Tesla Autopilot : Semi Autonomous Driving, an Uptick for Future Autonomy

Shantanu Ingle[1], Madhuri Phute[2]

[1]*Department of E&TC, Pune Institute of Computer Technology, Pune, Maharashtra, India*

[2] *Department of E&TC, Pune Institute of Computer Technology, Pune, Maharashtra, India*

Abstract - *Manual driving has certainly changed the way we travel and explore different parts of the globe, with total human control and with human intuitions and previous driving experiences. But manual control doesn't ensure safety and zero fatalities in every possible driving condition. Autonomous driving is the answer to that problem. However, artificial intelligence hasn't yet touched every aspect of technology. In this paper we present a brief overview about how Tesla Motor's semi autonomous driving technology called Tesla Autopilot is changing the way we navigate and transport by incorporating state of the art current artificial intelligence and hardware technology, and enhancing the next generation autonomous driving with real-time driving updates. Tesla Autopilot relieves drivers of the most tedious and potentially dangerous aspects of road travel.*

***Key Words*: Tesla Motors, Autopilot, Electric Vehicles, Radar, Ultrasonic sensors, Autosteer, Autolane change, Autopark**

1. INTRODUCTION

Tesla claims that Autopilot gives you more confidence behind the wheel, increases your safety on the road, and makes highway driving more enjoyable. While truly driverless cars are still a few years away, Tesla Autopilot functions a lot like the systems that airplane pilots use when conditions are clear. The driver is still responsible for, and ultimately in control of, the car[1]. What's more, Tesla gives the driver an intuitive access to the information which it is using to control its actions. Along with the usual combination of accident prevention technology such as Advanced Driver Assistance Systems(ADAS), which actuates emergency steering and braking, the autopilot technology that powers the Tesla Model S and Model X electric vehicles enables cars to autonomously steer, change lanes, follow vehicles and curves, and park automatically in the garage. The nature of these cars is boldly different from most of the other production vehicles out there in the consumer market. Tesla introduced its Model S software version 7.0 which is a software update for Tesla's autopilot hardware for Model S and Model X production vehicles, which allows vehicles to use data from the surrounding cameras, radar, and ultrasonic sensors to automatically steer down the highway(freeway), change lanes and adjust speed in response to traffic conditions. Once the driver arrives at the destination, Model S or Model X scans for a parking space and parallel parks on the driver's command[2]. In the new Autopilot, the instrument cluster's new driver focused design shows the real-time information used by the car to intelligently determine the vehicle's behavior in that moment relative to its surroundings[3]. Along with the autopilot feature, the driving behavior of each Tesla car, while navigating through different road conditions, is shared to its central server. Based on machine learning and Tesla design engineer recommendations, a new feature update is developed and launched to every other Tesla car on planet. The Instrument panel provides a visualization of the road as detected by the car's sensors, giving drivers the information their car is using for features including lane departure, blind spot detection, speed assist, collision warning, adaptive cruise and auto steer. Based on previous research done on self driving cars(not yet commercialized) and hardware resources available to consumer market, which enables Tesla's autopilot feature, we propose our views and assumptions of the operation and working of individual autopilot hardware modules.

2. MODULES OF AUTOPILOT

2.1 Radar and Camera Combination:

The front bumpers of Tesla Model S and Model X have radars behind them, with a range of several hundred meters, that can detect cars and moving objects from a substantial distance. However, unfortunately, the radar is unable to detect lanes or motionless objects like stationary humans.

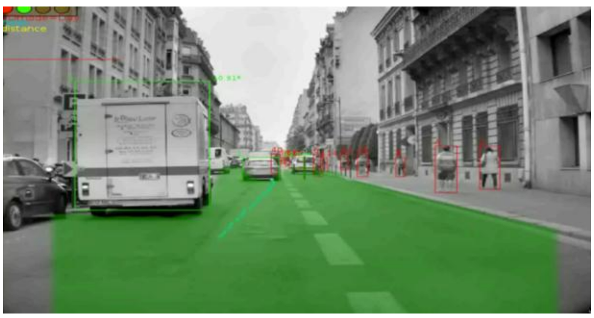

Figure 1: Vehicle and Pedestrian Detection

A camera system is an average wide angled camera equipped on the front or in a surround configuration on the car roof which recognizes various objects such as cars, trailer, bike, cyclists , pedestrians and road markings.

Figure 2: 3-D Mapping of Each Individual Vehicle

The chip behind autopilot on Tesla is Mobileye Eye Q3 processor which is based on the 40nm process. The tiny silicon packs 4 cores clocked at 500 Mhz with 64 MACs per core. The Eye Q3 processes the inputs taken from satellite imagery, radars, ultrasonic sensors and camera, and actuates steering and speed control systems. Mobileye has deployed the first DNN (Digital Neural Network) on the road with Tesla electric vehicles and is responsible for 4 major jobs; Free Space Pixel Labeling, Holistic Path Planning, General Object Detection and Sign Detection.

