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Autonomous and self-driving car

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ABSTRACT

Today, in twenty-first-century Information Technology is revolutionizing everything around us. All our daily drivers, things we depend on, things which makes our lives easy are getting smart day by day; the automobile industry is no behind and is moving with great pace. We are seeing intense growth in technology that is powering today's automobiles enabling us to rely heavily on the system, improving our driving abilities, minimizing the chances of accidents and saving human efforts and lives in the end. With technological advancements, application of Artificial Intelligence and Machine Learning and powerful hardware to drive the system, not in distant future, we will see the vehicles that can drive themselves on urban roads with heavy traffic scenarios relieving humans from putting their immense efforts and precious time in driving the vehicles and allowing them to invest the time in doing some productive work. There will be a time in future where roads will be grids for self-driving cabs, running with no drivers, when there will be no traffic jams or conjunctions because of rough driving, when meeting will be conducted in cars, your car will drop your kids to schools, take you to hospital in emergency situations and it will be your complete infotainment system. However, there remain many facets to polish when it comes to complete self-driving experience. We still have hurdles to cross such as extreme environmental conditions, pedestrians, ethical dilemmas of decision making, etc.

Keywords— *IRNSS, GPS, Shadow matching, VoxelNet learning, Mapping, and localization, Autonomous vehicle*

1. INTRODUCTION

Autonomous cars are ready, but is India ready?

Cars are an integral part of Indian society, cars, and other transport vehicles. The cars we use here in India are still pretty dumb, non-futuristic.

They still do miss out on basic features such as parking assistance, collision detection, GPS sensor, be alone cruise control option.

It is now extremely important for us to leave the conventional driving approach behind and infuse it with technology which can enable the computers to drive the vehicles.

Today this might seem like a luxurious or unnecessary investment but in coming future self-driving cars will be an essential part of our lives. The future generations won't be driving cars the way we do.

Self-driving cars are pretty common on the roads of countries like the USA and China. They are widely being tested for level 4and 5 autonomy. But India poses a completely different set of challenges; challenges where level 2 or 3 autonomy will also struggle to exist.

The current state:

Novus -Drive was a completely autonomous electric vehicle developed by The Hi-Tech Robotic Systems Ltd. and was launched in the Auto Expo Motor show 2016 in India.

Novus Drive offers shuttle services to the passengers in big campuses such as Universities, hospitals, business parks, amusement parks, group housing societies, resorts and golf courses, retirement communities.

Passengers can set destination goal points on the map, Passengers can also check Details of the destination drop off location, and a Snooze button for making the vehicle stop, Configurable cached maps for various locations, Cloud-Based Intelligence for a fleet management system, Audio/Visual Alerts in case of emergencies.

Indian Institute of Technology Kharagpur is developing a concept autonomous vehicle named AURO, which is being built taking Indian into consideration. Philosophy being "If we can have a solution that can work in India, it will undoubtedly work anywhere in the world".

Many companies in the automobile industry are getting their hands on the autonomous and self-driving cars. Companies such as Tata Motors, M&M, Maruti are heavily investing in the autonomous car technologies in terms of money and other resources.

2. LITERATURE SURVEY

Following are the technologies by which the literature survey was taken into consideration for:

- IRNSS
- Mapping and Localization
- Shadow Matching
- VoxelNet learning

2.1 IRNSS

- Indian Regional Navigational Satellite System (IRNSS) or Navigational Indian Constellation (NIC) is Indian's answer to the USA's Global Positioning Satellite (GPS).
- Similarly, Russia has GLONASS, China has Baidu, and India is building its own satellite constellation.
- IRSS is designed to provide accurate positioning information service to users in India as well as the region extending up to 1500 km from its boundary.
- It will give India its very own indigenous navigation system, which would provide information on location and time in all weather conditions.
- It will consist of three segments: a space segment, a ground segment, and user segment.
- Five out of seven satellites are already in place.
- Four of them are geostationary satellites positioned at 31.5°, 83° and131.5° East respectively.
- Rest three are geosynchronously positioned over longitudes of 55° East, 111.75° East.

