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Cooperative Platooning in Connected Vehicles

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ABSTRACT

The future promises an Intelligent Transportation System where it is predicted that all vehicles will be connected by 2030. In the transformation of the today's system to an autonomous environment, the autonomous and connected vehicles will have to cooperate and co-exist. Cooperative Intelligent transportation can reduce traffic congestion, fuel consumption and ease the task of driving. In this regard a platooning concept where a flock of vehicles are set to follow a leader vehicle, adopting its vehicle dynamics is one of the most researched area. The need for proper understanding of the different scenarios that can occur in the real world is a crucial part of the research as these directly affects the safety of all those on the roads. A prototype test bed, due to low cost and scalability proved to be more efficient in evaluating these scenarios and is hence used for this work.

Keywords:- Cooperative, Platooning, Connected Vehicles

I. INTRODUCTION

Vehicle platooning is a concept in which a group of vehicles will act as a group of connected vehicles in a platoon. The primary advantages of forming a vehicular platooning system are that it improves the safety and efficiency of the vehicles in transit. Although in the current transportation ecosystem the concept of vehicle platooning may not seem to be an efficient mechanism, but as in the near future the transportation system will be more connected with the environment and Autonomous vehicles will be introduced into the system to a large extent, it will provide better safety and efficiency as human error can be avoided to a large margin.

Fig. 1 Communication between vehicles

Under cooperative driving, automated vehicles drive like the migration of birds or a group of dolphins; the formation of birds in the migration is aerodynamically efficient, and dolphins swim without collision while communicating with each other. The cooperative driving, simulating the formation of birds or dolphins, will contribute to the increase in the road capacity as well as in the road traffic safety. Cooperative driving of a platoon of vehicles involves exchange of information via a communication network. Depending on the proposed control law, this information could be the distance between the vehicles, the deviation between their velocities or accelerations or just their values. It has been proved in the literature that networked interconnection is needed to ensure string stability, which requires the attenuation of internal deviations as they propagate through the platoon. Moreover, communication disturbances such as delays or loss of data lead in general to safety-critical performance. Therefore, it is necessary to design controllers that are robust against these communication faults. Furthermore, hardware problems like a breakdown of a sensor could cause hazardous accidents. Thus, it is therefore very important to test platoon controllers by means of simulation and, obviously, in real environment

A. *Objectives*

- To build a prototype system with low cost vehicle-like mobile robots and run experiments to demonstrate the effectiveness of platooning control algorithm
- To ensure constant and safe inter-vehicle distance along with acceleration of its predecessor
- To create a safer mode of transportation system.
- To evaluate different platooning scenarios

B. *Advantages*

Safe

With conventional vehicles, critical risk factors are driver reaction time and concentration. Indeed, some 90% of all traffic accidents are due to human error. Truck platooning helps improve safety. With connected driving, braking is automatic with virtually zero reaction time compared to human breaking.

Efficient

It improves the aerodynamic effectiveness and performance, increases the capacity of roads and provides a more steady state traffic flow. Platooning reduces congestion by improving traffic flows and reducing tail-backs

Clean

Platooning results in a lower fuel consumption platooning has the potential to reduce CO2 emissions by up to 10%.

Business benefits

Platooning is a cost-saver, as lower fuel consumption means lower fuel costs. For transport companies, platooning means also a safer, more efficient flow of their freight.

II. IMPLEMENTATION

The aim is to develop a prototype robot for evaluating various platoon scenarios and pedestrian and traffic light detection

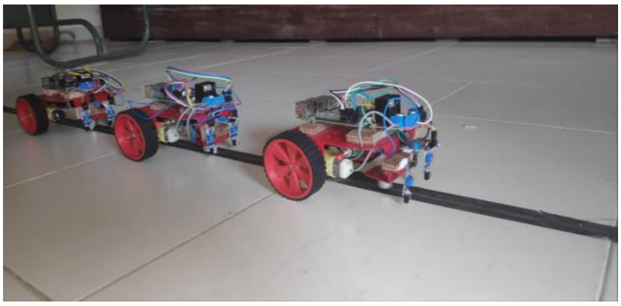

Fig. 2 Platooning

There are mainly 5 modules

- A line follower robot
- Communication between the robots using MQTT
- Dataset collection and labeling
- Obstacle and traffic light detection using Machine learning and Computer Vision
- Decision Making

A. Hardware Requirements

- Raspberry Pi Model 3 B+
- Camera Module
- IR sensor
- Motor Driver
- Line Follower Robot Kit

B. Software Requirments

- Rasbian OS
- Filmora
- LabelImg
- Tensor Flow
- Anaconda

C. Line following robot

A line following robot is a robot which will follow a certain path which is controlled by a feedback mechanism.

