THE SELF-DRIVING CAR USING LIDAR

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Abstract:

One advancing technology that has been impossible to ignore lately has been the work with self-driving vehicles. These vehicles have gone from scientific curiosity to mainstream within a few short years and soon we'll be seeing them as regular traffic on our streets.

A very distinctive component in a self-driving vehicle is the spinning LIDAR sensor mounted on the top of the vehicle. This is one of the principal components in self-driving vehicles as it collects data regarding the surrounding area to allow the navigation systems to guide the vehicle safely.

One advancing technology that has been impossible to ignore lately has been the work with self-driving vehicles. These vehicles have gone from scientific curiosity to mainstream within a few short years and soon we'll be seeing them as regular traffic on our streets.

Index Terms – **Arduino, Lidar, Colour Sensor**

I. INTRODUCTION

The main aim of this project is to offer a Self-Driving Car Using Lidar. Imagine a bus carrying passengers on its own, driving better than any bus driver could do. Imagine a taxi, which can be called through an app installed in your Smartphone, which carries you to your destination as fast and economically for you as possible. Imagine vehicles dedicating to agriculture on their own and without having to rest. Imagine vehicles travelling by themselves, mapping all the places they go by, not only on earth, but also on any rock out there in the universe. Imagine that your own car drives for you and you don't need to care about, while it drives better than you could ever do. Imagine the possibilities in a world where the vehicles are autonomously driven.

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II. BASIC IDEA

We are about to reach to that future, a future in which our elder and disabled loved ones will be able to maintain their independence, where time spent commuting will be time spent doing what you want to do and where deaths from traffic accidents (over 2 million worldwide every year) will be reduced dramatically, since 94% of the accidents are due to human error.

Autonomous vehicles don't drink alcohol nor take drugs, they are never tired or sick, they never take medicines, they never lose their concentration or talk by phone, they know how to drive since the first moment and don't need to learn, they never act recklessly when driving. On the other hand, they will drive much more smoothly, they will pollute less and, if they have an accident, they will ask for help autonomously.

2.1. BLOCK DIAGRAM OF BOARD

When Car start Lidar and Colour Sensor send their input to microcontroller. With the received information from Sensors , microcontroller decide to take next decision like Start, Stop, Move Forward, Move Backward, Turn Right, Turn Left, etc. Microcontroller end instruction to the motor driver for controlling motors with respective input taken from sensor. Regulated power supply is connected to the microcontroller as well as motor driver.
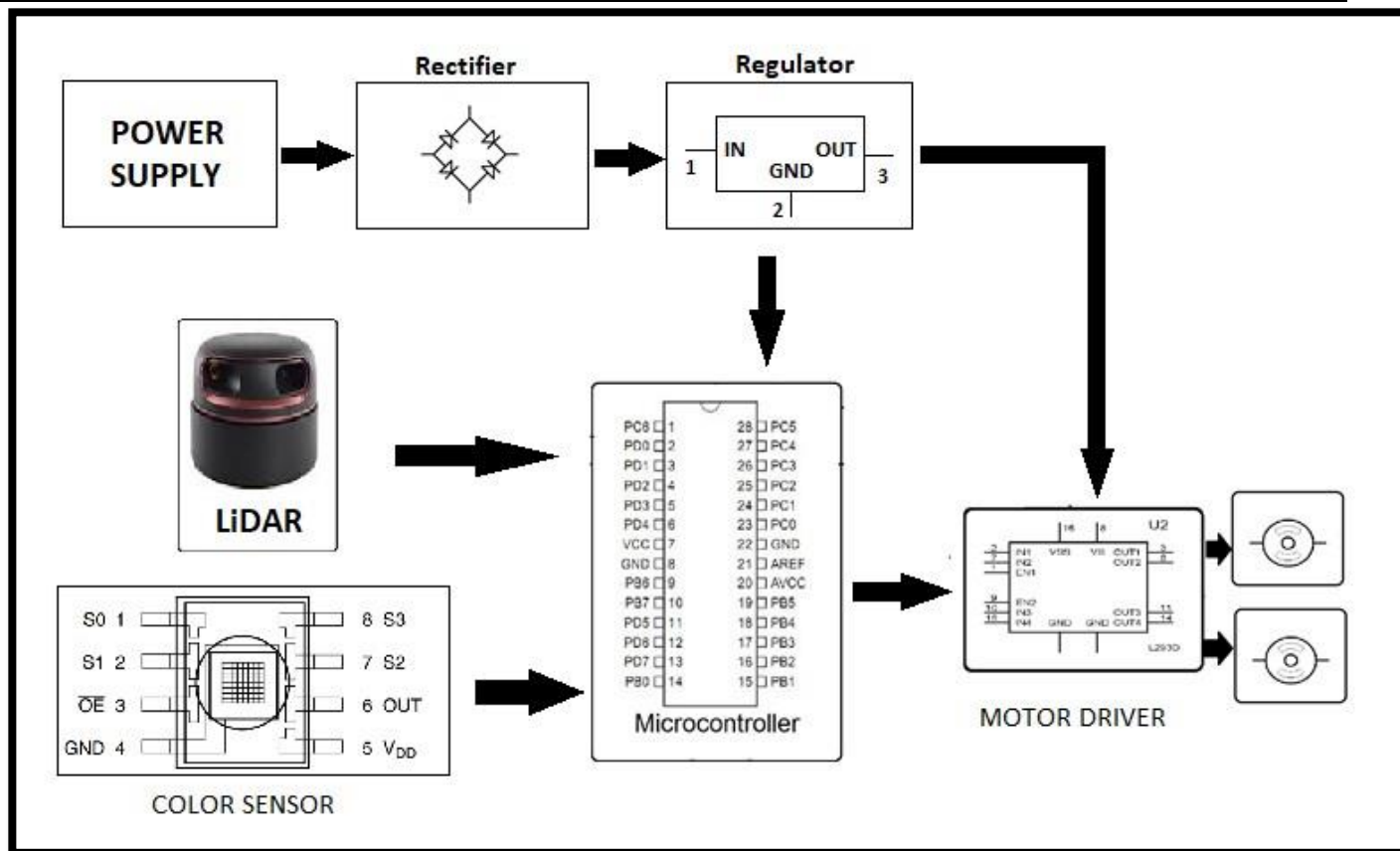
Figure 2.1: Block Diagram of the Self-Driving Car Using Lidar

