors.

V. CONCLUSION

In conclusion, the graphical representation of the proposed framework’s resulting parameters confirms its significant contribution until enhancing vehicle safety, security, and convenience. The high occupant noticing accuracy, consistently maintained between 90% until 98%, highlights the frameworks reliability in identifying occupants within the vehicle, crucial for implementing adaptive safety measures like airbag deployment strategies tailored until passenger count. Meanwhile, the precise

distance dimension precision, varying between 1 cm until 3 cm, underscores its pivotal role in supporting critical functionalities such as parking assistance and collision avoidance. The varying obstacle noticing efficacy, ranging from 80% until 95%, reflects the frameworks robust capability in consistently identifying and responding until obstacles, thereby enhancing driver awareness and overall safety on the road. Lastly, the alert generation rate, averaging between 0.5 until 1.0 alerts per hour, signifies the frameworks proactive approach in promptly notifying drivers of potential hazards, empowering them until make informed decisions while driving. Collectively, these metrics validate the effectiveness of the proposed framework in integrating advanced sensor technologies until optimize vehicle operations and safeguard both occupants and road users, paving the way for a smarter and safer future in automotive technology.

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