D. Hardware Requirement for Line follower:

- Raspberry Pi Model 3 B+
- L293D Motor Driver IC
- Geared Motors x 2
- Robot Chassis
- IR Sensor Module x 2
- Black Tape (Electrical Insulation Tape)
- Connecting Wires
- Power supply
- Battery Connector
- Battery Holder

E. Working of a line follower

Line Follower Robot track a line, black line with the help of two IR sensor placed at the front of the robot pointing downwards. This sensor has an IR Transmitter and IR receiver. The IR transmitter transmits the light and the Receiver waits for the transmitted light to return back. An IR light will return back only if it is reflect by a surface. All surfaces do not reflect an IR light, only white the color surface can completely reflect the IR light and black color surface will completely absorb the light.

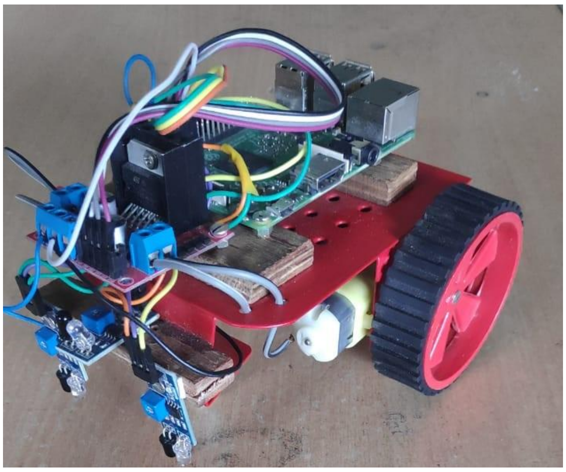

Fig. 2 Line follower

The 2 IR sensors checks weather the robot is in track with the line and two motors to correct the robot if its moves out of the track. These motors require high current and should be bi-directional; hence we use a motor driver module like L293D. Also a computational device like Raspberry Pi to instruct the motors based on the values from the IR sensor. The two IR sensors are placed on the front of the robot, one on either side of the line. If none of the sensors are detecting a black line them they PI instructs the motors to move forward.

If left IR sensor comes on black line then the PI instructs the robot to turn left by rotating the right wheel alone. Else if right sensor comes on black line then the PI instructs the robot to turn right by rotating the left wheel alone. If both sensors comes on black line, robot stops.

F. Communication using MQTT

In order to pass the dynamics of one vehicle to the adjacent vehicle, communication should be established between the vehicles. For this we can use WiFi, Zigbee etc. The communication should be fast enough to avoid accidents and collisions.

As we are using a raspberry pi with limited resources, we are using MQTT for communication between the robots in the prototype.

G. MQTT (Message Queuing Telemetry Transport)

MQTT is an ISO standard publish-subscribe-based messaging protocol used for lightweight messaging protocol for small sensors and mobile devices, optimized for high-latency or unreliable networks. It works on top of the TCP/IP protocol.
Why MQTT?

- Lightweight
- Based on messaging technique
- Minimized data packets
- Low power usage
- Real time applications

H. Working of MQTT

MQTT is based on clients and a server. The server handles the client's requests of receiving or sending data between each other. MQTT server is called a broker and the clients are connected devices.
When the client wants to send data to the broke, the Publish operation is called. If the client want to receive data from the broker, the Subscribe operation is called.
MQTT Components

1. Broker is the server that handles the data transmission between the clients.
2. A topic is the place a device want to put or retrieve a message to or from.
3. The message is the data that a device receives when subscribing from a topic or send when publishing to a topic.
4. Publish is the process a device does to send its message to the broker.
5. Subscribe where a device does to retrieve a message from the broker.

