Higher school of communication of Tunis

p2m Report

Subject

Camera /Radar data fusion in monoDrive Simulator for obstacle detection improvement

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Year:2020/2021

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1.Introduction

In recent years transportation has begun to be revolutionized by autonomous vehicles. This could enhance traffic safety. For driverless vehicles to succeed, several tasks that normally are the responsibility of a human driver needs to be solved through engineering.

One such task is the perception of the environment and the ability to keep track of other cars on the road and predict where they will be in the future. This ability is important to avoid collisions

With the power of perception, a car can detect vehicles ahead using cameras and other sensors, identify if they become potential hazards, and know to continuously track their movements. This capability extends to the 360-degree field around the vehicle, enabling the car to detect and track all moving and static objects as it travels.

Perception is the first stage in the computational pipeline for the safe functioning of a self-driving car. Once the vehicle can extract relevant data from the surrounding environment, it can plan the path and actuate, all without human intervention

2.problematic

For tracking applications, our main focus lies in the use of radar and camera sensors. These two types of sensors have different strengths and weaknesses

For example, cameras are a widely understood, mature technology. They are also reliable and relatively cheap to produce; they can detect RGB information. They also have the benefit of having extremely high resolution.

These capabilities allow the perception system of the vehicle to identify road signs, traffic lights, road lane markings, and barriers in the case of road traffic vehicles, and a host of other articles in the case of off-road vehicles.

But they have the disadvantage of the fact that they depend on Harsh weather conditions, such as glare, snow, mist, rain, haze, and fog, they can significantly impact the performance of the perception-based sensors for perception and navigation

Unlike cameras, radars are virtually impervious to adverse weather conditions, working reliably in dark, wet, or even foggy weather. but it does not have a good resolution.

Also the false detection of metal objects around the perceived surroundings like road signs or guardrails and the challenges of distinguishing static, stationary objects. For instance, the difference between an animal carcass (static objects) and the road may pose a challenge for radars to resolve due to the similarity in Doppler shift.

3.Camera/Radar data fusion solution

With each technology having its advantages and disadvantages, driverless cars are unlikely to rely on just one system to view and navigate the world.

So to ensure a reliable and safe solution, a vehicle should have access to a combination of different sensing technologies and then use sensor fusion to bring those inputs together to gain the best possible understanding of the environment.

Rather than just identify obstacles, it can discern stationary objects as well as moving ones, and predict behaviors by reading body language and other markers