2.1.1 GPS vs. IRNSS comparison [3]

Table 1: Comparison between GPS and IRNSS

GPS	IRNSS
Constellation of 31 satellites	Constellation of 7 satellites
Only 4 in Line of Sight	All 7 will be in Line of Sight
Frequency is only S, band	S and L band frequencies
Accuracy in meters	Accuracy in centimeters
For usage across the globe	For usage limited to India

2.1.2 IRNSS will provide two types of services [3]

- Standard Positioning Service (SPS): This will be provided to all the users.
- Restricted Service (RS): This will be an encrypted service and will be provided only to the authorized users.

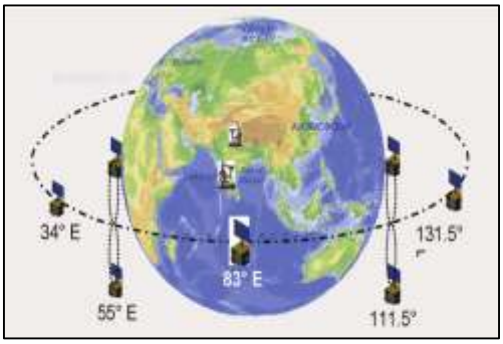

Fig. 1: Satellite constellation

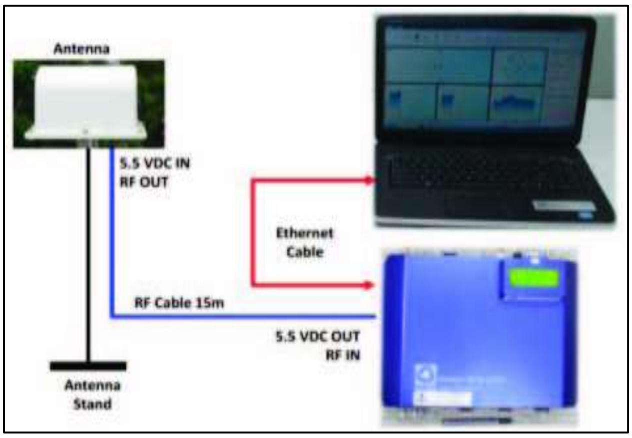

Fig. 2: IRNSS Signal receiver [3]

2.1.3 Applications of IRNSS [3]

- Terrestrial, Aerial and Marine Navigation
- Disaster Management
- Vehicle tracking and fleet management
- Precise timing
- Mapping and geospatial data
- Terrestrial aid for hikers and travelers
- Visual navigation system

2.1.4 Working [3]

- The ground segment consists of IRNSS Ranging and Integrity Monitoring Stations (IRIM) and Navigation control center (INC).
- IRIM receives the data from the space and transmits to the navigation control center.
- INC controls the IRNSS system and also maintains the accurate time reference with IRNSS network timing center.
- The User Segment consists of IRNSS receivers operating in – Single Frequency (L5 or S1 band) – Dual Frequency (L5 and S1 band) IRNSS signals are transmitted.
- As it can be seen in images below, IRNSS has a set of seven satellites revolving around the earth, as different angles.
- These satellites are placed in many different orbits viz. LEO, MEO, GEO, HEO orbits.
- Thus, all the satellites are situated at different heights and at different angles. This helps in getting precise location data.
- The variable altitude and angle of placement will enable us to get accurate location data, such as longitude and latitude.
- It is also possible to get altitude data of the bodies on the earth. GPS fails in delivering an accurate location in the crowded places.
- It is expected from IRNSS to deliver location accuracy up to two sigma that is 94.5%, which will be big deal on its own.
- We will also be able to get longitudinal and latitudinal data accurate up to 0.8 meters and altitude data accurate up to 5 meters, which is said to improve over time.
- The signal from the satellite is captured and stored by the antennas, the data consists of longitude, latitude, altitude, elevation, carrier to the noise of the body.

