Autonomous driving or Self-driving cars

Taking the example of Tesla

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A brew introduction: What is the problem we want to solve?

First of all we want to express that within the topics that have been considered to work in, this has been the most interesting, due to the increasing popularity that the Elon Musk brand is gaining along with the development of self-driving cars.

Next we will proceed to analyze the concept of what is a self-driving car and which problem we want to solve.

So, a totally self-driving car is a vehicle which is controlled by a computer and it's not requiring the action of a human as we have seen with the traditional cars we are used to seeing in daily life. With this idea the problem we want to settle is clearer; the main objective of self-driving cars is to upgrade the concept of the normal car to the next level, in order of being a conveyance without the intervention of a human as a driver. Autonomous cars are intended to be a more comfortable and safe way of (at the moment) human transport.
It’s predicted that the era of self-driving cars will be a disruptive change similar to the 1920’s that introduced the motor car.

As we will see later, there are at least 5 levels of autonomous driving, each one with its particular complexity.

The autonomous driving car needs from a variety of hardware resources to cope with its main objective, devices such as: radars, lidars, GPS, a lot of GPU's...
The aim of this resources is to collect information of the environment to help the software of the machine to do it's tasks. Also we will see that the car needs to process a lot of visual information so this problem is very related with the subject of Artificial Vision.

The different levels of autonomy

Totally self-driving cars are a difficult objective to achieve, that’s why we don't usually talk about a car that already knows what to do in every situation, but cars that are still learning or being programmed to work by themselves in new situations, that way the human inside the car is delegating new responsibilities to the automatic pilot from time to time.
Experts have defined five levels in the evolution of autonomous driving. Each level describes the extent to which a car takes over tasks and responsibilities from its driver, and how the car and driver interact.

The zero level is those systems that can help in some way to the driver of the car, but don’t help with the action of driving. We consider warnings and momentary assistance like automatic emergency braking or blind spot warning in this level.

The first level is always mentioned is the Driver Assistant system, that basically supports and makes a little bit easier or less tiring the action of driving, also those who help ensure additional safety. Normally in this level we consider those cars that can help providing brake/acceleration support or steering features like lane centering, which is less common, but not both at the same time cause the it would be considered a level two autonomy car.
So as we said the level two provides both steering and brake/acceleration support to the driver, is usually called a Partly Automated Driving.

The third level of autonomy is the line where the driven is considered to be Highly Automated in certain situations, but it requires the driver to be aware of the road. The vehicle can drive by itself in certain situations and will not operate unless all required conditions are met. While the feature is running the AI is responsible.

Level four for autonomous driving is considered to be the Fully Automated Driving, but not in every situation. It means that the car will drive by itself in most situations, but will be exceptions. The driver can use this time to, for example read, or any other activity. Is required that if the car won't be able to drive autonomously in that situation it warns the driver and gives him some time to react and go back to driving. Some people believe that this level should let you take a nap, but I don’t think that would be possible in if we encounter a situation where the driver has to take control of the car. Most people also think in this level the steering wheel and pedals must be installed for that reason.

The last level, level five, can self-drive in any situation. There is no more a driver, and no need for control elements like the steering wheel.

Different implementations on autonomous driving

In this section we are interested in analyze the scope of self-driving cars seeing the different implementations carried out by diverse companies. As examples we used three different approaches that would summary the global spectrum, those would be Waymo, Tesla and Comma.ai.
At the moment does not exist any level five implementation, or any perfect self-driving car, cause as Elon Musk says " - It will never be perfect", perfection does not exist in the real world, although it's already known by statistics that those systems will reduce accidents significantly, as so they are doing and also save a lot of wasted money.

Waymo is also known as Google self-driving car project. The approach of this company is very similar to for example to Uber's, with the objective of creating an autonomous taxi net in cities.
Both are known to use a LIDAR (light detection and ranging) system, its operation is based on the emission of light in 360º, which is captured and that forms a three-dimensional space where the current situation is analyzed, the scene is seen from above and this way it's easier to understand this map of points the LIDAR creates, and then the computer inside the car analyzes the forms of this map in search of other cars, pedestrians, vertical signs...
A big flaw of this sensor is the cost, and that works emitting light in the visual spectrum and it's really affected in situations where visibility is reduced. Here is a graph that shows which situations are most favorable with this sensor.

