

Autonomous Vehicle Technology

A brief overview of the technology and current trends in Autonomous Systems

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ABSTRACT- The ever evolving technological needs for automation has led to the development of Autonomous vehicle technology, to minimize human intervention or completely eliminate it. An Autonomous Vehicle is a system which navigates without any human interaction or intervention. The Autonomous vehicle technology is a leading research field in Computer Vision and Artificial Intelligence, having the potential to significantly improve transportation safety and offer immense social, economic and environmental benefits. The Paper presents a brief overview of the Autonomous vehicle technology, Semi- Autonomous vehicle and types of Autonomous vehicle. Later the description of various sensors used for Localization and Mapping is discussed. Also various Obstacle detection and Motion Planning algorithms used in Autonomous vehicle is discussed, followed by some of the filters used to account for sensor errors is mentioned. It is followed by the applications, advantages and disadvantages of Autonomous vehicle technology. Finally the Legislative concerns regarding Autonomous vehicle technology is highlighted.

KEYWORDS- Autonomous Vehicle, Drones, Swarms, LIDAR, Sensors, Odometer, SLAM, A Star, Dijkstra, Terrain Maps, Computer Vision, Artificial Intelligence and Legislation.

I. INTRODUCTION

Autonomous vehicle technology is a growing Research field which has the capacity to revolutionize Transportation. This technology which seemed like a futuristic dream, is already here to stay. Today we see self-driving cars, autonomous drones and swarms that work collaboratively to complete tasks autonomously. The technology is developed from the fields of Computer Vision and Artificial Intelligence.

An Autonomous Vehicle is a system which navigates without any human interaction or intervention. The major aspect of any autonomous system is its ability to sense its environment and interact with it. Here the concepts of SLAM- Simultaneous Localisation and Mapping comes into picture. Where an autonomous system like a robotic car or drone, Senses its environment using sensors like RADARS, LIDARS, Cameras, IMU, GPS, Odometer, etc. to build a map of the environment and use it to locate its position in the map and then calculate a path to navigate to the destination. The ability to identify objects as obstacles is done by computer vision, filter concepts and Optimal paths are found using various Motion Planning Algorithms like A*(Star) algorithm, Dijkstra algorithm, etc.



Fig. 1: An Autonomous car and Drone

(Source: <http://intelligente-welt.de/forschung-fuers-autonome-fahren-sensoren/> , <http://www.cityofsl.us/index.aspx?NID=859>)

II. HISTORY

The concept of Autonomous Vehicles was presented as early as the mid-1920s. On the streets of New York in 1926, “Inrrican Wonder” a radio-controlled Chandler was demonstrated. It was the first major public display of a driverless car in the United States. General Motors in 1939, introduced the Futurama ride at the World’s Fair and advocated for a national automated highway system, where automated vehicles would replace human drivers entirely.



Fig. 2: Images of early Autonomous vehicles

(Source: <http://www.riminiduepuntozero.it/wordpress/wp-content/uploads/2014/12/Convegno-TRC-Rimini.pdf> , <http://keithrbujak.com/the-future-of-the-autonomous-car-is-semi-autonomous/>)

Semi-autonomous Vehicles:

Autonomous vehicle which act independently, but need human intervention or monitoring are call Semi-Autonomous Vehicles. Planes with cruise control or UAV’s (Unmanned Ariel Vehicles) can be regarded as semi-autonomous system. Also new semi-autonomous cars have been introduced with features like, Auto-parking, lane warning, intelligent cruise control, emergency braking etc. A good example could be the recently introduced Tesla Model S auto-pilot mode, which allows hands free driving on Highways but still requires human intervention for safety purposes.



Fig. 3: Tesla Model S auto-pilot mode

(Source: <http://www.dailyherald.com/article/20151110/submitted/151119875/> , <https://www.carthrottle.com/post/the-legalities-of-autonomous-cars-and-what-it-means-for-us-as-drivers/>)

Types of Autonomous Vehicles:

Autonomous vehicles can be grouped into different types based on the terrains they navigate, such has:

a) Land:

Self-driving cars is the well-known example of Autonomous Vehicle which navigate on land. Though other less-known example is the metro systems, which make use of self-driving trains. Major mining company uses automated trucks and trains to transport mineral ores.



