SELF DRIVING AUTOMOBILES

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Abstract: *Many of us would prefer to enter our cars, indicate the destination point and the car to get you there, when you are staying relaxed or completing your daily tasks. Tesla company makes not only electric cars, but also very accurate autopilots. Their products are not cheap, but have a high safety grade. Comma.ai company is made an autopilot that works based on a camera only and no sensors, which is more affordable. It is not so evolved yet, but it can beat Tesla in the near future. I wanted to study more this domain and make a real project, so I got involved in Bosch Future Mobility Challenge to make an autopilot for a model car. It's an electric model, with a mini-computer under the hood and a simple web-cam on the top. The main goal is to complete the route without getting out of the lane and* abide by the traffic rules.

Keywords: *autopilot, traffic, automation, challenge, machine-learning, open-source*

Introduction

Nowadays, self-driving cars became a reality at an affordable price. You can buy a car and pay around 5000$ for an autopilot, or choose a cheaper 999$ kit to upgrade the current car, if it is a new supported mode, which doesn't come with this option available. Currently, there are no such companies that are able to offer a fully autonomous ride in any weather conditions, following the road markings, without any human supervision.

The self-driving improvement is being achieved by reaching more advanced levels of automation. These levels are numbered from 0 to 5, where 0 means that the driver controls the car without support from a driver assistance system. The first level includes the Active Cruise Control with Stop&Go function, which can adjust the distance to the car in front. At this level can also be implemented the Collision and Pedestrian Warning with City Brake Activation, which prevents collisions via automatic braking. These function are meant for driver assistance only. The second level is a partly automated driving. It offers a Steering and Lane Control Assistant including Traffic Jam Assistant, making daily driving much less stressful. They can brake automatically, accelerate and, unlike level 1, take over steering. The third level will give drivers more freedom to completely turn their attention away from the road under certain conditions, being able to hand over complete control to the car, driving this way autonomously over long distances in certain traffic situations.

Level 4 represent fully autonomous driving, although a human driver can still request control, and the car still has a cockpit. The technology in level 4 is developed to the point that a car can handle highly complex urban driving situations, such as the sudden appearance of construction sites, without any driver intervention. The driver, however, must remain fit to drive and capable of taking over control if needed, yet the driver would be able to sleep temporarily. If the driver ignores a warning alarm, the car has the authority to move into safe conditions, for example by pulling over. While level 4 still requires the presence of a driver, cars won't need drivers at all in the next, final level of autonomous driving.

Unlike levels 3 and 4, the "Full Automation" of level 5 is where true autonomous driving becomes a reality. The car performs any and all driving tasks – there isn't even a cockpit. Therefore, every person in the car becomes a passenger, opening up new mobility possibilities for people with disabilities, for example. And best part about it is that you don't even need to have a license. No more bothering because of cops!

Corporate and open-source autopilot software

Tesla is known for being an extremely innovative company that has disrupted the auto industry by creating electric cars that are not only appealing, but also included advanced technology far beyond what most other cars offered. It's a car that keeps improving with software updates, even after you buy it.

Tesla's hallmark features are advanced self-driving technology, known as Autopilot and Full Self-Driving. When originally introduced in 2014, known as Autopilot 1.0, Tesla and Mobileye provided for the first time the self-driving technology. Tesla felt Mobileye wasn't moving fast enough and decided to roll out its own system known as Autopilot 2.0.

Nowadays, the cost of Autopilot, which is currently classed as a level 2 automated system, depends on several factors such as the date a Model S, Model X or Model 3 was purchased and also if Autopilot was added at the time of vehicle purchase. Therefore, it can vary between $2000 and $4000. The cost for Tesla's Full Self-Driving feature also varies, but it can be much higher, between $2000 and $7000. It is an almost level 4 of automation and it's features include auto-parking in both parallel and perpendicular spaces, automatic driving from highway on-ramp to off-ramp including interchanges and overtaking slower cars, parked car will come find you anywhere in a parking lot and responding to traffic lights and stop signs.