4.Theoretical study

4.1. Literature research on autonomous driving

Roadmap for Autonomous Drive

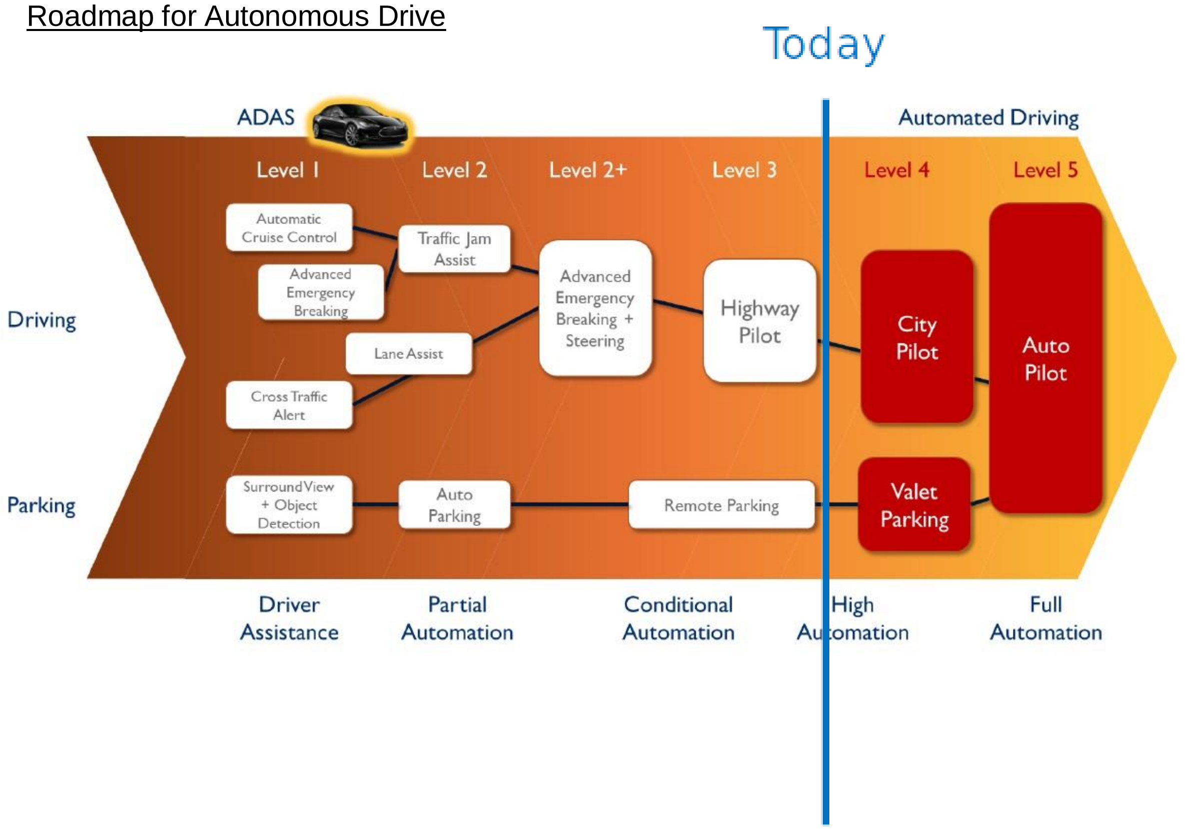


Figure 1 : Autonomous Car Roadmap

4.2. automotive radar

4.2.1. Functionality

Radar (Radio Detection And Ranging) is a transmitter and receiver of electromagnetic waves. This system is used for the detection of the presence, the position of an object as well as its speed. It sends an electromagnetic wave through its transmitter, the wave sent

will be reflected by the target, and the return signals are picked up by its receiver, therefore, with this principle, we can determine:

- Resolution: This is the range: this is the distance between the radar and the target
- Velocity: This is the speed of the target
- Doppler and angular position of the detected targets: this is the Doppler angle and the target positio

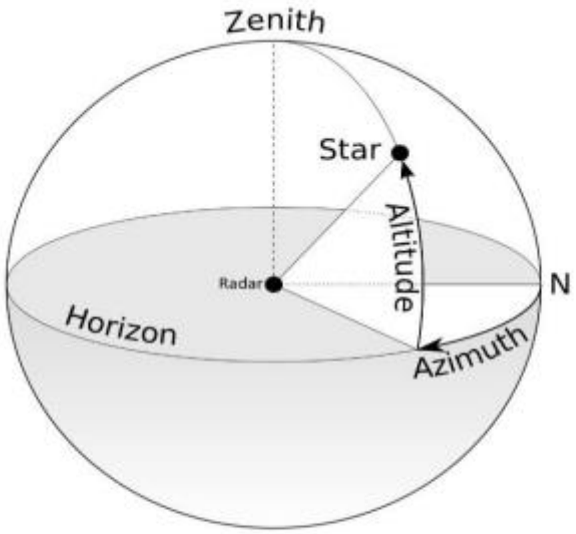


Figure 2 : Radar fields of vision

4.2.2. Types of radars

In the automobile, there are two types of radar and each type has its function and its property.

Long and medium range radar :

The long range radar is a high performance radar.
Its properties are:

- ➢ A bandwidth between 76-77GHz.
- ➢ A resolution range of 15 cm up to 250m
- ➢ Field of vision: ± 15 ° azimuth

Short-range radar :

Its properties are:

- ➢ A bandwidth between: 77-81 GHz.
- ➢ A resolution range between 3.75 cm and 100 m
- ➢ Field of vision: ± 45-60 ° azimuth Figure: BSD

4.3. fusion algorithms :

4.3.1 Extended Kalman Filter:

This algorithm is a recursive two-step process: *prediction*, and *update*. The **prediction step** produces estimates of the current variables along with their uncertainties.

These estimates are based on the assumed model of how the estimates change over time. The **update step** is done when the next measurement *(subject to noise)* is observed.

In this step, the estimates *(let's call it **state** from here on)* are updated based on the weighted average of the predicted state and the state based on the current measurement.