Fig. 4: Autonomous Train and Car

(Source: https://en.wikipedia.org/wiki/Shanghai%E2%80%93Hangzhou_Maglev_Line , <http://technews.tw/2016/05/16/google-will-pay-arizona-drivers-20-per-hour-to-test-self-driving-cars/>)

b) Air:

Autonomous Vehicle which navigate in air have been developed much before self-driving cars. Spacecraft have been using Autonomous technology for decades. Unmanned Aircraft Systems (UAS) comprising the Unmanned Aerial Vehicles (UAV), and the more known Drones is where a lot of research in the areas of autonomous and unmanned vehicle technology is taking place and is expected to grow exponentially in coming years.



Fig. 5: UAV and Drone

(Source: <http://www.concordebattery.com/background-downloader.php?id=192> , <http://6spot.net/design-2/israel-engineer-design-land-drone-delivery/>)

c) Water:

Autonomous and unmanned Drones and Submarines are being used in marine environments, both as underwater and surface vessels, for mapping and studying aquatic life and coral reefs. Though this is a very recent development.

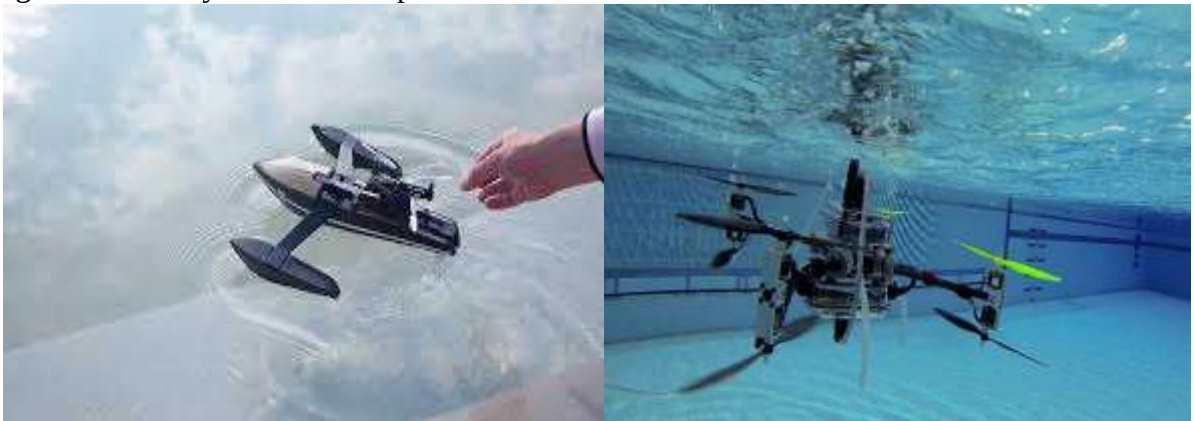


Fig. 6: Surface and Underwater Vessels

(Source: <http://www.72byte.com/product/parrot-hydrofoil> , <http://www.lavoz.com.ar/tecnologia/conoce-naviator-el-drone-anfibio-que-vuela-y-es-submarino>)

IV. SWARMS

Swarm robotics is a new approach in Autonomous vehicle technology used for the coordination of multi-robot systems which consist a large collection of simple robots. A desired collective behavior is obtained by the interaction between the robots themselves and the robots interaction with the environment. This is inspired by nature of collective strength of bees and ants.



Fig. 7: Swarm land and air robots

(Source: <http://www.fainaidea.com/archives/60725> , <http://motherboard.vice.com/read/why-the-us-military-is-funding-tiny-autonomous-flying-robots>)

SLAM (Simultaneous Localization and Mapping):

Autonomous systems work using the concepts of SLAM (Simultaneous Localization and Mapping). SLAM according to Wikipedia “Is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of robot's location within it”. It can be divided into two tasks. Localization and Mapping.

A) LOCALISATION:

Localization is the task by which the robot determines its position relative to the map. It is achieved by using various proximity and position sensors. Such as:

Odometers:

Odometers such as wheel encoders are used to calculate the heading of the robot i.e. by how much has the robot moved in a particular direction. This is done by calculating the RPM of the motor, which is used to calculate distance moved.



Fig. 8: Wheel encoder

(Source: <http://kursuselektronikaku.blogspot.in/2015/07/membuat-alat-pengukur-kecepatan-putaran.html>)

GPS:

The Global Positioning System (GPS) is a satellite-based navigation system consisting of a network of 24 satellites placed into orbit by the U.S. Department of Defense. It is used to provide location and time information. It works when there is an unobstructed line of sight to four or more GPS satellites, anywhere on or near the Earth. Also, it functions in any weather condition.



