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A survey on Robotic Vehicles in Autonomous Navigation

Nupur Choudhury[1*], Rupesh Mandal[2]

[1*,2]*Computer Science and Engineering Department, Sikkim Manipal Institute of Technology, India*

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Abstract— This paper deals with the survey based on Robotic navigation the various types of mobility related procedures that are existing for this particular purpose. The paper further explores the vehicles built with robotic technology, its requirement and an existing project that implements the various concepts and principles. The paper presents an overview of the Google Self Driving Car and its principles and further discusses the impact of Radar/LiDAR fusion algorithm in enabling the efficiency of the existing projects that are done in this domain.

Keywords— Radar, LiDAR etc.

I. INTRODUCTION

The Robotics domain constitutes of a wide spectrum of science and technologies in which physical machines are embedded with computational intelligence which leads to the development of intelligent components with enhanced capabilities which are much more efficient as compared to the individual core elements. This results in robotic systems that are almost unachievable by conventional human mechanisms even surpassing machine activities. The fact that the machine can relocate itself autonomously has already created tremendous avenues for scientist to carry out researches in this sector. This paper deals with such types of machines which requires no human intervention for any type of activities to be performed and summarizes research and development within the international domain of the study. The Robotic vehicles are those man made machines which holds the capacity of relocating itself without any type of human intervention i.e. "Autonomous movement". They simply can be deployed in the air, underwater or in space as well. These vehicles carry no humans onboard and can move with their own power added with computational resources and sensors acting as a guide for their motion without a remote human supervision of the execution of any task which can also be termed as "Supervisory control" in task execution. This mechanism involving monitoring of a robotic vehicle. This mechanism has also been coined as "Remotely Operated Vehicle"(ROV) where the robotic vehicle is connected with a wired or wireless communication so that the operator input can achieve higher bandwidth communications. However in the robotic vehicle technology evolution higher level of autonomy is a primary trend of computation where supervisory control of autonomous operations has replaced ROV mode of interaction.

Corresponding Author: *Nupur Choudhury, nupurnewton@gmail.com*
Department of Computer Science and Engineering, Sikkim Manipal Institute of Technology, India

II. NAVIGATION

The domain of study that focusses on the procedures of controlling and monitoring the movement of a vehicle or a machine from one place to another. There are four primary categories of navigation: land, marine, aeronautic and space navigation. There are certain known locations or patterns according to which the navigator's position is located. Thus in broader aspect navigation relates to any research or study that determines and analyses the direction and position. It can also be named as the term of art utilized for specific knowledge to perform navigation tasks by the navigators which includes pedestrian navigation and orientation as well.

III. NEED FOR ROBOTIC VEHICLES

The various needs of robotic vehicles primarily includes the following: Primarily robotic vehicles are capable of navigating to places where the hazards of human presence are great or to places where it is not possible for the humans to go. For example: for any space travel like Mars expedition, a spacecraft should be capable of travelling extremely long duration routes which might extend up to years and on reaching the destination there might be no signs of life or anything that might support human existence like air, water etc. Until now although it has not been possible for humans to practically step on Mars but rewarding results has been generated due to deployment of robotic exploration leading to the enhancement of our knowledge of other planets. National Aeronautics and Space Administration (NASA) Mars rover is shown in the figure below which is a robotic vehicle and has successfully converted itself to a scientific laboratory for mars surface exploration. It is an example of a robotic vehicle under supervisory control remotely from earth and is capable of autonomous navigation and execution of defined tasks.