One of the problems that is common in autopilots is **hitting stationary objects at high speed.** When you engage Traffic Aware Cruise Control with Autosteer at freeway speeds, Automatic Emergency Braking is reduced to avoid false-positive sudden braking, which could cause more accidents. *Tesla's owner's manual states: "Traffic-Aware Cruise Control cannot detect all objects and may not brake/decelerate for stationary vehicles, especially in situations when you are driving over 50 mph (80 km/h) and a vehicle you are following moves out of your driving path and a stationary vehicle or object is in front of you instead".* Whether it's a broken-down vehicle suddenly appearing in the path ahead or a vehicle crossing a divided highway, these are examples of why drivers must pay attention. The possibility of incidents like this one shows how conscience are the developers to this situations, being morally forced to program the pilot to sacrifice driver's life in order to avoid a chain of traffic accidents.

When choosing an autopilot to drive your car, you can find out about the Openpilot. The U.S. hacker George Hotz, best known for developing exploits that targeted Apple's iOS operating system and for reverse-engineering Sony's PlayStation 3, in September 2015, founded Comma.ai. The company have the goal of developing a semi-automated system that would improve cars' visual perception and electromechanical motor control.

Openpilot is an open source software built to improve upon the existing driver assistance in many new cars on the road today. It offers Tesla Autopilot like functionality for new models of Toyota, Honda, Ford, Audi, Mercedes Benz, Volkswagen and more models are adapted consistently by developers who want to integrate the openpilot software, but their car is not yet supported. It enables your car to steer, accelerate, and brake automatically within its lane. To drive on a highway, you only have to press the cruise control SET button and openpilot will engage. To disengage, you have to use pedal. While engaged, openpilot includes camera based driver monitoring, that works both day and night to alert the driver, when his eyes are not on the road ahead, as a safety feature.

The software runs on a phone, which you can purchase with the connection cables included and software installed, for only 999$. The software receives updates, improving the driving accuracy and getting more handling capacities in non-standard situations, as Tesla's more expensive autopilot does. This is achieved by sending the data from the camera and car behavior, corrected by the driver, back to Comma.ai's servers for teaching the autopilot in the context of the situation happened.

A big downside of the Comma AI's configuration is the lack of any distance sensors. It is driving based on the camera image only. However, in some situations it behaves better than Tesla's autopilot. This downside is making the car incapable to handle optical illusions and adapt in the situations when the obstacle is not recognized by the camera. The addition of distance sensors to the pilot can increase significantly it's confidence in the action it makes, improving the driving experience and make it safer.

Bosch Future Mobility Challenge

This year, I decided to participate at BFMC 2020, within the team named "Data Punks". We are challenged to make a car model to drive by itself on a down-sized race track with traffic lights, traffic signs and pedestrians. The biggest challenge for us, is to train the autopilot to park on the designed area, between the parking signs. In order the car to park, it have to maneuver between the parking signs, in area indicated by on-road white line markings. At the final test, there will also be other cars on the track. For facing this challenge, we work on the implementation of distance sensors.

At the beginning, we had an interview with Muntean Ionut, the organizer of this event, who came to know us and talk about our visions. After few days, we got an email, saying that we were accepted, along with another 41 teams from Romania and Bulgaria. There was organized a kick-off for the competition, that took place at Cluj-Napoca at their headquarters. As we couldn't be present, we watched the event and asked questions through skype.

The competition is well organized. There is a website with all the useful information, which is updated during the contest, and a forum where you can receive answers to your questions from other participants and the organizers. There we found a great and helpful community. The model car offered by the organizers is a high quality 4x4 car, which can develop decent speed from an electric motor. It had the minicomputer already mounted, which is a Raspberry PI 4 B, the most powerful version of development board at the moment, and a motor-controller board connected to it. It also has an on-board battery that can power both the computer and motor for a few laps.

