What are the different sensors that are typically used to obtain the data which is fed into the navigation stack for autonomous systems? What are the advantages and disadvantages associated with these sensors? When do we use which? What about sensor fusion? (Answer in around 200 words. Be clear and concise. Use diagrams if required.)

Types of Sensors used in an autonomous vehicle:

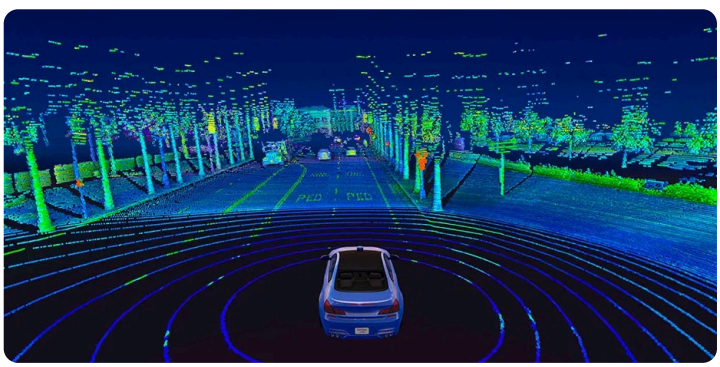
- **LIDAR :** LIght Detection And Ranging

Advantage: Maximum accuracy as well as maximum range from point of view. Almost all autonomous cars use this technology as it is the most reliable and thus provide some most accurate data. It also adds a great deal of depth perception

Disadvantage: it is extremely expensive to procure. This is one of the primary reasons why Tesla refuses to use LIDAR as it increases the production cost quite significantly.

Also its current form is difficult to integrate with in a normal car's body shape, thus you see companies like Waymo has a big unit attached on top of the cars roofs, rather than smoothly integrate with the car's body.

Note: Luminar, a startup backed by Peter Thiel Fellowship is working to miniaturise the LIDAR module and make it more financially accessible. Maybe in the future we will have a more affordable LIDAR system.



- **GPS :** Global Positioning System

This is a pretty bulletproof technology at the moment, and uses satellites to locate the vehicle's position. We use it to find the general location of the vehicle, and even it's position down to the meter, in some powerful modules.

Although it was pretty expensive at the beginning, the modules have been standardised so much that the car company and cost is really low compared to the net cost of the vehicle.

- **RGB Camera:** camera module that is used in our phones, as well as cameras.

Advantages: Extremely low per component cost as well as extremely small footprint thus it can be integrated very well into the car's body. Moreover the technology is very much charge does reliability is very high compared to other technologies.

Disadvantages: It produces only two dimensional image thus requiring copious amounts of machine learning and deep learning to extract reliable conclusions from the image that we all percieve. Moreover there is absolutely no depth perception, and thus we are forced to rely on computation, which is fine, but the computer learns what it sees. Thus if there is an edge case that is missed, then the computer will not know how to interpret that and that can lead to really dangerous situation.

Tesla uses 2d cameras, multiple ones to create a virtual map of the car's position. They are making slow, but steady progress with their models to achieve level 5 autonomy in the future. But currently the climb looks really steep for them, as well as for others who are not using LIDAR.

- **RADAR:** Radio Detection And Ranging

Advantages: Provides a good depth map in front of the car. This is mainly used in the application of radar activated cruise control. where the radar is used to check the speed of the car ahead and adjust it's speed accordingly.