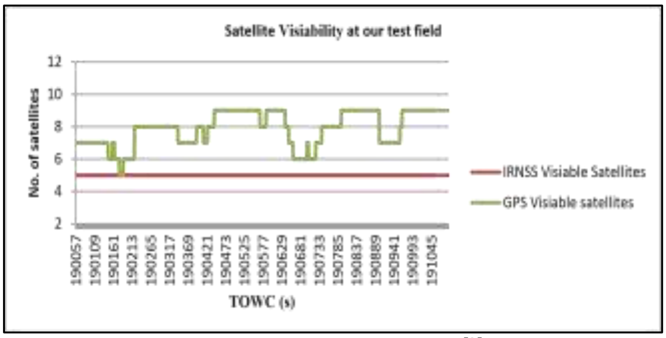

Fig. 3: Satellite visibility [3]

The above is the comparative data between GPS and IRNSS signal reception. The graph shows that IRNSS is constant throughout the time whereas GPS antennas lose connections with satellites every now and then. All the IRNSS satellites are in the line of sight at any given time which is not the case with GPS satellites.

The table given below is the data captured from the receiver over a course of time across eight points the moving trajectory. Here we can see, we got the most accurate latitudinal, longitudinal position of the body along with its altitude.

Table 2: IRNSS

Points	TOWC	IRNSS				
		Latitude	Longitude	Altitude	C/No (dB-Hz)	
					L5 band	S1 band
P1	190057	12.64157	77.4369	593.290	52.296	46.774
P2	190271	12.64479	77.43876	596.988	52.188	46.462
P3	190506	12.65009	77.44151	591.456	52.236	46.832
P4	190591	12.65225	77.44229	588.199	51.19	46.766
P5	190785	12.6583	77.44442	583.445	51.694	47.31
P6	190936	12.65295	77.44258	585.912	48.936	46.90
P7	190975	12.65009	77.44153	591.173	50.256	47.542
P8	191092	12.64159	77.43693	594.703	50.37	46.568

2.2 Mapping and localization [2]

- We can make use of maps produced by IRNSS in order to drive our vehicles. The maps can act as a grid on which vehicles can calibrate themselves up and use it as a guide while driving.
- The hardware used for this system is any conventional car, a GPS navigation system module to receive a signal from satellites, LIDAR sensors, cameras, radars.
- The autonomous vehicles require localization accuracy exceeding that is available from GSP-based inertial guidance systems.
- The system uses GPS, IMU, and Velodyne LIDAR data to generate a high-resolution infrared remittance ground map that can be subsequently used for localization.
- The system's approach yields substantial improvements over previous work in vehicle localization, including higher precision, the ability to learn and improve maps over time, and increased robustness to environment changes and dynamic obstacles.
- Furthermore, by using offline SLAM to align multiple passes of the same environment possibly separated in time by days or even months, it is possible to build an increasingly robust understanding of the world that can be then exploited for localization.
- Localizing our vehicle against these probabilistic maps in various dynamic environments, the system has achieved lateral RMS accuracy better than 10cm, which is sufficiently precise for any public road. In hundreds of miles of testing, the vehicle has experienced no catastrophic localization failures with the system

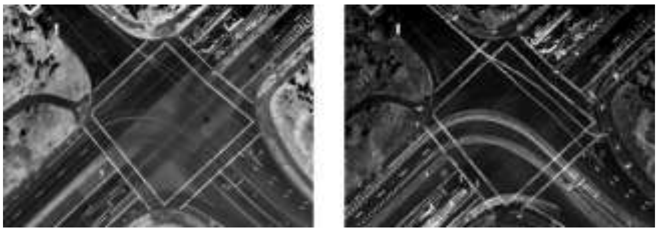

Fig. 4: Probabilistic map [2]

The two channels of the probabilistic maps. On the left, we see the average infrared reflectivity, or brightness, of each cell. The suggested approach is novel in also considering the extent to which the brightness of each cell varies, as shown on the right.

2.3 Shadow mapping[4]

- While GPS works well under clear skies, its location estimates can be wildly inaccurate with a margin of error of 50 meters or more when we need it the most: in densely populated and highly built-up urban areas, where many of our users are located.
- To overcome this challenge, Uber developed a system which substantially improves location accuracy in urban environments via a client-server architecture that utilizes 3D maps and performs sophisticated probabilistic computations on GPS data.