Our team chosen to program the car to be steered by a neural network, as this is a modern and popular solution and seems more trustworthy to us, because it can face the non-standard situation and make the optimal decision based on the data on which it was trained. The advantage of this option, in comparison with simple algorithms made of lists of instructions, it can suggest at least any movement or steering with a low confidence score, without getting in a state when it doesn't understand what to do. For further improving, the software doesn't have to be debugged and changed in some way, as the only action required is to train the network again, on a better data-set. A good data-set represent the characteristics of different types of behaviors in many different situations. If the car is not acting correctly at some point, that means we need to provide more training data for that specific edge-case.

To automate the training process, we came with the solution consisting of a virtual track, where we can drive the car and at the same time, train the neural network. This process required 3d modeling of all the components of the track, which we did with Blender. It is a software used not only for modeling, but also for making CGI (computer generate images) animations.

Our plan is to have two neural networks running. One of them is responsible for image processing in order to detect the traffic signs, pedestrians and other cars involved. The other one outputs the steering angle, looking at the road. We have to run them on the Raspberry PI, a single-board computer with ARM processor architecture, and 4 GB of RAM. It is very energy-efficient, consuming up to 10W, without peripherals. In our kit, there is an 8 Megapixels camera, connected with a ribbon cable. It is positioned on the roof of the car, and so we did in our simulation. It will provide the input data for our neural networks to identify objects and decide the steering angle, along with the distance sensors. Unfortunately, the Raspberry PI 4 B can't satisfy our needs of running two neural networks on the CPU, because it is not powerful enough in terms of computing.

We discussed this problem with our mentor from university, Mr. Viorel Carbune, who found a solution and offered to us the Movidius™ Neural Compute Stick from Intel, which is designed to speed up the processing, dealing with complex computations better than the on-board CPU. It is used with an application programming interface to load the neural network on it and process the images. In our case, we firstly trained a neural network to distinguish between common on-road objects as stop, parking, priority road and road crossing signs, pedestrians, other cars on the road and the color of the traffic light. All of the training part was done on a powerful workstation. To speed up the training process, there is a configuration of the Tensorflow framework, which we used to train our neural networks, and the NVidia graphics cards. This method requires more installation steps, but it can shorten the training time from 3 up to 20 times, depending on computer's components.

After we got the Movidius™ stick we prepared one of the neural networks on the workstation. As a result, we achieved an increase of performance up to 3 times. The other one was running fast enough to run on CPU. One more part of hardware that we received is the BNO055 smart sensor, used in AR, immersive gaming, fitness and indoor navigation.

We expect the pilot to be able to wait for the green traffic light at the beginning of the track, to start driving. At intersections, there can be stop signs, where it should come to a complete stop for 3 seconds, and continue its path, or it can be a priority road sign, indicating that the car can continue its movement. There can be obstacles on the road, which can be avoided by crossing the dotted central line. Reaching at the road crossing sign, it should slow down and if there is a pedestrian on the right side of the lane, waiting to cross the road, the car should stop and wait for him. When it will detect parking signs, it should park between them. Luckily, for the first round, we have to only drive on the lane, make turns at intersection and act correspondingly to stop and priority signs.

Conclusions

Most experts tend to agree that, technologically, we are about 90% of the way to perfecting the hardware, guidance systems, and software to make vehicles that can reliably and safely drive themselves. This means that we are few years away from fully self-driving cars on our public roads. Almost all of the fully autonomous vehicles currently allowed on public roads are still under the direct supervision of human pilots, and they're only driving on roads that have been heavily studied and mapped in three dimensions. There are legal questions, such as whether a car company will accept liability when the driver is its software. Ethical challenges may prove even harder. Should a self-driving car swerve to avoid a young child, risking the life of its owner-occupant?

The most advanced cars are equipped with sensors that can make detection at night, the thing that human eye is not capable of. These includes radar and LIDAR types of sensors. They use radio waves or light pulses to scan the road ahead for potential obstacles. Thus, technology proved to be better at sensing environment and fast reacting, but make the right decisions in hard ethical cases is still a big subject that need to be discussed and implemented in current legislation. There are few countries accepted this technology on their public roads, the other ones are not ready yet. This can become a bigger challenge than making autopilots, especially when legalizing the fully automated driving autopilots.

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