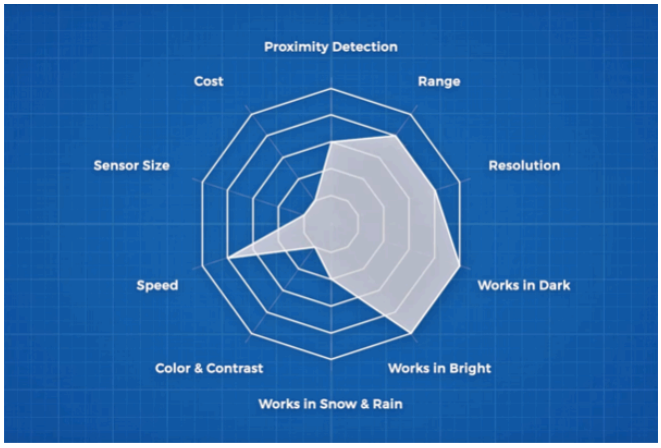

Image 1. Strenghts and witnesses

The cars the company uses are built (according
to Waymo members) for full autonomy. To complement the LIDAR (main sensor) they also use short-range lasers that detect and focus on objects near the vehicle, and a radar is used to see around vehicles and track objects in motion.
The interior of these cars include buttons for riders to control certain functions like "Help", "Lock", "Pull over", and "Start ride".
The car has been tested in so many difficult conditions at level 4 of autonomy with and without someone sitting behind the steering wheel and also sharing roadways with other drivers and pedestrians.

In the annexes there is a video showing how a LIDAR works.

Tesla Autopilot is an advanced driver-assistance system feature offered by Tesla and has a different approach compared with Waymo like companies, and decided not to use a LIDAR sensor, instead its main perception comes from cameras, which not only makes the car look like a common car physically, but also cheaper and more battery efficient..
Among many functionalities as Adaptive cruise control, Autosteer, Safety features, Speed assist or Navigate on Autopilot there is considered to be a level 2-3 autonomy at this moment because the car isn't prepared to detect Traffic Lights or Signaling, but the capabilities of the system is improved via software updates.

As an upgrade to the base Autopilot capabilities, the company's stated intent is to offer full self-driving (FSD) at a future time, acknowledging that legal, regulatory, and technical hurdles must be overcome to achieve this goal.

The project of the company Comma.ai, leaded by George Hotz, is called Openpilot and is different respect the previous two projects because it allows users to modify their existing car with increased computing power, enhanced sensors, and continuously-updated driver assistance features that improve with user-submitted data. So this is a project that not involves the development of a self-driving car, it is more on the development of an intelligent driving agent which is open source.
Openpilot provides to the user a Lane centering and an Adaptive cruise control plus a face recognition system which detects if the driver is distracted for a couple of seconds.
There is also many car brands which can work with this system, such as; Jeep, Honda or Toyota.

The Tesla example

We chose the example of Tesla cause is a company that exploded in popularity, and the one who already has a big float of cars in the roads having a total of more than a billion kilometers driven, and also uses a base technology known by all of us, cameras, and software related to image treatment, object recognition and other AI related.

Body of a Tesla car (Study of hardware features)

Tesla has the objective of accelerating the world's transition to sustainable transport, and that's a reason why they decided not to use LIDAR in their cars, they defend it's an expensive technology that can be replaced by the sensors they use, the words "Anyone relying on Lidar is doomed" and "it sidesteps visual recognition that is necessary for autonomy, and gives a false sense of progress and is ultimately a crutch" aroused a lot of controversy.
To replace Lidar Tesla uses mainly cameras, a radar and ultrasonic sensors, that way each other can cover the flaws of the other.
Before talking about the sensors we have to also name that to process that much of information Tela designed their own computer with GPU's that is capable of evaluating up to 2300 frames per second. (equivalent to 2,5 gigapixels per second) and 36'8 tera operations per second for the neuronal network. And to be safe of any problem in it almost every system in the computer has a duplicated one lowering the risk of total failures.