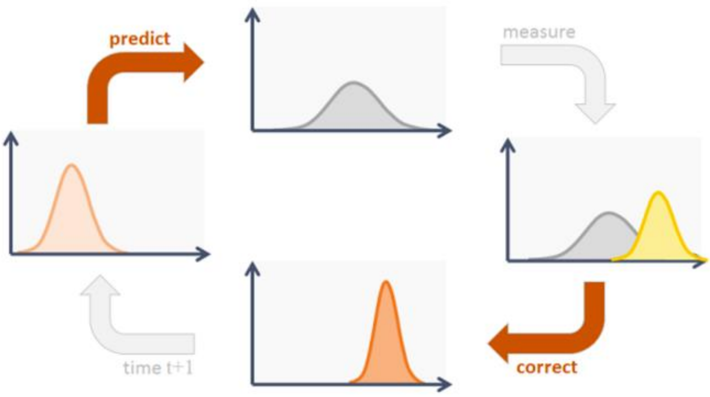
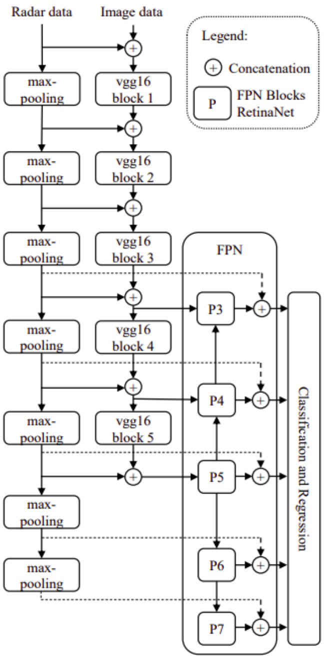


Figure 3 :Extended kalman Filter

4.3.2. CRF-Net

The main pipeline of the fusion network is shown in the figure , it is composed of the VGG blocks. The camera and radar data is concatenated and fed into the network in the top row. This branch of the network is processed via the VGG layers for both the camera and radar data. In the left branch, the raw radar data is additionally fed into the network at deeper layers of the network at accordingly scaled input sizes through max-pooling. The radar data is concatenated to the output of the previous fused network layers of the main branch of the network.



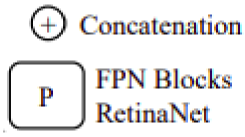


Figure 4 :Structure of camera radar fusion network

5.Practical solution

5.1.monoDrive simulator

monoDrive simulator allows the generation of realistic scenarios and resulting sensor information for perception and planning system validation.

- Low latency networked vehicle control
- Parameterized vehicle dynamics models with run time physics modification
- Fast scenario regeneration, with super real time replay
- Parameterized and accurate real time sensor emulation

5.2.Data

The monoDrive (client version) allowed us to visualize and understand more profoundly the process of creating an autonomous car, including deciding what sensors to use and where to place them in the car, applying signal processing algorithms, and finally the reason behind using sensor fusion.

Unfortunately, the problem encountered with the monoDrive simulator (client version) is that it does not allow data collection (can't save the log files) through sensors, and due to that, we were stuck and unable to advance any further with our project.

We worked around this problem by creating our own simple simulator, which can be customized by adding more objects to the scene (in our case the targets are randomly placed) and adding as many

radars as needed in the front bumper of the vehicle (in our case we worked with 3 radars, one in the middle which will be later on referenced as the main radar, and 2 as the side radars)
Each Radar is described by its x-axis position in the front bumper of the vehicle, its field of view, an error rate, a maximum range, and objects detected List which saves all objects detected by the radar (with a certain error rate)

We tried to make the radar as realistic as possible, that objects hidden behind other targets and a small portion of the objects directly in contact with the radar will not be detected

Each SceneObject on the other hand is simply described by an x and y-axis (in order to visualize it) and each RadarObject is stored using its distance, angle of arrival, and radius (replacing the Surface équivalente radar) we also saved the x and y-axis cords (considering the error rate, just to visualize it)

The data generated by the simulator is a List of RadarObjects for each radar which we used later on in order to achieve the radar data fusion