2.2 WORKING OF PROJECT

When we switch on the car then Lidar and Colour sensor get activated and send focused light beam aimed at an objects and a sensor looks for its reflection. If beam is detected its intensity and angle is measured. There values are then plugged into an equation run by a microcontroller Atmega 328p.
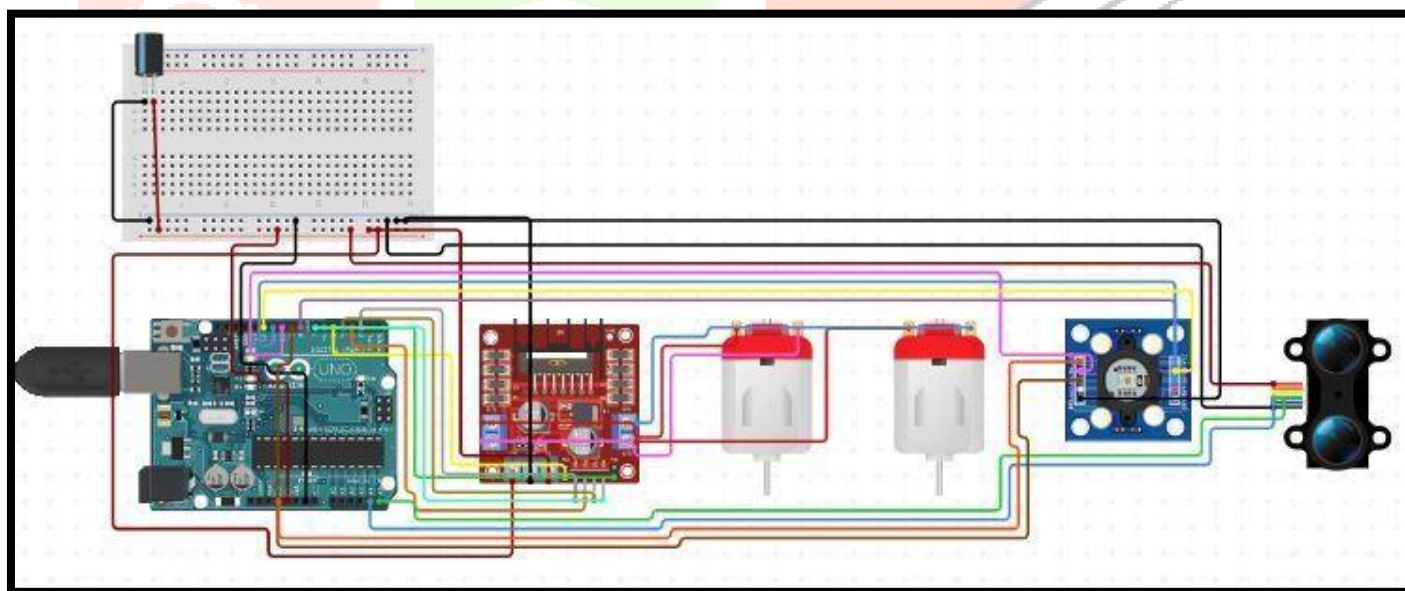