The DNN was trained with various side, front and rear sides of various cars until it is able to detect them to a reasonable accuracy and consequently construct a 3D model of the same. Free Space Pixel Labeling is basically recognizing the area on-camera which is obstruction free. It is also the area upon which the car will be allowed to go. Holistic Path Planning capability of the Mobileye chip which allows it to decide the way forward with very little visual cues. This is the process which tells the car where to drive and also controls the steering. The chip on-board the Tesla is capable of identifying over 250 signs in more than 50 countries[4]. These include everything from turn signs to speed limits. The system is also capable of identifying and interpreting traffic lights, road markings and general items such as traffic cones. The system has the capability to detect the road surface as well as any debris present. This allows the Tesla car to be aware of not only what kind of road the car is traveling on (highway, country side etc) but also to detect debris and other undesirables such as potholes on the road (and consequently avoid them).

Figure 3: Road Type and Curve Detection

2.2 Vehicle Tracking with Ultrasonic Sensors

Ultrasonic sensors, which are mounted on corners of the car body, detect vehicles on the adjacent lane during lane changing or auto-steering. These ultrasonic sensors are already in cars that offer automatic 'Reverse Park Assist' technology, which help navigate the car into tight reverse parking spots.

Figure 4: Blue car is in the blind spot of red car's driver. The blue arcs depict the sensor range of the red car's sensors. The orange rectangles depict the critical zone which should be supervised.

The Tesla car is equipped with an array of 12 ultrasonic sensors. The single sensors are placed equally on its front and rear. For the job in the above diagram only six of them are used, three on each side of the car: the front-side and the rear sensor (aperture 75 deg.) and additionally the passive rear-side sensor (aperture 50 deg.), which only receives ultrasonic echoes emitted by the rear sensor. The particle filter with mixture tracking capabilities[5] to perform Bayesian filtering in terms of Monte Carlo sampling is implemented to fuse signals from all ultrasonic sensors[6].

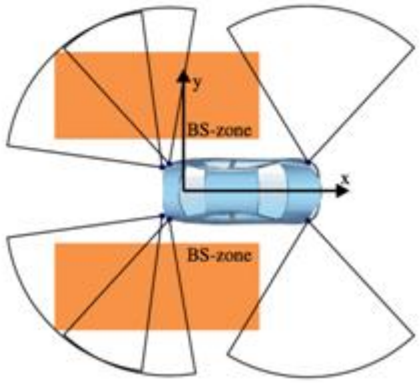

Figure 5: Coverage of the used ultrasonic sensors (black arcs) and blind spot zone. The coordinate system is fixed to the host car as shown and is the base system for the particle filter.

2.3 Satellite Imagery

Road monitoring using satellite system consists of three parts: an in-car unit, a central computer server and a mobile satellite communication system. The in-car system reads the vehicle's position every second using the Global Positioning System (GPS). An algorithm called the 'map matcher' uses that position and tachometer data, which has vehicle's speed, to identify the road on which it is being driven. Any traffic congestion is automatically detected for each road segment, based on a prior knowledge of that road, such as the expected speed of traffic under non- congested conditions.

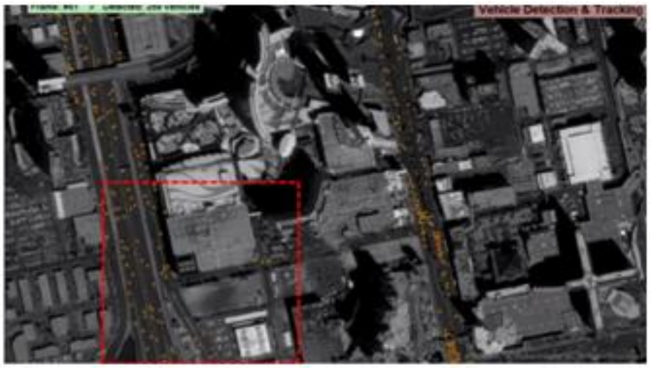

Figure 6: Road Mapping and Vehicle Tracking

3. TESLA AUTOPILOT FEATURES

3.1 AutoSteer and AutoLane Change

AutoSteer keeps the car in the current lane and engages Traffic-Aware cruise control to maintain the car's speed. Using a variety of measures including steering angle, steering rate, and speed to determine the appropriate operation, AutoSteer assists the driver on the road, making the driving experience easier[7]. Changing lanes when AutoLane Change is engaged is simple; engage the turn signal and Model S will move itself to the adjacent lane when it's safe to do so[8].