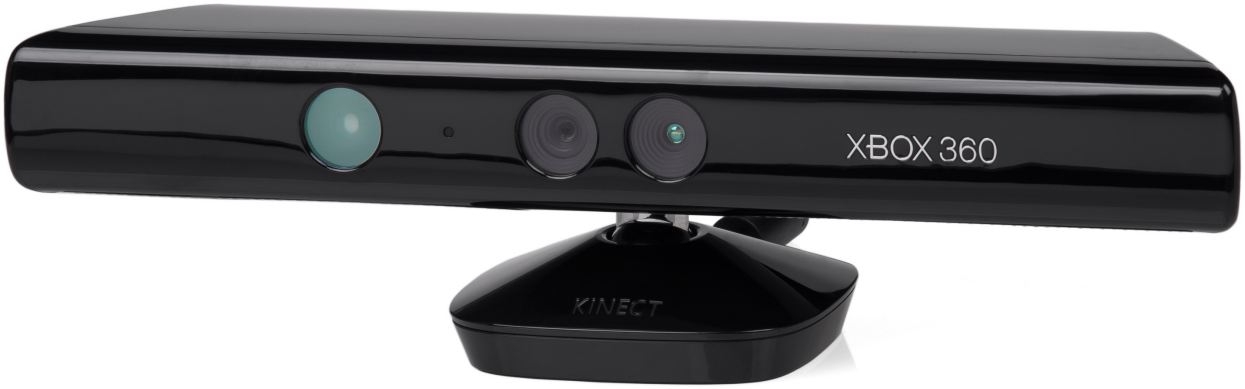
Disadvantages: It doesn't have a very long range, and can typically be associated only with detecting the speed and relative position of the car ahead. So it is used in Auto Emergency braking as well.

It is not as useful as LIDAR, which can produce some sort of imaging, nor is it as cheap as RGB cameras. It is middle of the ground.

- **3D CAMERA**

Advantages: Can produce a convincing map of the obstacles ahead. It is also not as expensive as LIDAR and moreover, it can produce as well as construct a proper 3D image that can then be used for analysis.

Disadvantages: Apart from cost, and more AI training, there really isn't much disadvantages. Even for the cost factor, it is more expensive as compared to RGB modules, but not as expensive as compared to LIDAR (not as accurate also)



Although the Kinect was a commercial failure, it is a hobbyist favourite for DIY projects that require depth information!

2. Below is a research paper which talks about detecting intersections given a bird's eye view image (obtained through some manipulations from the image from the stereo camera).

Link to the paper: https://robotik.informatik.uni-wuerzburg.de/telematics/download/iv2012.pdf

Make a brief documentation on your understanding of the above paper. The documentation can include insights, results, alternatives and any suggestions/improvements that you can think of. We essentially want you to explain the algorithm to us, discuss how well it will/won't work.

The algorithm consists of the following main steps

- Preprocessing
- Beam model construction
- Analysis
- Conclusion

Essentially this algorithm is for situations where there is very limited GPS or satellite imagery available such that a decision has to be made on spot to ensure that proper path planning is done.

The way it works is by using LIDAR mainly. Essentially the liner data is taken and the extra parts such as trees and nearby cars are removed through an algorithm such that at the end we have only the roads and the intersections.

If you want to ask how the pedestrians Audi cars are removed it is by the algorithm which essentially generates a threshold cube and then we compare that with existing database for an average dimensions of a pedestrian or other cars, then we remove those cells, such that we have only the line of the road.

Once we have the preprocessed data, we now implement the beam method that was given in the title of the paper the entire data is converted into 360 beams, for 360°. Now what we do is that we normalise the distance is that the beans have if the beam is unobstructed then it has a value, say L.

So taking that value as one we then normalise the other values from 0 to 1. So if we plot the graph between the normalised distances and the serial numbers of the beams, for a plus shaped intersection we will have four peaks and if you have a T-shaped intersection, we will have 2 peaks.

This will allow us to differentiate between the intersections.

Feasibility:

Although the paper quotes 80% accuracy rate I am sceptical about the sufficiency during bumper to bumper traffic. Most of the line or beams will be obstructed by trees pedestrians and mainly cars and does the data that is acquired will be so less. However this seems to be as robust as a mechanism we can get with the current infrastructure and sensors.

-however we must also note that this algorithm/approach is used only for remote areas in which anyways we will have less traffic. If we had more traffic it will be pretty well mapped.

I feel the success of this method really lies on the algorithm which removes pedestrians and cars and tries to keep as much data as possible.

Sources

- Justin Huang YT Channel : https://www.youtube.com/watch?v=bJB9tv4ThV4
- How to install TurtleBot for ROS noetic on ubuntu : https://automaticaddison.com/how-to-launch-the-turtlebot3-simulation-with-ros/

- OPEN CV Contour detection: https://www.youtube.com/watch?v=AMFhjir4WgQ