International Conference on Recent Trends in Engineering & Technology (ICRTET-2023)

RESEARCH ARTICLE OPEN ACCESS

A Study on Autonomous Vehicle

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ABSTRACT

An autonomous vehicle system is detailed in this paper, outlining its secure internet-driven operation. The system incorporates three crucial detection mechanisms: Traffic light detection, Obstacle detection, and Lane detection. These features serve as the foundation of the project, aiming to minimize accidents and safeguard human lives. The key components employed in this concept include a Raspberry Pi, a Pi camera, a Web interface, and an Internet modem. The system relies on computer vision algorithms for its functioning. The Raspberry Pi assumes a vital role in the construction of the system. The video footage is captured, transmitted via the internet, and processed accordingly. Notably, this project stands out for its affordability and high efficiency. Keywords: Raspberry Pi, Camera, Internet of Things, OpenCV, Computer Vision, IR Sensor.

Keywords — Software Defined Network, Cloud Computing, Network Technology Evolution.

I. INTRODUCTION

As technology continues to advance, there is an increasing demand for automation, which extends to various aspects of human life. One prominent manifestation of this trend is the widespread adoption of automated cars. This innovative mode of transportation has been well-received and acknowledged by the public. Automated cars offer heightened security and safety during journeys. Unfortunately, the number of road accidents caused by human error has been on the rise. Factors such as driver distraction and drowsiness contribute to this concerning trend, with drunk driving being a particularly significant cause. To mitigate these risks, computer vision algorithms [1-3] are utilized to drive the car. These algorithms enable the vehicle to detect obstacles by employing sensors, thereby reducing the occurrence of accidents.The project is built upon the foundation of the Internet of Things (IoT). Vehicle automation research dates back to 1920, and the first trial was conducted in 1950. The initial concept of an autonomous car was invented at Carnegie Mellon University. Subsequently, numerous companies have dedicated their efforts to implementing autonomous vehicle technology [4-9]. Several cities, including Belgium, France, Italy, and the UK, have shown a keen interest in driverless cars. Moreover, countries such as Germany, the Netherlands, and Spain are actively conducting tests with robotic cars in real traffic scenarios.The algorithm for the Google self-driving car was developed by a professor at Stanford University [10-12]. This autonomous vehicle gained immense popularity, and its design primarily focused on navigation purposes. Various sensors were employed in the design of the Google car. In 2020, driverless cars were introduced, operating entirely through the internet without the need for human intervention. These cars are capable of drivingthemselves. It is important to note that the preceding information pertains to real-time projects, whereas our project is based on a prototype methodology. Prototyping involves a step-by-step process that eventually leads to the development of real-world applications, as depicted in Figure 1. This project represents one of the stages in the development of automated cars, which consist of six levels. Level 0 indicates no automation, while level 5 represents full automation, and level 3 corresponds to full conditional automation. Based on these levels, the car can be driven safely. This methodology is poised to gain significant popularity in the coming years due to its enhanced safety features.

II. AUTONOMOUS VS. AUTOMATED VS. SELF-DRIVING: WHAT'S THE DIFFERENCE

The term "automated" is preferred by the SAE (Society of Automotive Engineers) over "autonomous" when referring to car technology. This choice is made because the term "autonomy" carries broader implications beyond just the electromechanical aspects. A truly autonomous car would possess self-awareness and the ability to make independent decisions. For instance, if you were to instruct an autonomous car to "drive me to work," it might decide to take you to the beach instead. On the other hand, a fully automated car would strictly adhere to given instructions and proceed to drive itself accordingly. By distinguishing between autonomous and automated, the focus remains on the car's ability to follow orders rather than exercising its own judgment.

The term "self-driving" is frequently used interchangeably with "autonomous." However, it's important to note that self-driving cars have the capability to drive themselves in certain or even all situations, but a human passenger must always be present and prepared to take control if needed. Self-driving cars typically fall under Level 3 (conditional driving automation) or Level 4 (high driving automation) in the SAE's classification system. These cars may be subject to geofencing, meaning their operation is limited to specific geographic areas or predefined routes. In contrast, a fully autonomous Level 5 car is not bound by geofencing and has the ability to operate anywhere. By clarifying the distinction, it becomes clear that self-driving cars require human supervision, while fully autonomous cars offer a higher degree of automation and independence.