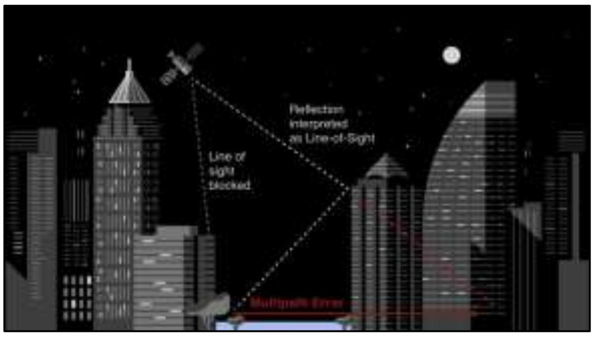

Fig. 5: Line-of-sight blockage [4]

- A major assumption behind GNSS-based positioning is that the receiver has a direct line-of-sight to each satellite whose pseudorange it is computing.
- This works seamlessly in open terrain but really breaks down in urban environments as it can be seen in the above representation.
- Buildings often block the lines of sight to satellites, so the receiver frequently processes signals corresponding to strong reflections off of other buildings
- The significant inaccuracy (positive offsets) in pseudoranges resulting from this phenomenon can lead to errors in position estimates that can be 50 meters or more in urban canyons.

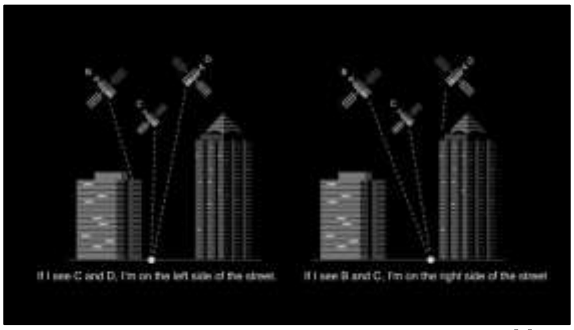

Fig. 6: Combined satellite signal strength [4]

Uber's approach relies on putting the following intuition in a mathematical framework: if the SNR for a satellite is low, then the line-of-sight path is probably blocked or shadowed; if the SNR is high, then the LOS is probably clear. This way we can precisely find out the position on a vehicle in the urban high-rise localities.

2.4 VoxelNet learning [1]

- Point cloud-based 3D object detection is an important component of a variety of real-world applications, such as autonomous navigation.
- Compared to image-based detection, LiDAR provides reliable depth information that can be used to accurately localize objects and characterize their shapes.

Table 3: Performance evaluation on KITTI test set [1]

Benchmark	Easy	Moderate	Hard
Car (3D Detection)	77.47	65.11	57.73
Car (Bird's Eye View)	89.35	79.26	77.39
Pedestrian (3D Detection)	39.48	33.69	31.51
Pedestrian (Bird's Eye View)	46.13	40.74	38.11
Cyclist (3D Detection)	61.22	48.36	44.37
Cyclist (Bird's Eye View)	66.70	54.76	50.55

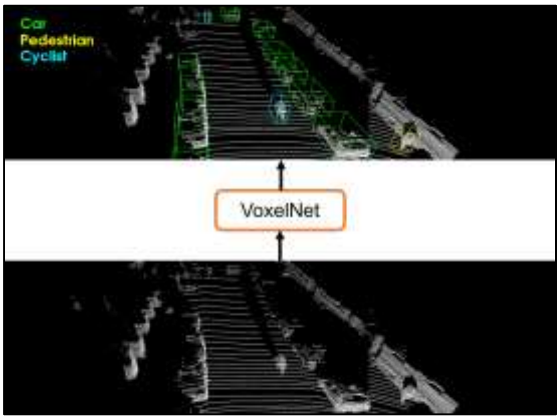

Fig. 7: VoxelNet LIDAR leaning [1]

VoxelNet directly operates on the raw point cloud (no need for feature engineering) and produces the 3D detection results using a single end-to-end trainable network.

Fig. 8: Qualitative results. For better visualization 3D boxes detected using LiDAR are projected on to the RGB images. [1]

- Evaluation in 3D Compared to the bird's eye view detection, which requires only accurate localization of objects in the 2D plane, 3D detection is a more challenging task as it requires finer localization of shapes in 3D space.
- The following table summarizes the comparison. For the class Car, VoxelNet significantly outperforms all other approaches in AP across all difficulty levels. Specifically, using only LiDAR, VoxelNet significantly.
- Most existing methods in LiDAR-based 3D detection rely on hand-crafted feature representations, for example, a bird's eye view projection.
- This system removes the bottleneck of manual feature engineering and proposes VoxelNet, a novel end-to-end trainable deep architecture for point cloud-based 3D detection.
- This approach can operate directly on sparse 3D points and capture 3D shape information effectively.