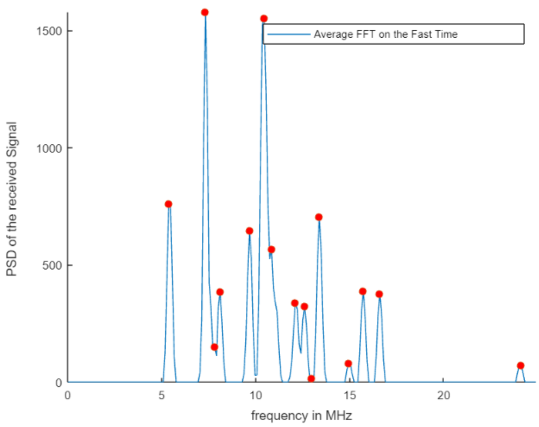
5.3. Radar signal processing

With radar data cubes in place, there are three processing algorithms:

- Beamforming
- Matched filterin
- Doppler processing

We tried the doppler processing these are the results

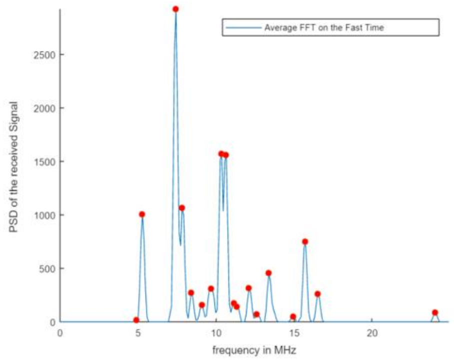
1/




```
number of objects detected :15
   22.2363
   30.3223
   32.3438
   33.5566
   40.0254
   43.2598
   44.8770
   50.1328
   52.1543
   53.7715
   55.3887
   61.8574
   65.0918
   68.7305
   99.8613
```

Figure 5 : position 0 on the front bumper

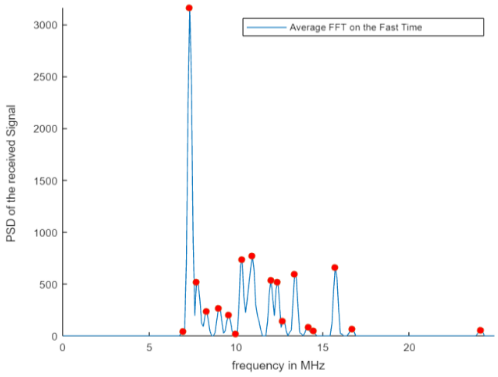
2/




```
number of objects detected :18
   20.2148
   21.8320
   30.7266
   32.3438
   34.7695
   37.5996
   40.0254
   42.8555
   44.0684
   46.0898
   46.8984
   50.1328
   52.1543
   55.3887
   61.8574
   65.0918
   68.3262
   99.4570
```

Figure 6 : position minus 80 on the front bumper

3/




```
number of objects detected :18
   28.7051
   30.3223
   31.9395
   34.3652
   37.1953
   39.6211
   41.2383
   42.8555
   45.2812
   49.7285
   51.3457
   52.5586
   55.3887
   58.6230
   59.8359
   65.0918
   69.1348
   99.8613
```

Figure 7 : position 80 on the front bumper

5.4. Radar data fusion solution

The fusion algorithm is based on simple trigonometry mathematics, we simply convert the distance and angle of arrival from one radar to another using the following equations.

$$\Theta_1 = 90 \pm AOA_1$$
$$\Theta_2 = 90 \pm AOA_2$$
$$x = sin(\Theta_1) \cdot d_1 \pm x_0$$
$$y = cos(\theta_2) \cdot d_1$$
$$d_2 = (x_0^2 + y_0^2)^{\frac{1}{2}}$$
$$\Theta_2 = \arcsin(\frac{y}{d_2})$$
$$AOA_2 = \pm(\arcsin(\frac{y}{d_2}) - 90)$$

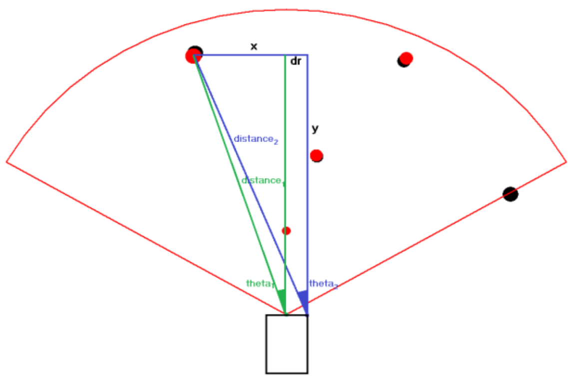


Figure 8 : trigonometry behind the fusion

In our case, we tell the simulator which radar to consider as the main sensor in order to convert all data generated by the other sensors and we repeat the simple fusion algorithm to get a final result which we store in the main radar's data

In order to visualize the result after fusion, press the "f" key.

