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A Level 4 Autonomy Self Driving Car Protocol for the UAE

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Abstract

Roy Amara's eponymous law famously states, "we tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run." In line with Dubai's Autonomous Transportation Strategy, Dubai, Abu Dhabi and the rest of the United Arab Emirates is making proactive efforts to make 25% of the total transportation autonomous. The current self driving car (Autonomy Level 3) technology allows the Driver much comfort on the road through a combination of various AI and Machine Learning based algorithms on Park Assist, Auto Pilot and Cruise Control and advanced sensors for simultaneous localisation and mapping. As the world is gearing towards a Level 4 Autonomy Car, a lot of issues in the Cyber Security of the car, Intelligence and unpredictable driving scenarios on the road remain unaddressed. Our team through this research paper has tried to propose three novel solutions namely Dynamic Region of Interest, Round-about Central Unit and Thermal Imaging Cameras for enhancement in the existing technology and then we implemented them to test their efficiency with our very own miniature prototype of a Level 4 Autonomy Self Driving Cars called Maverick. Based on our experience through this project and our knowledge of sensors and SLAM we have tried to extrapolate the technology used in the Maverick to the real world streets of the UAE.

Keywords : SLAM ; Autonomous ; Self Driving ; Intelligence ; Machine Learning ; Region of Interest ; Thermal Camera

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1. Introduction

In this paper we have tried to compile the multiple hurdles that we faced when we tried designing and developing our miniature Self-Driving Car model called Maverick and the solutions that our team envisioned. We have then tried to draw lines between our model world and the real streets of the UAE with real scenarios and problems. We have also justified these proposals with supporting data which showed enhanced performance with respect to the current technology in Self Driving Cars Autonomy 3. We have deemed our final design as an Autonomy Level 4 capability which is defined by 'designed to perform all safety-critical self driving functions and monitor roadway conditions for the entire journey but does not cover every driving scenario'. The following sections introduce our work :

1.1 Maverick (Self-Driving Car Model) Hardware Design :

The following are the salient features implemented on-board our mobile vehicle which are applied in a Sensor fusion algorithm to carry out Simultaneous Localisation and Mapping (SLAM) :

- Robot Operating System Framework running on a central Raspberry Pi 3 computer on the vehicle
- Arduino Micro-controller board in conjunction with the Raspi for data acquisition from sensors
- Inertial Measurement Unit / MPU-6050 (Orientation and Localisation)
- Ultrasonic Sensors (Obstacle Detection)
- Microsoft Kinect Depth Sensor(Mapping the Environment)
- RGB Camera (Lane Detection, Zebra crossing detection and Traffic Signal Following)
- GPS (Computational Motion Planning)

1.2 Maverick Software Specifications:

Since our central computer, the Raspberry pi 3 has limited computational power for advanced algorithms, we are using the Robot Operating System Multiple Machines framework in which we relay data from the Arduino board to the Raspberry pi and then publish it on ROS, after which the Laptop

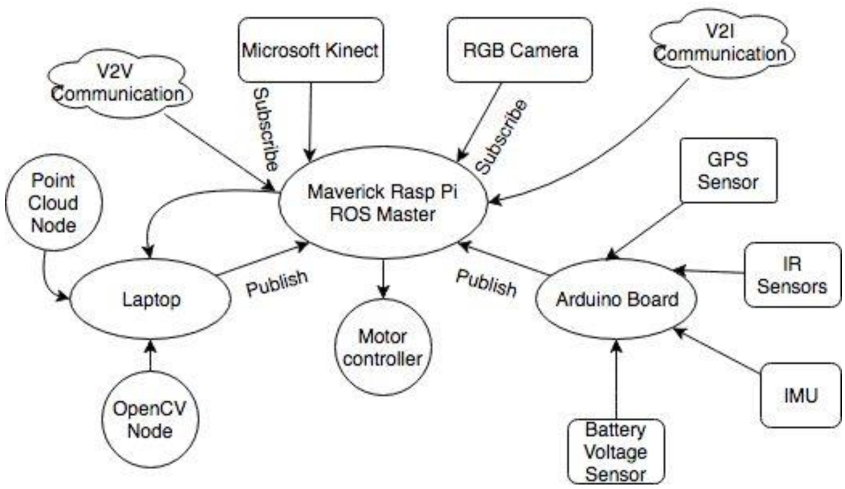

Figure 1:ROS Nodal Structure of Maverick

subscribes to this data, processes it and then sends motor commands back to the Raspberry Pi. The ROS nodal structure roughly looks like this :

Apart from the Sensor Fusion Algorithm we have assumed the Standard Vehicle 2 Vehicle communication and the Vehicle 2 Infrastructure communication protocols to come up with creative solutions to tackle complicated scenarios.