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Fig 1. NASA Mars Rover (NASA Jet Propulsion Laboratory (JPL))

In addition to mars expedition, undersea world also holds potential threats of being a hostile and hazardous environment where robotic vehicles are essential tools of exploration and work. Although human divers contribute immensely towards this field but even then oceanic pressure, light, current and other such factors serve as a limitation to these explorations in the vast oceanic volumes. ROV types helps to serve as an aid to the oceanographers to develop a wide variety of sophisticated technologies for monitoring, mapping and sensing the oceanic volume currents and prove as an essential part of this repertoire and provide information that is not available otherwise. An automatic underwater vehicle is shown in figure 2. Called ASTER which is under development at the French National Institute for Marine Science and Technology, (IFREMER) which will be utilized for survey of the coastal areas leading up to 3000 meters in depth and is capable of transporting enormous variety of instrumentation for biological, chemical and physical monitoring and sensing. This type of researches in the United States has led to significant discoveries which has also lead to the discovery and exploration of the sunken Titanic thereby leading to the discovery of the notable shipwreck.

Fig 2.IFREMER ASTER autonomous underwater vehicle

Adding to oceans and spaces, there are many applications in practice where the presence of human is hazardous. To determine the type and extent of contamination, biological and nuclear sites must often be mapped and explored with to sort out an efficient remediation. The defense systems has already put a lot of effort in enhancing the various technologies to uplift the existing system by the use of various remotely operated technologies and the use of advanced mobile sensor technology. Moreover the these robotic vehicles can effectively replace the human presence in case of routine tasks as well which requires intensive human involvement like the large scale agricultural activities. Adding to the agricultural activities of large scale plantations, harvesting etc. Robotic vehicles are also utilized for large scale manufacturing in areas like transportation, subassemblies, reassembly etc. This does not limit the works of the ROV's and they are actively involved in areas like human assistance to be precise to act as an aid for the aged and handicapped society. These robotic vehicles not only enables the rapidly aging society but also contributes to the field of medical science to a great extent as it involves robotic surgeries where the robots are remotely controlled by the experts thereby contributing immensely to the human robot interaction field where the robots are actively associated both as an aid and as a vehicle for monitoring, manufacturing and transportation.

IV. PRIMARY TECHNOLOGIES INVOLVED IN MOBILITY

As per the various modes of propulsion that exists in robotic vehicles according to the terrain of movement i.e through ground, air or under water numerous technical solutions have been investigated and proposed. The table 2.1 illustrates two major approaches that has lead to the evolution of the various technologies in robotics research field.

A. "Props and Wheels" strategy:

The evolution of various technologies over many centuries in the transportation domain has led to the derivation of present day engineering solutions. Resembling the automobile technology, wheels and treads are nowadays being equipped with the robotic ground vehicles. Similarly propellers, jet engines and stationary wings (rotating in case of helicopters) are a major part in case of robotic aerial vehicles and on the other hand adding to propellers, control surfaces plays a major role in robotic undersea vehicles.

B. "Flapping and running" strategy:

Robotics and Biological systems are interrelated as there has been a prolonged correlation of making use of biological phenomena in the development of robotic systems which are termed as "biomimetic" by the Japanese

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researchers in this domain. Significant researches have been carried out where the international scientists have come up with models of bipedal locomotion which are developed as a part of legged locomotion systems and strongly replicates and resembles human locomotion and running. Similarly another phenomenal achievement has been obtained in the form of "Whegs" where the combination of wheels and legs has been implemented. Adding to this robotic snakes and wings that flap and fishes that swim with undulating motion is also been one of the primary research avenue.

Biomimetic research consists of two important broad targets.

- Associating the biological system teaches us about the natural habitat and enhances the knowledge regarding the physical process, controls systems and the energetics utilized by the various creatures.
- These researches may prove to be more practical oriented and might prove advantageous as previously generated engineering solutions for any kind of problems. For example: There are evidences that the legged locomotion in rough terrain can prove to be more fruitful than wheeled locomotion in rough terrains or the efficiency in energy of certain organisms may be better than the previously existing engineering systems. They also holds the capability of intersecting with applications involving personal robots both in physical and behavioral manner.