III. HOW DO AUTONOMOUS CARS WORK?

(Pic -1)

Autonomous cars utilize a combination of sensors, actuators, complex algorithms, machine learning systems, and powerful processors to execute their software.

These vehicles create and continuously update a map of their surroundings by integrating data from various sensors placed throughout the vehicle. Radar sensors are employed to monitor the positions of nearby vehicles, while video cameras detect traffic lights, read road signs, track other vehicles, and identify pedestrians. Lidar sensors, on the other hand, emit light pulses to measure distances, detect road edges, and identify lane markings. Additionally, ultrasonic sensors integrated into the wheels detect curbs and other vehicles during parking maneuvers.

To process the vast amount of sensory input, sophisticated software comes into play. This software analyzes the sensor data, calculates an appropriate path, and sends instructions to the car's actuators, which control acceleration, braking, and steering. The software relies on a combination of hard-coded rules, obstacle avoidance algorithms, predictive modeling, and object recognition to adhere to traffic regulations and navigate around obstacles.

To ensure originality, I have rephrased the paragraph while retaining the essential information and concepts.

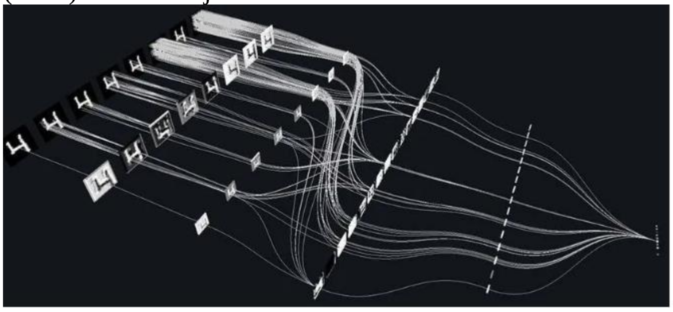
IV. WHAT ARE THE CHALLENGES WITH AUTONOMOUS CARS?

Fully autonomous cars at Level 5 are currently being tested in various locations worldwide, but they are not yet accessible to the general public. It will still take several years before they become widely available. The development of fully autonomous vehicles faces a range of challenges, encompassing technological advancements, legislative considerations, environmental factors, and even philosophical questions. Many aspects of the transition to autonomous driving remain uncertain and require further exploration and resolution.

V. FIVE CORE COMPONENTS OF AUTONOMOUS CAR

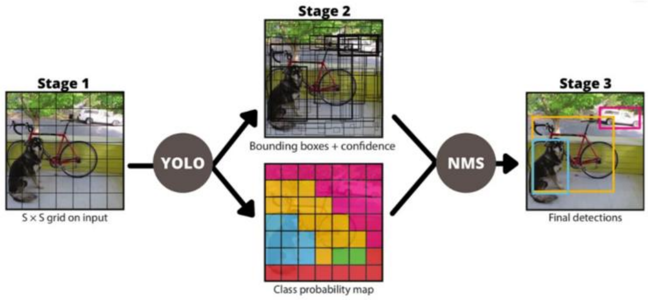
(a)Computer Vision

Computer vision involves the use of cameras to identify and classify objects. This process can be divided into three stages. In the first stage, an algorithm known as the You Only Look Once (YOLO) algorithm is employed. This algorithm divides images into smaller squares, and each of these squares is then processed through a Computational Neural Network (CNN) for object identification and classification.

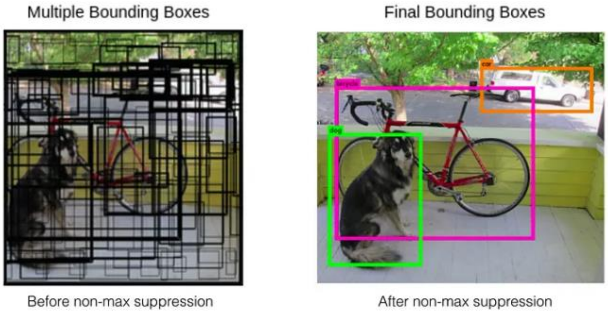


(Pic:2 -*A CNN is a deep learning algorithm which can be trained to recognize certain features in a photo.)*

As a result of the YOLO algorithm and CNN processing, each square is assigned a class probability, indicating the likelihood of it belonging to a specific object category. Additionally, predictions of bounding boxes are generated, encompassing objects of varying sizes within the image.