3. PROPOSED SOLUTION

As we have seen the various technologies in the above section, we can make use of all of them in a combined way for according to our needs.

- We can achieve extreme location accuracy in terms of latitude, longitude, and altitude using the IRNSS navigation system.
- IRNSS can help us to map the rural and urban areas with fine detailing in terms of roads and other infrastructure.
- Using IRNSS we can also create a 3-dimensional mapping of cities such as buildings and other places.
- This 3D data can help us to identify tall structures.
- IRNSS can also help us to plot the bridges, flyovers.
- We can use the altitude data received from the satellite to precisely locate the position of the car, whether it is above the fly over or under it.
- IRNSS will also give us up to date image data and it will always be in the line of sight so that there will be no loss in the connection when the vehicle is driving itself, be it in the densely populated urban environment or the sparsely rural environment.
- We can feed this data to SLAM algorithm which can build the vehicle trajectory over the grid of roads given by maps.
- This trajectory will get better with time as more vehicles travel from the trajectory.
- This will help the vehicle to autonomously drive itself on the roads.
- In the densely populated cities with tall structures, there might be a problem of IRNSS signal reception.
- We can make use of 3D map data generated by IRNSS and the Uber's shadow matching technology in order to detect the tall structures, what thing is blocking the signal reception.
- Shadow matching will help us to accurately plot the vehicle's position on the maps. So that, the vehicle will not lose its calibration in the cities and will still be able to drive itself properly following the lanes on the roads.
- But the main problem still remains unresolved which is the moving traffic, jaywalkers, cyclists, pedestrians, animals or any other obstacle which may come in front of the vehicle when it is driving itself.
- Using the technology like VoxelNet and hardware like LIDAR sensors we can identify any entity in 3D space be it a bird flying or a kid crossing the road or a cyclist.
- VoxelNet is faster than any other solution available out there.
- VoxelNet also has better performance capability in terms of identifying the objects in any kind of environment.
- Using VoxelNet, a vehicle will be capable enough to detect the obstacle and stop itself from the collision.
- Thus, a combination of these multiple technologies can help us in drive the cars on the roads with minimum resistance.

3.1 Laws and legislation

- Liability and Insurance
- Standard of performance
- Privacy, Data Protection, and Cyber Security
- Motor Vehicles Act, 1939
- Consumer Protection Act, 1986
- Information Technology Act, 2000
- Geospatial Information Regulation Bill, 2016

3.1.1 Liability and Insurance

- When autonomous vehicles get involved in accidents, the issue of liability may get complicated as resolving the question of fault will require consideration of novel and challenging questions
- The extant test is to determine the driver's liability and make a judgment accordingly, but in cases where there is no driver and the car runs entirely with software assist, there need to be different parameters of consideration.
- In the driverless future, actuaries may have to replace calculations about individuals with issues such as the hacking of cars, analyzing which parts of the country have better satellite imagery etc
- They will also have to identify the difference in the quality of the safety features across driverless cars.
- Every autonomous car ships with a black box which stores the logs of the car while it is driving. The data from the black box should be considered valuable proof for any kind of casualties happened with the vehicle.
- Based on the data, the insurance provider should consider whom to consider liable for the damage: the operator, the system or the external entities.

3.1.2 Standard of performance

- In the case of a driverless car getting into an accident, manufacturers will be held to a higher standard of responsibility than they are currently. Issues pertaining to negligence, manufacturing defects, design defects, failure to warn, misrepresentation, unfair trade practices, breach of warranty and strict liability will fall under the Consumer Protection Act, 1986 (CPA).
- Everything from speed, the requirement of a human operator in case of emergencies, licensing, roads, permissible infrastructure, penalties, and liabilities in case of damage to third parties or otherwise, level of automation permissible, shall have to be accounted for in addition to ethical issues.
- The issue of liability in a situation where there is a collision between two driverless cars also needs to be determined as it would involve all parties involved in assembling and manufacturing the two cars, thereby warranting a long list of plaintiffs and defendants in a potentially ensuing litigation.
- The speed limits should be set up for all the expressways, highways.
- There should be a proper sign on the roads which could be read by the vehicle's system in order to get the maximum speed limit allowed on the particular road.
- The signboards should have design constraints such as, the boards should be consistent in size, height at which they are displayed at, size and color of the sign and the font used to denote the speed limit. Numbering type such as Arabic or Devanagari.
- State and central government bodies should design standardization for such signboards which will be followed all over the state and the countrywide.