Figure 2.2: Circuit Diagram of the Self-Driving Car

Simultaneously, A Colour Sensor also emits light from a transmitter, and then detects the light reflected back from the detection object with a receiver. A Colour Sensor Can detect the received light intensity for Red, Blue and Green respectively making it possible to determine the colour of the target object.

Their output values are also plugged into microcontroller Atmega 328p. With the help of outputs and value provided by Lidar nd Colour sensor. Microcontroller instruct the vehicle for start, Stop, Move Forward, Slow Down, Turn Left and Right. Microcontroller Provide command to Motor Driver IC for Controlling Motors of a Vehicle.

III. LITERATURE SURVEY

➢ **Zhilu Chen and Xinming Huang, "End-to-End Learning for Lane Keeping of Self-Driving Cars", 2017 IEEE Intelligent Vehicles Symposium (IV) June 11-14, 2017, Redondo Beach, CA, USA. 978-1-5090-4804-5/17/$31.00 ©2017 IEEE**

This paper presents the end-to-end learning approach to lane keeping for self-driving cars that can automatically produce proper steering angles from image frames captured by the front-view camera. The CNN model is trained and evaluated using comma.ai dataset, which contains image frames and the steering angle data captured from road driving. The test results show that the model can produce relatively accurate steering of vehicle. Further discussions on evaluation and data augmentations are also presented for future improvement.

➢ **Mohammad Faisal Bin Ahmed, Md. Muneef Anjum Timu, Shakura Akter, Md. Jubayer Sarker, "The Issues and the Possible Solutions for Implementing Self-Driving Cars in Bangladesh", 2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC) 21 - 23 Dec 2017, Dhaka, Bangladesh. 978-1-5386-2175-2/17/$31.00 ©2017 IEEE**

Self-driving cars have potential to become the permanent solution to Bangladesh's infamous traffic problem. In this research, we have tried to achieve just that by finding out the issues and possible solutions. Despite our limitations like not having an actual selfdriving car and lack of funding for building a prototype, we believe our study is a good path forward for other researchers to follow. We have made necessary adjustments by observing our simulations. If the simulations are any indications, it will be possible to build a prototype on this that will work on Bangladeshi roads. With proper implementation and adjustment, Bangladesh can also take part in this driverless car revolution.

➢ **Gim Hee Lee, Friedrich Fraundorfer, Marc Pollefeys, "Motion Estimation for Self-Driving Cars with a Generalized Camera", 2013 IEEE Conference on Computer Vision and Pattern Recognition. 1063-6919/13 $26.00 © 2013 IEEE**

In this paper, they demonstrated visual ego-motion estimation for a car equipped with a multi-camera system with minimal field of-views. The camera system was modelled as a generalized camera and we showed that the generalized essential matrix simplifies significantly when constraining the motion to the Ackerman motion model (i.e. circular motion on a plane). We derived an analytical 2-point minimal solution for the general case with at least one inter-camera correspondence and a special case with only intra camera correspondences. We showed that a maximum of up to 6 solutions exists for the relative motion in both cases. We investigated the degenerate case of straight motion with intra-camera correspondences (which appears frequently in real data) and presented a practical solution using one ad-additional inter-camera feature correspondence. We evaluated our method on a large real-world dataset and compared it to GPS/INS ground truth. The results of the comparison clearly showed that our assumptions on the vehicle motion hold for real-world data.