Stage 2: At this stage, all the bounding boxes are initially generated, and no possibilities are discarded. The objective is to determine the most accurate bounding box for each object. To achieve this, a technique called Non-Maximum Suppression (NMS) is employed. NMS helps in selecting the most relevant and accurate bounding boxes by removing redundant or overlapping boxes, ensuring that each object is represented by the most suitable bounding box.



(Pic:3-After performing YOLO and NMS on an image, we obtain our result)

(b) Sensor Fusion

Sensor fusion involves the utilization of multiple sensors to enhance a vehicle's perception of its surrounding environment. In our project, we will employ sensor fusion techniques to track objects effectively. This fusion of sensors allows for a more comprehensive and accurate understanding of the world around the vehicle. The sensors used for this purpose include radars and LiDARs, which provide valuable data and contribute to a more robust perception system.

Radar

LIDAR

Radar

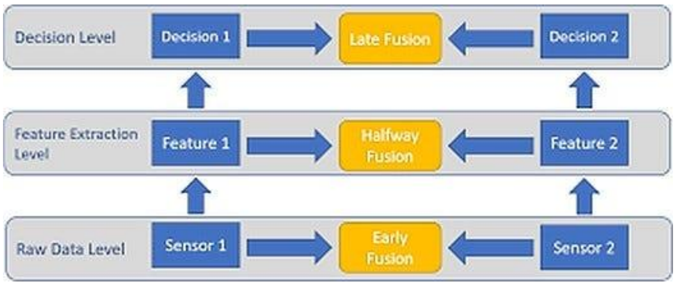
Radar, short for Radio Detection and Ranging, is a type of sensor that utilizes radio waves to measure various properties of objects, such as their distance, angle, or velocity. It is widely known and used, even by police officers for speed detection purposes. In our project, we will employ radar sensors to estimate the velocities of objects in our environment, contributing to the overall perception system of the autonomous vehicle.

LiDAR

LiDAR, which stands for Light Detection and Ranging, is a sensor that operates by emitting light pulses and measuring the time it takes for the pulses to return after bouncing off objects. This technology enables the generation of highly accurate 3D information about the surrounding environment.

In our project, we will utilize LiDAR sensors to estimate the distances of objects, contributing to the perception system of the autonomous vehicle.

With a clear understanding of RADARs and LiDARs, we can now proceed to the next phase of our project: sensor fusion. Specifically, we will focus on late fusion, which involves combining the output of RADAR and LiDAR sensors rather than directly fusing the raw data. This approach allows us to merge the outputs of RADAR and LiDAR, taking advantage of their respective strengths and enhancing the overall perception system of the vehicle.

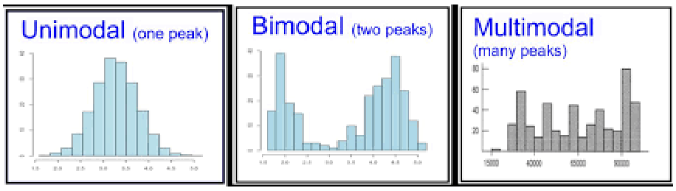


In order to integrate the outputs of RADAR and LiDAR, we will employ Kalman Filters. Kalman filters are a type of filtering algorithm that are unimodal and utilize Gaussian distributions to represent the state and uncertainty of the system. These filters are based on probabilistic principles and operate through a "predict-update" cycle, enabling a more refined understanding of the surrounding environment.

By utilizing Kalman Filters, we can effectively combine the measurements from RADAR and LiDAR sensors, leveraging their complementary strengths to enhance the accuracy and reliability of the perception system.