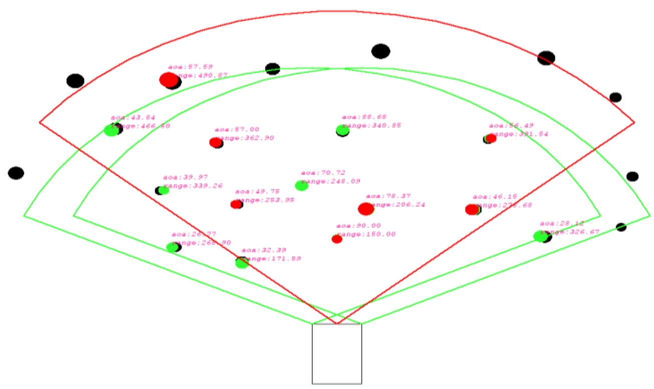


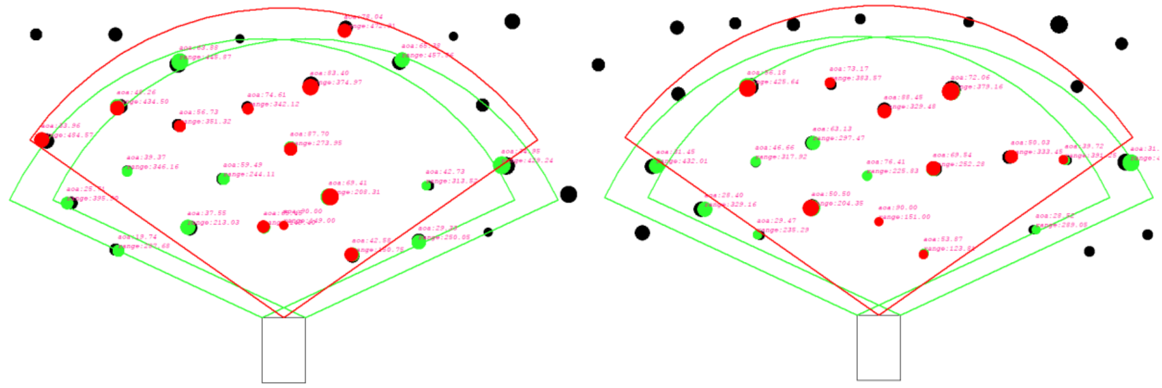
Figure 9 : with and without fusion

The **black** dots represent the undetected targets by all the radars implemented in the front bumper of the car.

The **green** dots are the objects detected after fusion.

The **red** dots on the other hand, are the targets initially detected without the use of radar data fusion, the fusion algorithm results are significantly satisfying.

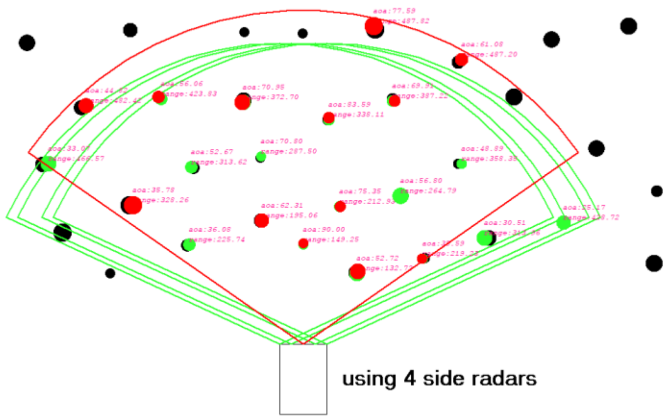
Scene exemples :



11 detected by the main radar
while 21 detected using data fusion

10 detected by the main radar
while 18 detected using data fusion

Figure 10 : different scenes



13 detected by the main radar
while 21 detected using the data fusion

Figure 11 : fusion with four side radars

we launched different scenes with different number of radars, our conclusion is, that it is best to use 3 radars for the optimal result of the sensor data fusion (considering the price-performance ratio), one with a slightly longer range while the rest of the type short-range, and a slightly wider field of view

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