The vehicle uses eight cameras which covers a complete 360º of vision, 12 ultrasonic sensors and a radar facing forward with enhanced processing capabilities.

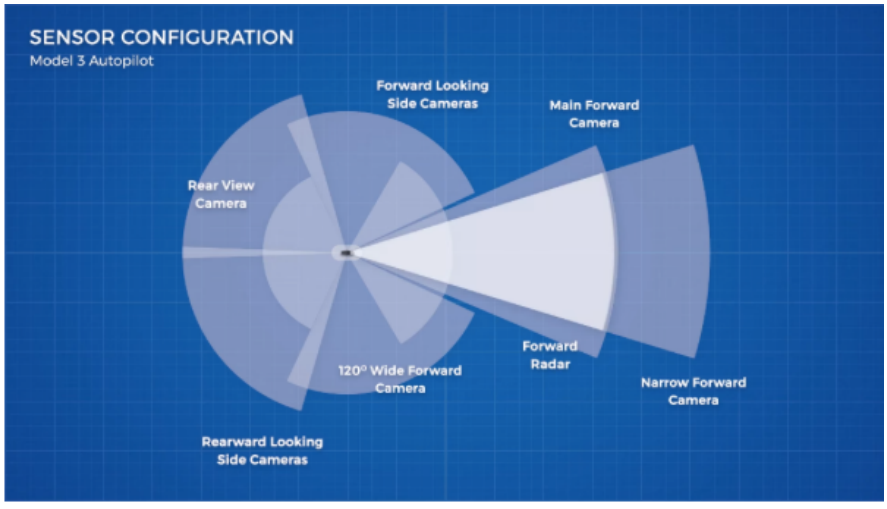

Image 2. Sensor configuration / Source: Real engineering

Cameras as we already said are the base of this implementation, really useful in long and medium distances and depth perception, and to understand the world around the car as humans would do with sight., but those have similar issues like the eyes, that don't see well in the dark or when raining, that's why they also added a radar that it's not really affected by that and that can measure distance much more precisely than cameras in medium distances. The radar generates a Point Cloud that tells us which objects are closer and its distance to us.
Finally until 8m distance precise detections can be made by ultrasonic sensors that will have a lot of importance in narrow situations or possible collisions. With those tree in the next images we can see they achieve a really high level in every check required.

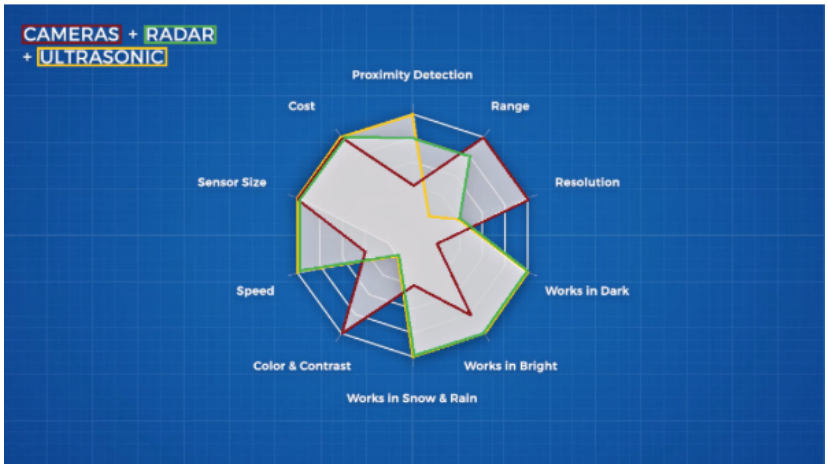

Image 3. Combined stats / Source: Real engineering

With this hardware Tesla claims they will be able to get to a Full Autonomous Driving via software updates. A big update is yearly created with new features and improvements in driving.