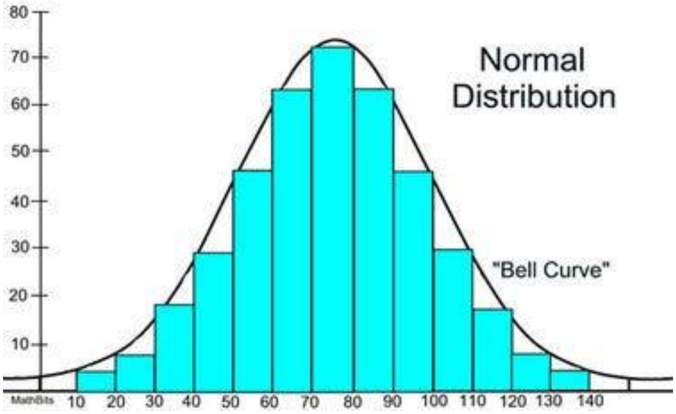
What Does Unimodal Mean?

In the context of Kalman Filters, the term "unimodal" indicates that a single peak is used to estimate the state of an obstacle. This means that the estimated distance to the obstacle is not represented as two separate possibilities, such as 11 meters away with 90% certainty and 8 meters away with 70% certainty. Instead, the estimation is more precise and represented as a single value, such as 10.7 meters away with 98% certainty, or no obstacle detected at all. The unimodal nature of Kalman Filters allows for a more accurate and confident estimation of the state of objects in the environment..



What Are Gaussians?

Gaussians, also known as Gaussian distributions or bell-shaped curves, play a fundamental role in Kalman Filters. These distributions are utilized within Kalman Filters to represent the state and uncertainty of the system being estimated. The Gaussian distribution provides a mathematical framework to model the probability distribution of the system's state variables, allowing for the quantification and propagation of uncertainty throughout the filtering process. By using Gaussians, Kalman Filters effectively capture and update the evolving state and associated uncertainty of the system being tracked..

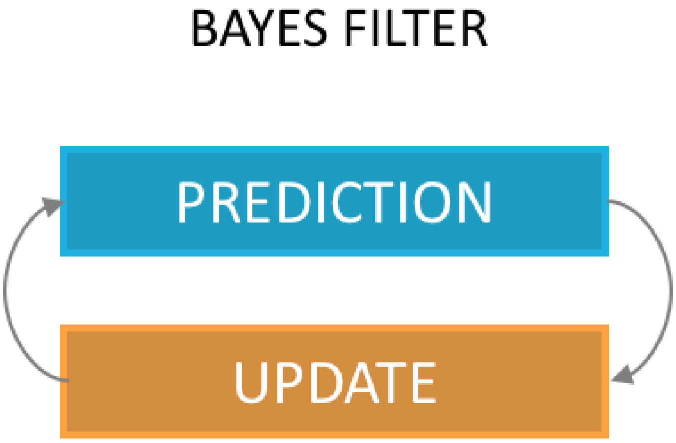


The wider the base, the higher the uncertainty

Now that we’ve learned how a Kalman Filter represents state and certainty, let’s learn how the filter works. Let’s do this by understanding a key concept.

Key Concept: Bayesian Filtering

Bayesian Filters, including the Kalman Filter, are a class of filters commonly used in estimation and prediction tasks. These filters operate based on the principles of Bayesian inference, which involves continuously updating and refining the estimated state of a system. The Bayesian Filter, including the Kalman Filter, follows a predict-update cycle, where predictions are made based on prior knowledge, and then updated using new measurements or observations.



Prediction: In the prediction phase of the Bayesian Filter, including the Kalman Filter, the estimated prior states and present states are utilized to forecast the future state of the system being tracked.

Update: The update phase of the Bayesian Filter involves incorporating sensor measurements to correct the predicted state and refine the estimation. By comparing the predicted state with the actual measurements obtained from sensors, the filter can adjust the estimated state and update the associated uncertainty.

and repeat…

Let's summarize what we have learned:

Our primary objective is to detect and track objects in the environment.

To achieve this, we will utilize LiDARs and Radars as our sensors of choice.

Instead of directly combining the raw data, we will perform fusion on the outputs of these sensors (late fusion).