Fig. 9: GPS Module

(Source: <http://jestemgeekiem.pl/gadzety-na-dlugi-weekend/> , <https://imu.nl/internet-marketing/werken-met-reactieve-satelietsites/>)

IMU:

Inertial Measurement Units (IMUs) is a system which consists of gyroscopes, accelerometers and magnetometers to measure linear and angular motion. It is a self-contained system which does not require any external component for it to function.

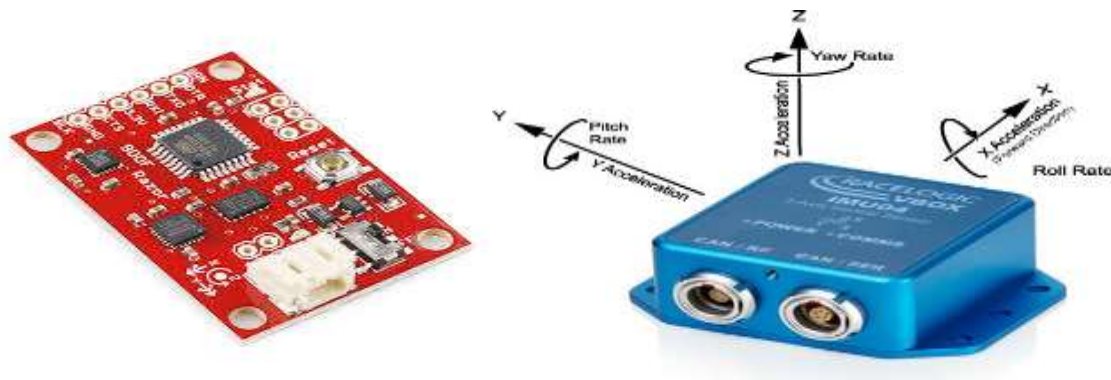


Fig. 10: IMU Sensor

(Source: <http://store.fut-electronics.com/collections/sensors-controls> , <https://wpstatic.idium.no/www.geoforum.no/2016/03/Odd-Erik-Mj%C3%B8rlund-Hvor-er-vi-om-10-%C3%A5r.pdf>)

B) MAPPING:

Mapping is the task by which a robot generates a Map of the terrain in which it is navigating by integrating the information gathered with the robot's sensors into a given representation. The Map generated can be 2D or 3D Map, depending on the needs of the navigation. The various sensors used for map creation are:

LIDAR:

LIDAR is a surveying technology that measures distance by illuminating a target with a Laser light. The LIDAR instrument fires rapid pulses of laser light at a surface and a sensor on the instrument measures the amount of time it takes for each pulse to bounce back. The LIDAR instrument calculates the distance between itself and the target with high accuracy, as light moves at a constant known speed. By repeating this in quick succession the instrument builds up a complex 'map' of the surface it is measuring.

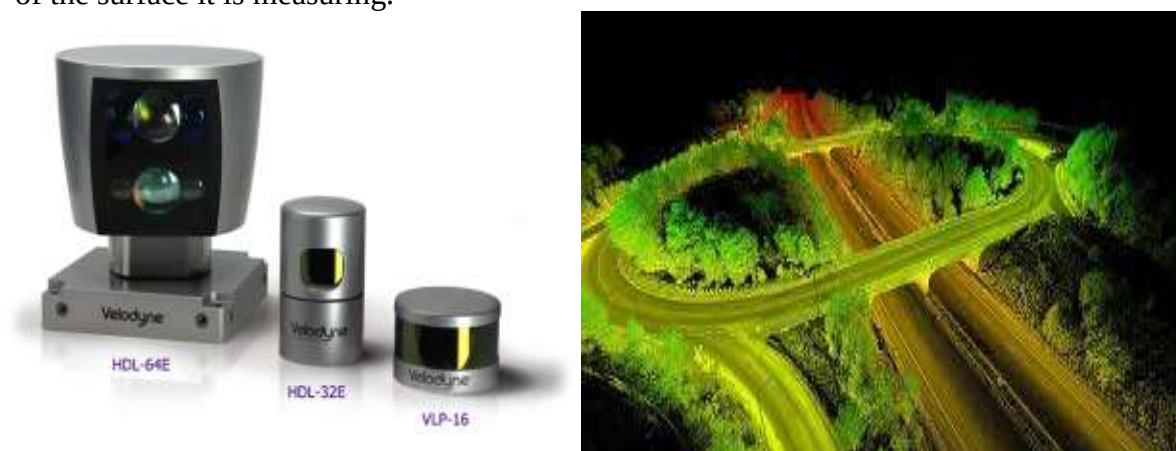


Fig. 11: LIDAR sensor and Map

(Source: http://velodynelidar.com/terms_of_use.html , <http://thetauav.com/our-services/>)

Radar:

Radar is an object-detection system, similar to LIDAR system, but uses radio waves to determine the distance, orientation and velocity of objects. Ultra-sonic and Infrared based sensors use Radar concept to detect objects and sense the environment.