Figure 7: AutoSteer & AutoLane Change

3.2 Automatic Emergency Steering and Side Collision Warning

Side collision warning further enhances the active safety capabilities of Model S by sensing range and alerting drivers to objects such as cars that are too close to its side. When the car detects an object close to its side, fluid lines will radiate from the Model S image in the instrument panel to alert the driver.

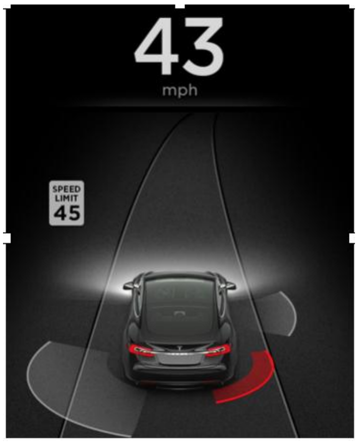

Figure 8: Blindspot detection and side collision warning while lane changing and steering

3.3 AutoPark

Model S can parallel park itself, eliminating the need for drivers to worry about complex and difficult parking maneuvers. When driving at low speeds around cities, a "P" will appear on the instrument panel when the Tesla car detects a parking spot. The Auto-Park guide will appear on the touch-screen along with the rear camera display, and, once activated, Auto-Park will begin to park itself to by controlling the steering and the vehicle speed[9].

With the new update of "Summon", once you arrive home and exit Model S or Model X, you can prompt it to do the rest: open your garage door, enter your garage, park itself, and shut down. In the morning, you wake up, walk out the front door, and summon your car, it will open the garage door and come to greet you. More broadly, Summon also eliminates the burden of having to squeeze in and out of tight parking spots. During beta stage of Summon, it expects customers to become familiar with it on private property. Eventually, the Tesla car will be able to drive anywhere across the country to meet the customers, charging itself along the way. It will sync with customer's calendar to know exactly when to arrive[10].

Figure 9: AutoPark - Summon

4. CONCLUSION

Tesla Motors warns that Tesla Model S and Model X requires drivers to remain engaged and aware when AutoSteer is enabled. Drivers must keep their hands on the steering wheel, as they claim it hasn't yet reached full autonomy. Consumer-report experts believe that these two messages—your vehicle can drive itself, but you may need to take over the controls at a moment's notice—create potential for driver confusion. Following a series of crashes, one of which - the Florida crash - was fatal, has prompted investigations by National Highway Transportation and Safety Association [NHTSA] and the National Transportation Safety Board [NTSB][11]. As of now, Tesla claimed the crash occurred due to inefficiency of the Mobileye Q3processor, to which Mobileye ended their collaboration with Tesla motors, but they will continue providing technical assistance to Autopilot with no further development[12].

Now as a footstep for achieving complete autonomy, Tesla is constantly introducing enhancements in its software and hardware, proven over millions of miles of internal testing, to ensure that drivers supported by Autopilot remain safer than those operating without assistance. To be fair to humans however, there are various scenarios in which an AI powered car would be completely incapable to respond but a human would be able to. But results have proven by talking on concrete grounds, and looking at the exponential increase in processing capabilities, and progress being made in leaps and bounds especially by Mobileye and Tesla Engineers, that it looks like the first hints of fully autonomous driving might be here by 2018.

We are finally seeing the vestiges of something resembling the promised future, where cars are fully autonomous and manual driving is frowned upon.

5. REFERENCES

[1] Tesla Model S Wikipedia: https://en.wikipedia.org/wiki/Tesla_Model_S.

[2] Tesla Motors Website: https://www.tesla.com/models.

[3] http://teslatap.com/articles/instrument-panel-7-0-user-interface-evolution-and-analysis/

[4] S.A. Larsen H., Koren, and Rune Solberg, "Traffic monitoring using very high resolution satellite imagery," *Photogrammet- ric Engineering & Remote Sensing*, vol. 75, pp. 859–869, July 2009

[5] J. Vermaak, A. Doucet, and P. Perez, "Maintaining multimodality through mixture tracking," in *Proc. Ninth IEEE Int Computer Vision Conf*, Nice, France, Oct. 2003, pp. 1110–1116.

[6] A. Doucet, N. Defreitas, and N. Gordon, Sequential Monte Carlo Methods in Practice, *"Statistics for Engineering and Information Science"*, 1st ed. Springer New York, June 2001.

[7] Tesla Website:https://www.tesla.com/videos/autopilot-autosteer

[8] Tesla Website:https://www.tesla.com/videos/autopilot-lane-change

[9] Tesla Website:https://www.tesla.com/videos/autopilot-autopark

[10] https://www.wired.com/2016/03/teslas-summon-feature-like-knight-rider-kinda/

[11] http://jalopnik.com/does-teslas-semi-autonomous-driving-system-suffer-from-1782935594

[12] http://www.wsj.com/articles/mobileye-ends-partnership-with-tesla-1469544028