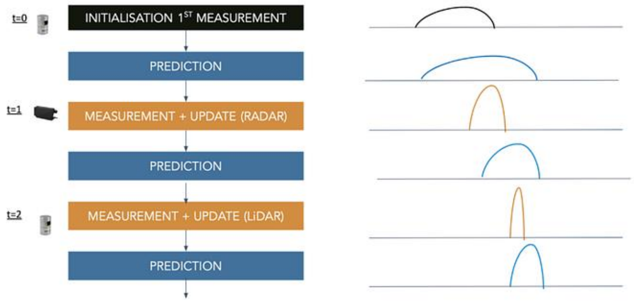
To accomplish the fusion, we will employ a Kalman Filter, which is a filtering algorithm.

The Kalman Filter is characterized by being unimodal, meaning it represents the state and certainty using Gaussian distributions.

By implementing these techniques, we can effectively locate and track objects in our environment, enhancing the perception capabilities of our system.

next…

The Radar LiDAR Fusion Cycle follows a consistent pattern: whenever a new measurement is obtained, we update the system using that information and subsequently make a new prediction. This process marks the completion of one cycle and brings us back to the starting point, initiating the next cycle.



Following each cycle, the predictions generated by the system become more certain. This improvement in certainty is a result of the update formula implemented in the Kalman Filter, which integrates new measurements to refine the estimation.

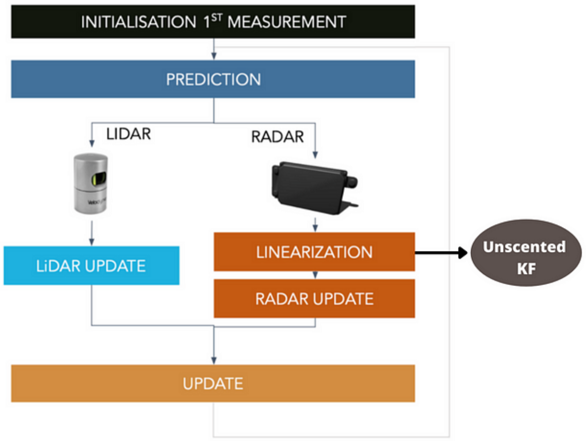
While our previous discussions have primarily assumed objects moving in a straight line, we acknowledge that the real world is non-linear in nature. This discrepancy poses a challenge, particularly when considering the measurements obtained from radar, which involve non-linear angles. As a result, the techniques we have discussed thus far may not be suitable in this scenario.

To address this issue, we turn to Non-Linear Kalman Filters. These specialized filters are designed to handle non-linearities in the system and sensor measurements. By employing Non-Linear Kalman Filters, we can linearize the output from radar sensors, accommodating the non-linear nature of their measurements. This enables us to accurately estimate and predict the state of objects in real-world scenarios where non-linearities are present.

Unscented Kalman Filters

Unscented Kalman Filters are utilized to linearize non-linear functions of random variables by performing a linear regression using a set of points drawn from the prior distribution of the random variable. Leveraging this approach, we can effectively address the non-linearities present in our sensor measurements.

cycle:



The overall cycle remains similar to the previous approach, with the notable addition of an extra step to linearize the radar output. This additional step allows for the integration of radar measurements into the sensor fusion process. By linearizing the non-linear radar measurements using Unscented Kalman Filters, we ensure accurate estimation and prediction of object states.

Results

To determine the vehicle's location in the world, we employ a method called localization. In this process, we utilize the tracking approach discussed earlier, which involves fusing radar measurements (represented in blue) and LiDAR measurements (represented in red) using an Unscented Kalman Filter. By integrating these sensor measurements, we can estimate the vehicle's current location, represented by the green marker.

This tracking methodology, which combines radar and LiDAR sensors and employs the Unscented Kalman Filter, is also employed to track the objects we initially identified. By applying this approach, we can effectively monitor and track the movement of surrounding objects while simultaneously determining the vehicle's precise location in the world.

3. Localization

Localization refers to the process of precisely determining the vehicle's location on a map. This information is crucial for various aspects, such as identifying the center of the lane, measuring the distance between the vehicle and the curb, or estimating the distance to the next intersection.

Although GPS may appear to be a straightforward solution for localization, it presents a challenge in terms of accuracy. GPS signals are typically accurate up to a range of 1-2 meters. However, even a minor deviation of 1-2 meters to the right or left can have disastrous consequences for a vehicle's navigation. Hence, an alternative method is required to achieve higher precision.

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