Fig. 12: Radar sensor and Map

(Source: <http://arduinosenors.com/> , <http://sosyal.projehocam.com/index.php?a=profile&u=robimek>)

Cameras:

A camera is an Optical device used to capture images of the environment, using which objects can be detected. A conventional camera produces a 2D image but a stereo camera produce 3D images with also has the depth information of the objects in the image.



Fig. 13: 2D and 3D Camera

(Source: <http://www.saelig.com/product/BOVI009.htm> , <http://stevivor.com/2015/06/page/2/>)

Once a map is generated and the robot location in the map is known, then we have the task of Obstacle detection and finding a route to reach the destination. For this we make use of various algorithms. Such as:

Obstacle Detection Algorithms:

Here the algorithms are used to classify objects has obstacles by filtering and detection algorithms. Here an obstacle is an object which hinders or comes in way of the robot planned motion. Some of the obstacle detection algorithms used are:

- Edge-Detection Algorithm – used to detect edges of objects.
- Motion-Detection Algorithm – used to detect any changes in object position.
- Tracking Algorithm – used for object tracking.

Motion Planning Algorithms:

Here the algorithm is used to find a shortest and optimal path to reach the target destination by avoiding all the obstacles. These algorithms use the concepts of Graph Theory. Some of the commonly used motion planning algorithms are:

- Dijkstra Algorithm – computation cost is less.
- A* (star) Algorithm – fast and optimal path is found.
- Rapidly Exploring Random Tree Algorithm – uses spanning tree concept.
- Probabilistic Roadmap Algorithm – uses probability distribution concept.

Apart from the above mentioned algorithms, Statistical techniques are used for prediction, approximate and optimization of sensor data using filter, as the sensor data have error and lack precision. Some of the popular filters are:

- Particle Filter - is a sequential Monte Carlo algorithm, i.e. a sampling method for approximating a distribution that makes use of its temporal structure
- Kalman Filter - is an algorithm that uses a series of measurements observed over time, containing statistical noise and other inaccuracies, and produces estimates of unknown variables that tend to be more precise than those based on a single measurement alone.

So, by making use of the above mentioned sensors and algorithms an autonomous vehicle is able to navigate autonomously without any human intervention.

V. APPLICATIONS

The applications of Autonomous vehicles is limit less and vast. With major applications in the fields of commerce, consumer, research and public sectors. Below is a list of examples of where Autonomous vehicles can be and in many cases already are employed.

1) Agriculture:

Autonomous vehicles form a precision agriculture system, where it is used for crop health survey using its surveillance capabilities, and pesticides or fertilizers can be applied using them in select target areas. With further development, agricultural tasks such as pollination, planting and harvesting of crops can be carried out by Autonomous vehicles.



Fig. 14: Agricultural application drones

(Source: <http://titanvine.com/2015/12/23/8-industries-in-the-firing-line-for-digital-disruption/> ,
<https://twitter.com/sjlanyon/status/572736633318989824>)

2) Public Services:

Another major application of Autonomous vehicles is in public services. Autonomous vehicles can be useful in carrying out search and rescue operations during emergency and disaster situations. A drone fitted with cameras can reach inaccessible and dangerous locations, to locate stranded victims of a natural disaster, or missing trekkers.



Fig. 15: Drone for Emergency with Medical Kit

(Source: <http://www.tweaktown.com/news/41965/medical-emergency-ambulance-drone-help/index.html>)

3) Surveillance:

Autonomous vehicles can be used for surveillance. Drones are used to carryout surveillance tasks such as border control and monitoring, locating terrorists and crime suspects, monitoring illegal trafficking of whales. Also, plans of monitoring oil and gas pipelines using drones is proposed.



Fig. 16: Surveillance Camera equipped drone

(Source: <http://www.bbc.com/news/uk-northern-ireland-17356921>)

4) Transportation:

Autonomous vehicles can be used for transporting goods autonomously to the customer. Amazon has expressed interest to utilize autonomous vehicles for parcel deliveries. Domino's has demonstrated the use of autonomous vehicle for pizza delivery. Autonomous train systems to transport mineral ores have been in existence for a long period of time.