Mind of a Tesla car (Study of software features)

As we already said the real challenge is not in the hardware but how to program cars to be autonomous, and for doing that purpose Tesla uses a lot of Data coming from real driving or simulators, with that data they train a model based in neuronal networks that learns to drive with experience, similar to something we found called the YOLO method of object detection. They probably use a lot of other algorithms of AI, segmentation of images and object recognition, and extra safety measures, but we couldn't have access to that information, but we could find what does a Tesla car "see", and how they classify the information of the sensors, cameras and radar.

To get an automatic driving in an unpredictable urban situation we need many real-time systems.
Localization, perception of the environment, planning and control systems are needed to achieve automatic driving through what cameras and sensors perceive.
These real-time systems of Tesla distinguish in real time the different vehicles and pedestrians perceived by cameras and sensors, the areas enabled for the car and the lanes through which it can pass. All this information obtained every moment allows the car to be driven autonomously.
The first is identify the enabled zone through which the car can pass. Then if there are different lanes, it indicates them with two lines to delimit it using a different color for each lane. And it indicates with an arrow the direction that the car is currently taking and with a line it draws the itinerary that it is following at that moment.
It also identifies any type of vehicle it perceives and pedestrians, differentiating them by type (Car, Minivan. L. Truck, Moto, and Pedestrian), by the distance between the vehicle or pedestrian and the car, and an identifier that indicates position of object taking as reference the lane that follows the car.

Image 4. Combining computer vision (vehicle clustering) and depth vision by radar (yellow points)

The same source has a video showing the "point cloud" that the radar gives us, and in a recent conference by Tesla a 3D map generated by the perception of the car in six seconds of driving, those are linked inside the annexes.

Topics related with the subject

As we could see in the section before, the part of a Tesla's software connects directly with a few topics that have been studied in Artificial Vision.

There is an essential thing that a self-driving car must do. We are talking about object recognition. This matter was studied in at the classes at the same time we saw HoG and Template Matching. Furthermore as we said, we can consider that YOLO algorithm it is also a Segmentation technique in order to clustering the image in different objects and then recognize them at the same time. This topic was also seen in the diapositives provided in the 'Campus Virtual'.

We would like to say that this topics were also seen in the laboratory classes, which gave us a better understanding in studying self-driving cars.

The problem with what we learned in class to classify objects it's not fast enough for being able to be used in a self-driving system, cause it has to be really fast for safety and real-time computing.

So we finally discovered that probably Tesla and other companies that use object recognition and classification would have trained a neural network similar to YOLO, acronym of You Only Look Once.
This method detects and classifies objects in images all at once, and it's capable of doing so within only a few milliseconds with the right hardware (GPU's are really important), and a good training of the model with a big set of data.

The algorithm uses what are called convolutional neural networks, it's trained previously with objects we want to detect and can be train for any purpose, in this case we would probably want to train with images of pedrastians, all kinds of vehicles in roads, and signs, etc.
In parallel the image is divided into cells that are analyzed and it calculates the probabilities of objects being there, then those cells with a probability higher than a threshold are clustered and labeled with the type of object the neural network thinks it is.
This method is really fast cause it divides the image in cells, without having to think of every pixel in the image, and the important cells come to be only a few, cause most of the cells are predicted to have a really low probability of having an object, and all of them are done at the same time.

Possible extensions of the application studied

The use of self-driving vehicles will be a big change in the world, one of the most talked possible futures is where cars are not usually property of someone but instead totally automated vehicles form a net of taxis that drive around taking people in their regular schedules.
A next step to achieve level five autonomy will probably be thinking about driving as a multiagent problem, when more autonomous cars are in roads, making possible the communication between cars and improving traffic.

The train dilemma and possible dystopian futures

Autonomous cars can have a great impact in the world but there is certain moral problems that can lead to dilemas like the known ass the train/tranvia dilema, that is summary would be deciding between two options with a tragic output where an action is involved, like choosing between following your direction and crash with passengers inside or changing your direction resulting pedestrian run over.
We also have the influence in jobs related with transport, and privacy problematics.

Webgraphy

Autonomous Driving Levels:
The 5 Autonomous Driving Levels Explained
Self-driving car
BMW Autonomous driving
SAE Levels of autonomy

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