3.1.3 Privacy, data protection, and cybersecurity

- India's privacy and data protection acts should also consider taking the data generated by autonomous cars into consideration.
- The safety and security of personal information in autonomous vehicles, interconnected through a central server, is of utmost importance. With no provisions or regulations protecting the data collected by driverless vehicles, sensor-loaded driverless cars have the potential for serious privacy violations.
- As the number of cars connected to internet increases, the probability of them being attacked by hackers increases drastically. In the United States, manufacturers are required to establish real-time monitoring to detect, report and prevent cyber-attacks. NHTSA is already working for security protocols for the autonomous vehicles to securely transfer the data over the internet.
- Since the vehicle is going to be connected to the internet there arises the question of privacy, security and protection data generated by vehicles.
- The car can capture personal data such as daily travel route of the individual, all the voice commands or in general talks that take place in the ride, all these lies under Sensitive Data and Personal Information (SDPI) which can be used by advertisers for targeted advertising or opinion mining, manipulations.
- There is a need for a law which can protect the SDPI and stop unauthorized usage of riders' personal information. Primarily, all the information about the occupants can be derived — who they are, where they've been, where they're going and what their preferences are. Unauthorized parties such as hackers and terrorists could illegally access a person's regular travel route, alter records, instigate attacks on the system or invade privacy by tracking individual vehicles.

3.1.4 Motor Vehicle Act, 1939

- According to the act, in India, only an adult above the age of 18 years is legally permitted to drive a vehicle. Anything happened to the vehicle or by vehicle, the owner of that vehicle is solely responsible for that.
- Now in the age of autonomous cars, there are chances of vehicles not being owned by end user directly but using vehicles as PaaS. Given that most of the functions of an autonomous vehicle, if not all, would be controlled by internal processors, the question also arises whether people below the age of 18 would be allowed to 'operate' the said vehicle.
- Further, provisions of the law that ban driving when mentally or physically unfit, under the influence of substances, would possibly be redundant in the case of autonomous cars.
- Instead of just a driving test, Indian soon need to consider educating drivers to operate an autonomous vehicle.
- There should be guidelines defining what capabilities an operator must possess in order to operate an autonomous car.
- The driving tests must be redesigned taking the autonomous vehicles into consideration.

3.1.5 Consumer Protection Act, 1986

- In the case of a driverless car getting into an accident, manufacturers will be held to a higher standard of responsibility than they are currently. Issues pertaining to negligence, manufacturing defects, design defects, failure to warn, misrepresentation, unfair trade practices, breach of warranty and strict liability will fall under the Consumer Protection Act, 1986 (CPA).
- The consumer will have to be educated accordingly, on how the driverless cars operate and how not to panic and take control in case of emergencies.
- Since driverless technology discounts the possibility of human error, human error, the liability would lie either with the manufacturer or the technology provider.
- Manufacturers like Google, Mercedes-Benz, and Volvo have pledged to accept liability in the event that their vehicles were to cause an accident.
- The autonomous car manufacturing companies must be brought under the shade of this law and should be considered responsible for the behavior of the vehicle.

3.1.6 Information Technology Act, 2000

- The act lay down provisions for the protection of Sensitive Data and Personal Information (SDPI).
- The scope of this action is needed to be enlarged in order to accommodate protection of data generated by autonomous and self-driving cars.
- Laws will also have to incorporate necessary provisions dealing with protection and responsible utilization of passenger data, along with increasing threat of hackers, cyber espionage, and warfare.
- The act should abide by all the guidelines suggested in the Privacy and Data Protection Act.