Fig. 17: Autonomous Transportation Vehicles

(Source: <http://zimo.dnevnik.hr/clanak/upoznajite-dru-robota-koji-dostavlja-pizzu---430425.html> , <http://smartdesignworldwide.com/thinking/the-ux-of-commercial-drones/>)

5) Military:

A major use of Autonomous vehicle technology has been in military contexts. The defense sector has driven much of the research into Autonomous vehicles which has enabled commercial use. Military Drones and UAV's are used for surveillance, intelligence gathering, armed strikes and bombing. The civilian casualties and environmental destruction has raised controversy and concern over there use.



Fig. 18: Autonomous Military Vehicles

(Source: <http://peopleus.blogspot.in/2014/03/from-flying-to-amphibious-drones-could.html> , <http://www.ocorreiodedeus.com.br/2013/09/anteriormente-dado-como-nao.html>)

6) Media:

Autonomous vehicles has enabled to capture footages in an economical manner. When in the past, helicopters where used to capture aerial views, now drones are being used. The drones enable capturing multiple angles. For example, they can film both a close up of an object and then fly back for a long-range view. Also, feature like automatic tracking and following help to record footage of athletes in a race.



Fig. 19: Person following drone

(Source: <http://www.popsci.com/technology/article/2013-05/meet-pet-drone-follows-people-lost-puppy-video>)

VI. ADVANTAGES

The advantages of Autonomous Vehicles are numerous, such as:

- The lack of human error whilst driving, will result in a much safer journey.
- Traffic jams could be prevented by using autonomous vehicle with a central control, this would result in fuel and economical Savings.
- Drones and other autonomous vehicles can be used for transporting goods and cargos autonomously.
- The sensors on the Autonomous cars allow them to be accurate and precise, so they are capable to move closer together and thus increasing car density on roads.
- Even a person with disabilities would be capable of driving.
- Autonomous cars would be able to drop you off and come pick you up at your workplace, whenever required, avoiding the need of a parking space.
- The time spent on driving can be spent on doing other useful work, with the use of an autonomous vehicle.
- Driving test and driving license would no longer be needed.

VII. DISADVANTAGES

However there are still some disadvantages of Autonomous Vehicles:

- The possibility of the computer system malfunctioning or crashing could result in a major collision.
- There will be loss to the economy due to unemployment of drivers, as their profession would be redundant with the introduction of Autonomous Vehicles.
- Autonomous vehicle system would be costly and expensive.
- People enthusiastic of driving may not like autonomous cars.

VIII. LEGISLATIVE CONCERNS

The major legislative concern and issue in regard to the Autonomous Vehicle systems is the question of who is liable in the event of an accident caused by an Autonomous Vehicle, whether the person in the car or the manufacturer who built the autonomous system. The legislative regulation for Autonomous Vehicles differs from country to country. Many countries currently exercise tight restrictions over their operation, but some countries have lenient regulation, example Australia. The present laws and regulations need to be mended for Autonomous Vehicles to become commercially viable. Many countries currently impose restrictions, such as always having a person monitoring the Autonomous Vehicles and capable of taking control whenever required.

IX. CONCLUSION

Through most of the past century, automated vehicles could only be found science fiction novels, the current technologies has made the Autonomous Vehicles a reality. Though a lot of development is yet to be done. But we can be sure that the Autonomous Vehicles are here to stay and surely the world we live in is going to change soon. Yet before we can reap the huge potential benefits of Autonomous Vehicles, we must ensure that we have policies in place to guide its safety regulations and liability regimes.

REFERENCES

- [1] ‘Autonomous Vehicles Handling Over Control: Opportunities and Risks for Insurance’, Lloyds (2014).
- [2] ‘Top misconceptions of autonomous cars and self-driving vehicles’, Patrick Salleo (2015).
- [3] ‘Safety and Liability of Autonomous Vehicle Technologies’, Richard Ni, Jason Leung (2014).
- [4] ‘Self-driving cars: The next revolution’, kpmg.com, cargroup.org (2012).
- [5] ‘A 3D State Space Formulation of a Navigation Kalman Filter for Autonomous Vehicles’, Alonzo Kelly (2011).
- [6] ‘Ultra-thin, flexible electronics’, R McPherson, R Dean, R W Johnson, L Del Castillo (2009).

- [7] 'A Sensor Based Navigation Algorithm for a Mobile Robot using the DVFF Approach', Oualid Djekoune, Karim Achour, Redouane Toumi (2009).
- [8] '3D Modeling of Indoor Environment', Johan Dahlin (2013).

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