1.3 Accelerometer based Dynamic Region of Interest for Visual Lane Detection

One of the very first important algorithms for an Autonomous car on the UAE streets will be the automatic steering control through Visual Detection of Lane Lines on the road. A High Definition camera coupled with a fast computer can be used as eyes for this task. Each frame must be processed and lane lines must be isolated and then the steering must be controlled accordingly to follow the lane precisely. On Maverick we tried to implement the same algorithm using a raspberry pi 3 and a camera module. We tested many different lane detection algorithms and then finally settled with the most efficient one. Our lane detection algorithm is described in the adjoining flowchart. One of the most integral parts of any lane detection algorithm is the Region of Interest which classifies the road from the surroundings. Since there are speed breakers, potholes in the car and the inclination/ declination of the road changes from place to place, the camera viewing horizon keeps on varying and it becomes extremely difficult to focus attention on the road itself. So on Maverick we tried to implement a hardware solution for finding out the Region of Interest for each frame. This improves the accuracy and the success rate of the Image processing stage immensely. We have used an MPU-6050 3 axis accelerometer and 3 axis gyro-meter to track the orientation of the car in realtime. We are subscribing to the Yaw angle readings from the MPU-6050 to track any change in the camera horizon and then changing the Region of interest dynamically with each frame. For every range of Yaw

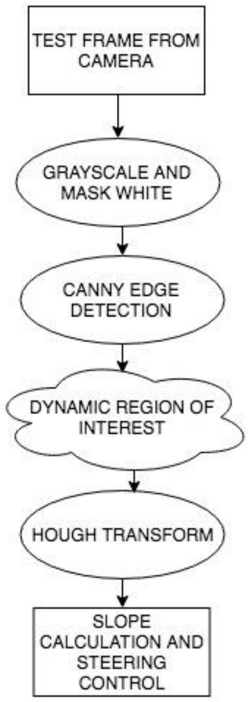

Figure 2: Lane Detection Algorithm

	DYNAMIC ROI	STATIC ROI
NUMBER OF SAMPLES	100	100
SPEED OF RECOGNITION	110ms	140ms
INCORRECT RATE OF DETECTION	10%	28%
MISSING RATE OF DETECTION	4%	4%
CORRECT RATE OF DETECTION	82%	65%

Table 1: Comparison of Dynamic and Static ROI

angles we have a change in the dimensions of the polygon which centres our attention on the road and nothing else. Specifically on bad rugged roads with potholes, cameras can produces very noisy images which cannot be used for further processing. The same solution can be used to detect this and then specific smoothing techniques like Gaussian blur can be used for de-noising before further processing.

We compared our results before and after Dynamic Region of Interest and found huge improvement in the success rate as well as the speed of recognition. We have tabulated the results here.

1,4 Round-About Central Control Unit for Orchestrating Error-Free Traversing

Round-Abouts are one of the most common features of Dubai and UAE roads. Most of the accidents on the Dubai roads today are due to unskilled and poor judgement calls while lane changing and swerving at Roundabouts. This can be essentially eliminated by a high performance autonomous vehicle to ensure error-free judgement in a roundabout. Roundabouts have sharper turns and require both lane changing and avoiding traffic accidents simultaneously. The Car must also ensure that it does not stop in the midst of traversing a roundabout. The data from on board sensors are limited by line of sight, measurement noise and motion parameters of the vehicle which affect the accuracy of prediction. For such a complicated scenario the car heavily relies on GPS to map its own trajectory and also the standard Vehicle to Vehicle Communication for real time data on velocities, heading angles and trajectories of other cars in the immediate surroundings. Now with all this data at the car's disposal, at times we can have 10 to 20 cars at one time in the round-about which makes it an incredibly complicated problem even for the best computer in the world to solve let alone a raspberry pi 3. So in this paper we propose a Round-About Central Control Unit (RCCU) which will be a high power computer server which will primarily enable Vehicle to Infrastructure Communication. The RCCU will act like a filter which will take data from all the cars and then push data of only relevant cars to a particular self driving car essentially making the scenario much less scarier. As per our calculations the computation time of the self driving car to ensure its trajectory is collision free reduced drastically. The RCCU will also solve other problems like line of sight limitation and noise. Once the filter is functional then each car will independently generate a trajectory through Simultaneous Localisation and Mapping (SLAM) and on-board Obstacle Avoidance

Mechanisms. To test SLAM algorithms on the Maverick we have used a sensor fusion of GPS data, Ultrasonic sensors, Microsoft Kinect sensor (replacement for LIDAR) and our raspberry pi camera which will implement and follow our planned trajectory.