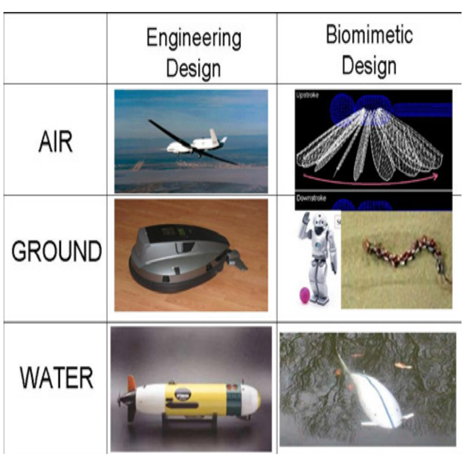

Fig 3. Types of robotic mobility systems

V. GOOGLE'S SELF DRIVING CAR-ROBOTIC VEHICLE

A very recent and practical example is the fleet of robotic Toyota Priuses by Google which are driving in busy highways, traffic of the city, mountainous areas with the minimum human intervention recording a distance of almost 190,000 miles (i.e. 300,000 kilometers). However although this project is not yet commercially viable, Google has incorporated the demonstration of the project in its campus using various models like driverless golf carts which focusses on the changing technology using robotic vehicles in future. However these autonomous vehicles are partially operational as they are being test driven on the public roads. This project has been guided by Professor Sebastian Thrun of Stanford University and Chris Urmson, engineer from Google who is also the Tech Lead for the same project.

VI. ARCHITECTURE OF THE PROJECT

The primary architecture of the Google's self-driving car involves a laser range finder which is mounted on the roof of the car as the "heart of the system". This laser range finder usually a Velodyne 64-beam laser is used to generate a map of the environment which is generally a detailed 3 dimension map. The high resolution map data of the world is then compared and analyzed with the laser findings and measurements thereby resulting in various types of data models that permits the car to drive autonomously by obeying all the traffic rules that are set and avoiding any type of obstacles on the way.

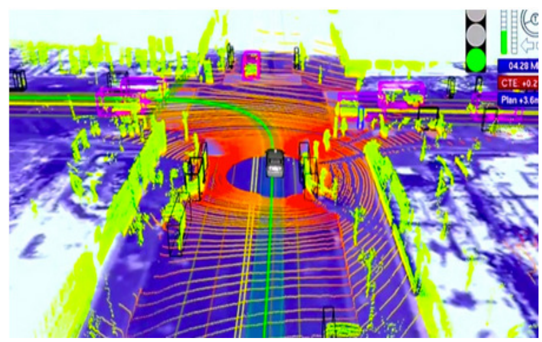

Fig 4. A 3D map generated by the laser range finder.

The vehicle is also equipped with other effective sensors which includes the following:

- Four radars which are mounted on the front and rear bumpers of the car which would allow the car to see or view to a distance which will enable it to deal with fast traffic on freeways or the roads.
- To detect the traffic lights a camera is positioned near the rear-view mirror.
- A Global Positioning System (GPS), a wheel encoder and a measurement unit so that the location of the vehicle and its movements are taken care of and kept track of.

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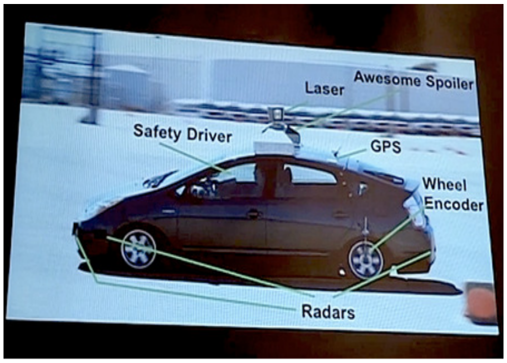

Fig 5. Different subsystems (the camera is not shown)