➢ **Rassolkin, T. Vaimann, A. Kallaste, R. Sell, " Propulsion Motor Drive Topology Selection For Further Development of ISEAUTO Self-Driving Car", 2018 IEEE 59th International Scientific Conference On Power and Electrical Engineering of Riga Technical University (RTUCON), 978-1- 5386-6903-7/18/$31.00 ©2018 European Union**

The energy required from the propulsion unit depends on the desired acceleration and the road load force that the vehicle has to overcome and it is necessary for the design and selection of the energy source or batteries to cover a certain distance. An energy storage system is not a part of the propulsion drive system, but its features have influence on the system is not a part of the propulsion drive system, but its features have influence on the systems, as an electric car.

➢ **Raivo Sell, Anton Rassolkin, Mairo Leier, Juhan-Peep Ernits, "Self-driving car ISEAUTO for research and education", 2018 19th International Conference on Research and Education in Mechatronics (REM) June 7-8, 2018, Delft, The Netherlands. 978-1-5386-5413-2/18/$31.00 ©2018 IEEE.**

Building a self-driving car is an undertaking that requires multidisciplinary collaboration from mechanical and electrical engineering, mechatronics, electronics, computer systems and software engineers. Thus participating in such a project helps to develop various important skills such as cross-discipline communication, working on large projects, and understanding large and complex legacy systems. There are currently 15 students involved in various aspects of software development, 11 students in the electronics and low-level microcontroller software development. We are integrating the project work into the studies of students in two main ways: final theses and project courses. For example, in the software development sub team, we awarded 72 ECTS in the first half year for project courses and students plan to achieve 60 ECTS for project courses and 98 ECTS for thesis in the second semester. Such arrangement enables students to work on the project for more than one semester as the software is complex and building up understanding of the principles requires time. This far we have observed that the clear objective and exciting equipment available in the project has maintained student motivation for two semesters. The project courses are set up as 10-12 ECTS courses where student teams of four to six are supposed to complete a realistic task within a semester. The first project course was a 10 ECTS start-up project course, where student teams are expected to come up with an idea and implement a minimal viable product. One of the teams chose the self-driving car project with a goal to make the self-driving car drive autonomously in the Gazebo simulator closely integrated with ROS. In that process, the students discovered that the vector maps are essential to enable autonomous driving and that the vector map creation tools are not available in Auto ware. As a result, they developed a prototype vector map creation tool, based on a widely used GIS software ArcGIS. In the second project, the students were supposed to carry out a predefined software development task. The task was to make Auto ware drive the car based platform autonomously. At the time of writing, the students are on track of achieving it by the end of the semester. The achievement is supported by 4 MSc students pursuing their MSc theses related to various aspects of the software of the self-driving car.

➢ **Chris Urmson and William "Red" Whittaker, "Self-Driving Cars and the Urban Challenge", IEEE INTELLIGENT SYSTEMS Published by the IEEE Computer Society, 1541-1672/08/$25.00 © 2008 IEEE**

Although the Urban Challenge was a resounding success, the challenge of fully autonomous urban driving hasn't yet been met. Despite the Urban Challenge vehicles' strengths, none of them could interact with traffic lights, most would operate poorly around pedestrians, and all relied on sensors that are too expensive or unwieldy for consumer vehicles. As the bounds of what's possible for autonomous vehicles are pushed forward, these technical issues and the social and legal issues associated with relinquishing driving control will be at the forefront of the research agenda. Despite the challenges, the future appears to be now. Heavy equipment manufacturers are announcing autonomous haul trucks, with some ready for deployment as early as 2010. General Motors announced that autonomous vehicles will be ready for market by 2020. These are heady times for Autonomous vehicle research.

➢ **Stamatis Karnouskos, "Self-Driving Car Acceptance and the Role of Ethics", IEEE Transactions on Engineering Management, 2018.0018-9391 ©2018 IEEE**

In the near future, millions of self-driving cars are expected to roam the streets and take instant decisions in critical situations that involve life and death of humans. Such machine-driven decision-making process has an ethical dimension, which although not new, is not sufficiently investigated with respect to its impact on the self-driving car acceptance. This paper addressed the specific white spot, i.e., if and what impact do the different ethical frameworks have in the self-Driving car acceptance. Five ethical frameworks (utilitarianism, deontology, relativism, Absolutism, and pluralism) are identified in the literature and are adopted as factors that it was hypothesized could impact self-driving car acceptance. A model investigating their impact was proposed, and a survey was carried out to gather empirical data to test the hypotheses. The results revealed that all five factors have a statistically significant effect on self-driving car acceptance (in the empirical data collected). As such, the respective posed hypotheses are supported. The implications of the findings and the critical discussions in this paper make it evident that more emphasis should be put toward research in this domain, as the success or failure of the market introduction of self-driving cars could be affected by the ethical frameworks they employ in order to derive their decisions. Hence, all stakeholders, e.g., the technology providers, the legislators, the consumer associations, and the manufacturers, ought to consider the discussed insights as food for thought, in order to further investigate in detail the role of ethics in self-driving car critical decision-making, prior to their eminent public introduction. It has also become evident from the discus-sions and challenges presented that the issue addressed in this paper is part of a huge area with many dimensions, and as such, it is complex by itself with many intertwined aspects that need to be carefully addressed in an interdisciplinary.