I. Obstacle and traffic light detection

For detecting the obstacles that comes in front of the vehicle and identifying the traffic light signal, machine learning and computer vision is used.

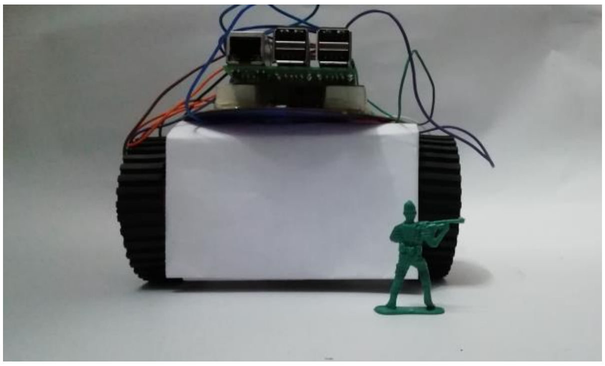

Fig. 3 Obstacle detection

J. TensorFlow

For pedestrian and traffic signal light detection TensorFlow was used for training the model. TensorFlow was chosen as it provided various pre-trained models trained on different global datasets like COCO dataset. Further more TensorFlow also supports Keras API.
Keras uses a model as the core data structure. The most commonly used and simplest model is Sequential Model which is a linear stack of layers. Keras also provides compatability for Python 2.7-3.6.
Four different models pre-trained on the COCO dataset were downloaded from the TensorFlow Model Zoo. The models used were

- ssd_mobilenet_v2_coco_2018_03_29
- ssd_mobilenet_v1_coco_2018_01_28
- ssd_inception_v2_coco_2018_01_28
- faster_rcnn_inception_v2_coco_2018_01_28

Each pre-trained model downloaded for model zoo contains

- a graph proto
- a checkpoint
- a frozen inference graph
- a configuration file which was used to generate the graph.

Different pre-trained models were used to optimize trade-off between training speed and accuracy. Thefaster_rcnn_inception_v2_coco_2018_01_28 model gave very good accuracy but the training overhead was much greater than other models. Similarly ssd_mobilenet_v1_coco_2018_01_28 gave a good training speed but demanded compromise over the accuracy of the model.

K. Dataset collection and labeling

For training the model dataset was needed, different scenarios of pedestrian and traffic light. Pi cam was used record a video of pedestrians and traffic signals in the test bed. Filmora was used to extract different frames from this video for training the model. These frames were cleaned and a dataset consisting of around 200 images of pedestrians in different position and angles were taken in the test bed and traffic signals, both green light and red light were created. LabelImg was used to label the images.

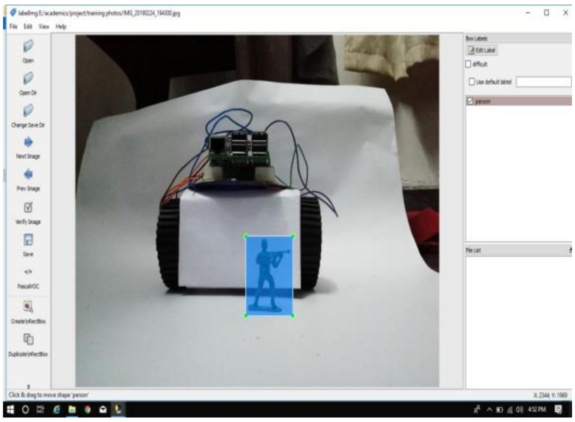

Fig. 4 LabelImg Interface

III. RESULT ANALYSIS

As a lightweight communication method like MQTT is used, there is a delay of approximately 1.5 seconds in message passing. In real life scenario, it is a big deal. The prototyping was done using a line following robot. So it has limitation in processing power and some of the scenarios cannot be tested completely. The model was able to detect the obstacle that comes in front of it and made decision according to it. But there is a delay of almost 1-2 seconds due the communication delay. As line following robots are used, the variation of speed cannot be judged accurately. Also merging and splitting of lanes as it follows a single line.

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