3.1.7 Geospatial Information Regulation Bill, 2016

- Driverless cars require enhanced mapping data in order to precisely locate itself over the grid of roads. This also comes with the need of increased investment in satellite infrastructure in order to ensure that such cars are provided a detailed and highly accurate global positioning system, not only to autonomously and accurately arrive at its destination but to also circumvent the various obstacles en route.
- India not only fails to provide rich geospatial data but also restraints foreign entities such as Google from doing that for us, in the name of national security.

- With the launch of IRNSS, India should consider allowing private firms to map the cities in 3 dimensions. Allowing the private firms will increase the competition and also improve the mapping data which will benefit the autonomous vehicles.

3.2 Overcoming the challenges in implementation

- Social and economic hurdles
- Local infrastructure
- Perception of surrounding
- Legislative and regulatory hurdles

3.2.1 Social and economic hurdles

- India is a country where cars are still considered as a status symbol, getting a driving license or a voter ID is a symbol of adolescents. Its long history of distinct financial classes has made the automobile a symbol of success.
- It has been estimated that a complete transition to driverless cars might take up to 15-20 years in India given the social mileage attached to the act of driving.
- Autonomous cars will have a staggering impact on the employment. According to research at Oxford, approximately 47% of jobs are susceptible to automation.
- So, in the country like India, which is suffering from poverty and unemployment this will raise overwhelming chaos in the population and can have serious effects on the political situation.
- Instead of considering autonomous vehicles as a technology staling a job, we should start looking at the brighter side of new employment it will create to support the technology.
- So instead of banning the autonomous vehicles, India should welcome the new technology.

3.2.2 Local infrastructure

- The important most thing an autonomous vehicle needs to operate is the good road infrastructure.
- There should be the implication of strict rules in the construction of new roads regarding the width, lane markings, signboards, speed breakers, crossings, signals, intersections, direction boards and so on.
- The cars would need to be customized keeping in mind the nature of Indian roads. Information about speed limits, height and width restrictions, types of road traversed, common or restricted use for a particular type of transportation such as bullock carts, cyclists, two-wheelers, trucks, animal crossings would have to be fed into the systems and algorithms accordingly tweaked.
- Potholes, speed breakers, road dividers dangerously placed on highways by the police, gravel and tar left by road repair crews, open drainages, supplemented with uniquely Indian traffic obstructions such as cattle or religious festivals being celebrated on the roads would mean that driverless cars would have to be especially smarter if they are to take over Indian roads.
- A vast majority of the Indian population cannot afford an automobile and will have to depend on existing infrastructure for their daily commutes, making the transition more difficult.

3.2.3 Perception of surrounding and cultural nuances

- Given India’s cultural diversity, the computer operating the driverless car will have to adapt to localized graphical representations, informative signs, traffic symbols and language barriers.
- Further, the issue of a lack of trust could arise given the Indian consumer’s long-standing habit of using landmarks for navigation rather than street names.
- Mapping would have to be made absolutely accurate in order to allow the car to effectively perceive its surroundings and change consumer behavior.
- Driverless Cars would also need to be able to accurately interpret the various hand signals and indications such as flashing of headlights that are a common feature on Indian roads.
- Auto rickshaws, scooters, mopeds, hand carts, ox carts, cycle rickshaws, tractors and other such vehicles of varying shapes and sizes plying on Indian roads would require driverless cars to be equipped with extra sensitive sensors
- The cars would also have to discern a variety of life forms of different compositions including stray animals and people sleeping on the streets in order to detect and avoid such obstacles.

3.2.4 Legislative and regulatory hurdles

- The Indian government has always reacted with suspicion and has curtailed new technologies if their impact is not yet fully understood.
- This can be seen in banning the drones or other aerial vehicles, prohibiting Google from launching street view service in India.
- The government should be welcoming these new technologies and allow organizations to do research and development which can generate employment opportunities also.

4. CONCLUSION

This report consists of the study of various approaches to make autonomously driving vehicle possible in India. We have made a suggestion for necessary changes to be made in the current technologies, making use of new technologies such as IRNSS and combination of multiple technologies to make the autonomous future possible.

Along with the technological advances we have put considerations for changes in the existing legislative system to incorporate the entities coming with autonomous vehicles.

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