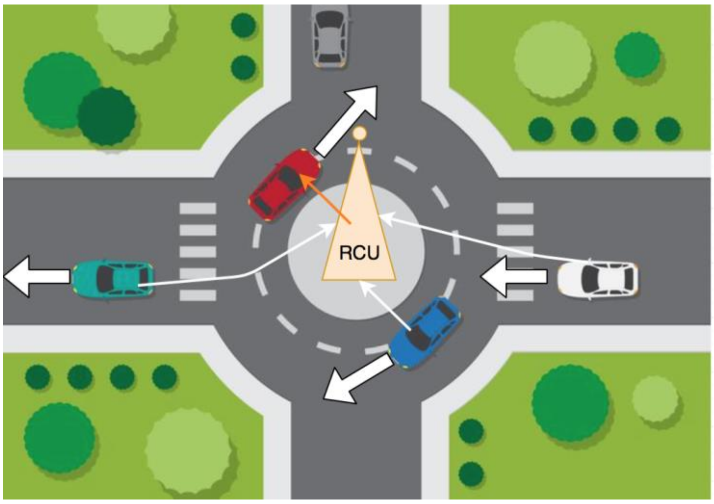

Figure 3:Animation of an RCCU in action

Round-About Central Control Unit Design can have either an omni-directional antenna with a horizontal and vertical orientation. Transmission level and transmission power will be dependent on the size of the round-about and rush hour traffic level. We assume that both wired LAN connection and wireless link are available for each RCU to the backbone network. All RCCUs will be battery operated.

Summarizing the design on the RCCU for a typical roundabout :

• Transmission Power of Antenna : -100 to -300 dB

• Communication Range : 400 to 800 meters

• Communication Framework topology : Multi-hop communication between vehicles with an upper safety cap.

1.5 Pedestrian to Vehicle Interaction with Thermal Imaging Camera.

Thermal Imaging Cameras are the recent centre of research for interaction of robots with humans. They are powerful to endow robots with an ability to read and interpret human psychophysiological and even emotional states. Thermal imaging cameras detect differences in temperatures as low as 0.01 degrees celsius.

One of the major obstacles in bringing self driving cars to the UAE roads will be how it accurately classifies humans from other obstacles and objects on the road and how it can predict behaviour of these human essentially reducing accidents by judgemental errors. In this paper we propose a thermal imaging camera to carry out both these tasks on crowded roads. Due to their function on infrared wavelengths to catch electromagnetic radiation they can detect heat energy through almost any environmental conditions including through dust and smoke. They can also function in total darkness through fog, rain, snow and sand conditions. On uncertain conditions on the road, thermal cameras is best bet for self driving cars. Based on the current technology pedestrians are classified based on lengthy Machine Learning algorithms and through Motion detection algorithms by cameras. But these either have a high failure rate in the road conditions described above or they still haven't reached the sophisticated standards that UAE streets demand. Obstacle detection is carried out through conventional sensors like LIDAR or the Microsoft Kinect. But to classify pedestrians

Figure 4:LED Pedestrian Interaction Strip

from stationary obstacles, thermal imaging cameras must be used. In this paper we recommend the Zenmuse FLIR thermal cameras with 4k 12MP Visual Sensors.Once the pedestrians have been detected different interaction avenues can be employed. One of the main reasons why humans are skeptical about self driving cars on the street is the uncertainty they bring when a someone is about to cross paths with the car. Hence the visual cues that are exchanged usually between the driver of a normal car and a pedestrian must be replaced with different interaction techniques so that a human is able to converse with a robot car. We suggest an LED Interaction panel as shown which can communicate the cars decision to the pedestrians. Once the ambiguity of the cars intentions is cleared a pedestrian will feel the most secure while crossing paths with an autonomous car.

Comparing the results obtained in the 2015 paper ‘Robust Pedestrian Detection by combining Visible and Thermal Cameras’ with our results we can formulate the following table :

ENVIRONMENT	THERMAL CAMERA PRECISION	IMAGE PROCESSING PRECISION
MORNING	93.23	94.61
AFTERNOON	90.15	92.41
NIGHT	79.78	NOT POSSIBLE
RAINY DAY	93.60	33.11

Table 2:Comparison of Thermal and Visual Camera

2. Conclusion and Future Scope

Self Driving Car technology is dawning on the UAE faster than we can all imagine. As engineers and fellow citizen we must be proud and contribute to this transformation in any way possible. The three proposals in this paper can improve the functioning of the autonomous cars for the better and help in welcoming the distant reality of self-driving cars even sooner. The hardest scenarios on the roads must be tackled innovatively and solutions must be incorporated in the machines of tomorrow.

Thermal Imaging Cameras can be used to track everything from facial expressions to peripheral vascular tone and even heart beat breath rate modulation. Advanced Machine Learning and Reinforcement learning algorithms can be used to first study and track human behaviour on roads and then after building a dataset actually predicting human decisions, judgements and trajectories for an error proof car-pedestrian interaction.

In this paper Dynamic Region of interest is used to complement the Image Processing Algorithms. Dynamic ROI can also be used with upcoming Image Segmentation using Deep Learning to improve its accuracy and success rate. Software based Dynamic ROIs can also be developed with increasing computational power of our self driving cars.

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