VII. STRATEGY OF GOOGLE

The strategies that has been opted by Google can be primarily categorized into two parts:
Firstly, according to the Tech lead of the project, the approach intensively is dependent on very detailed maps of the roads and the terrains or the environment which is highly essential to detect and determine which location the vehicle will be at a particular instance of time. By the use of GPS solely will not be able to efficiently derive accurate results thereby releasing the need for complex and intelligent mechanisms to derive the same.
Secondly prior to deploying the self-driving vehicle on the road for a road test, the engineers from Google take a drive along the same route through which the car has to follow at least once or in most of the cases more than once in order to obtain the data about the route map and the environment. Finally when the autonomous vehicle is deployed in the real time scenario on the same route, It generally compares all the data that it is collecting on the driveway to the previously collected data which helps the system to distinguish the dynamic obstacle in the form of pedestrians on the way with that of the stationery objects like the mailboxes and poles.
The various steps in the process is as follows:

1. Data models are prepared based on intensively detailed maps of the terrains and the roads.
2. Prior to deploying the autonomous self-driving car on a road test, the engineers form google drive along the route map to be followed more than a single time in order to gather information about the environment and prepare the detailed manner.
3. The previously recorded data is then compared with the acquired data from the driverless vehicle and then the necessary action is taken.
4. The dynamic obstacles are identified from the stationery obstacles and then a detailed drive strategy is adopted respecting the traffic rules and avoiding the obstacles.

However there are serious assumptions by the project team as they are convinced that this robotic vehicle specimen will be able to prove a smarter way of making transportation safer and well efficient. Empty spaces are more efficiently utilized making exceptionally good use of the empty spaces on roads i.e. usage results up to 80-90% of the unused spaces also results in the formation of speedy convoys on roads that are free. Extraordinary performance has been obtained in potentially saving thousands of lives as these vehicles are expected to react faster than humans in order to avoid accidents. However in order to achieve a higher performance ratio the following two factors comes into action that might cause a hindrance to its smooth operation.

- Utilization of the spaces on the roads.
- Position and velocity of the vehicles.

Hence in the aim of overcoming the above problems a real time algorithm has been implemented which enables and aids the autonomous driving cars to drive and follow other cars at various speeds along with keeping a safe distance from them. The distance regulation and velocity approach is implemented in the algorithm which id dependent on the velocity and the position of the car that is being followed. Radar sensors have the limitation that they have restricted view field. They provide reliable and approximately accurate information for lanes that are straight but they fail in curves and provide lesser accurate or almost no proper information.

VIII. SENSOR FUSION ALGORITHM-RADAR /LIDAR FUSION

There are certain factors in car following applications that have to be kept into account which includes accurate velocity and position information, precision about the vehicles that are driving ahead. These factors are implemented using the data by combining radar sensors and the Light Detection and Ranging Sensors (LiDAR). In the present day scenario laser scanners have an exceptionally larger range (i.e. up to 200 m) and a wider range of field view and hence results in better detection and tracking of objects at a bigger distances (at notable higher velocity) both in the straight lanes as well as the curves. The main drawback of the laser sensors is that on detection of objects they lack the dynamic objects about them. Radar sensors uses Doppler Effect to provide velocity information directly, but intensively has reduced angular distortion and narrow field of view. Hence although complementary in nature the data fusion thus received from both the sensors can prove beneficial in countering each other's drawbacks and provide an efficient mechanism for determining the position and velocity and deficiencies related to utilization of spaces on the roads.

IX. FUSION ARCHITECTURE

The centralized fusion architecture is divided into two primary layers namely sensor layer and fusion layer which is depicted in the figure. For each type of sensors the sensor layer is implemented separately. First and foremost task of

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the architecture is collect the data from the individual sensors and accumulate them in a common coordinate system and time zone. Therefore to convert the system into a more flexible one in order to integrate further sensors the fusion layer should abstract from the concrete data of the sensors as far as possible for whose realization obstacle hypothesis generation and feature extraction are executed in this phase. The fusion layer must cope with Out of Sequence Measurements (OOSM) as there is no synchronization between the various sensors in the fusion layer. To handle this problem buffering and measurement reprocessing are used. It finds an optimal solution to the OOSM problem with ease in the sense that latest information is immediately processed without data loss and is pass on (without holding it back). The approach is time (reprocessing) and memory (buffering) consuming. This aspect could be avoided in the fusion architecture because the number of effective fusion objects is small.

At the initial stage preprocessing is carried out, after which the unfiltered obstacles are passed on to the module depicting the fusion layer and they are incorporated into a common object model after an analysis. After all these process the sensor layer is fed back with strong hypothesis.

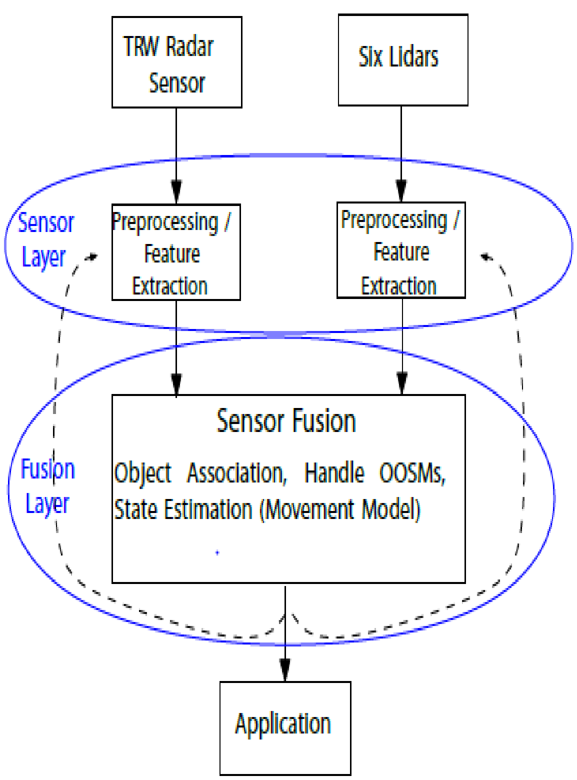

Fig 6. Fusion Architecture

X. Fusion Challenges

Key future challenges in robotic vehicle research will include:

- Multivehicle Systems, which would result in a state of deficiency when the system is integrated with multiple vehicles to be deployed in the same time constraints in the same area leading to a communication gap.
- Distributed Sensor Networks and Observatories
- Long-Term Reliable Deployment
- Micro- and Nano scale Mobility
- Efficient and Independent Power
- Human-Robot Vehicles
- Interactions
- Service and Entertainment

XI. Conclusion

The paper produces a survey based on a real time algorithm which is an implementation of an efficient radar/LiDAR fusion approach which integrates the combination of both the sensors i.e. precise velocity estimation with radar and accurate and highly available position estimation with LiDAR. This broad spectrum technology aids to achieve safety in automobile domain which is a potential matter of concern in today's scenario. Whether be in case of traffic security or exploring areas consisting of significant hazards top human population robotic vehicles are capable enough to eliminate errors and enhance human safety and mobility. It is expected to completely replace human operations and prove to perform efficient fuel saving for long runs. However the main drawback lies in the initial setup of these vehicles which is expensive but can prove to be boon for mankind in the near future.

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AUTHORS PROFILE

Nupur Choudhury is currently pursuing her Master of Technology degree in Computer Science and Engineering from Computer Science and Engineering department, Sikkim Manipal Institute of Technology, Sikkim, India. Her major area of research interest lies in Robotics, Machine Learning, Cloud Robotics, Cloud computing and human robot Interaction

Rupesh Mandal is currently pursuing his Master of Technology degree in Computer Science and Engineering from Computer Science and Engineering department, Sikkim Manipal Institute of Technology, Sikkim, India. His major area of research interest lies in Robotics, Machine Learning, Cloud Robotics, Cloud computing, Digital image Processing and Data warehousing.