➢ **Sertac Karaman, Ariel Anders, Michael Boulet, Jane Connor, Kenneth Gregson, Winter Guerra, Owen Guldner, Mubarik Mohamoud, Brian Plancher, Robert Shin, and John Vivilecchia, "Project-based, Collaborative, Algorithmic Robotics for High School Students: Programming Self-driving Race Cars at MIT", 2017 IEEE Integrated STEM Conference (ISEC), 978-1-5090-5379-7/17/$31.00 (c) 2017 IEEE.**

They presented a new high-school robotics program, called the MIT Beaver Works Robotics Institute Robotics Program. The program focuses on robotics software, and allows the students to design and develop complex software systems to run on mini race platform. In particular, the course challenge involves the design and implementation of software systems that allow the mini race car to operate completely autonomously. The program champions project-based and team oriented learning. The program was implemented for the first time in the summer of 2016 on MIT campus as a four-week residential program with the participation of 46 students, 24 of which participated from outside of Massachusetts and stayed in the Boston Area during this program. The self-assessment suggests that the students benefit in many directions in terms of both technical and teamwork skills. Our future plans include the expansion of the platform, particularly with an online supported teaching, in which the students follow online classes during the semester building up to the summer to understand the foundations, and then use their time at MIT to design and build complex robotic software systems.

3.1 HISTORY OF PROJECT

In the past five years, autonomous driving has gone from "maybe possible" to "definitely possible" to "inevitable" to "how did anyone ever think this wasn't inevitable?" to "now commercially available." In December 2018, Waymo, the company that emerged from Google's self-driving-car project, officially started its commercial self-driving-car service in the suburbs of Phoenix. The details of the program—it's available only to a few hundred vetted riders, and human safety operators will remain behind the wheel—may be underwhelming but don't erase its significance. People are now paying for robot rides. And it's just a start. Waymo will expand the service's capability and availability over time. Meanwhile, its onetime monopoly has evaporated. Smaller startups like May Mobility and Drive.ai are running small-scale but revenue-generating shuttle services. Every significant automaker is pursuing the tech, eager to rebrand and rebuild itself as a "mobility provider" before the idea of car ownership goes kaput. Ride hailing companies like Lyft and Uber are hustling to dismiss the profit-gobbling human drivers who now shuttle their users about. Tech giants like Apple, IBM, and Intel are looking to carve off their slice of the pie. Countless hungry startups have materialized to fill niches in a burgeoning ecosystem, focusing on laser sensors, compressing mapping data, setting up service centers, and more.

3.2 NEED OF PROJECT

In this modern age there it needs to be defined on which time scope the review addresses. While the technological development is already making progress, the adoption of self-driving cars is just beginning. There are plenty of scenarios on how the route towards a large-scale use of AVs will look like, with technological, societal, legal and economic barriers.

The traffic situation in India leads to design this project prototype, which aims at relaxing driver and creating an automated vehicle whose destination is dynamic unlike Google car, whose destination is static and fixed. This research has been a need for India if implemented in real time.

3.3 OBJECTIVE OF A PROJECT

Self-driving cars help reduce the pollution emitted by vehicles. Autonomous capabilities such as consistent driving speeds and keeping a measured distance between vehicles can reduce unnecessary breaking and re-acceleration. Electronic models of self-driving cars with an electric or hybrid engine further reduce pollution by eliminating or lessening the use of fuel. Road accidents result in 1.25 million deaths and 20-50 million injuries worldwide. If nothing changes, road traffic injuries may become the fifth leading cause of death by 2030.

Self-driving cars may be the solution to road accidents. Since human error is the cause of around 90% of traffic accidents, delegating most or all of the vehicle operating responsibilities to the ADS can increase road safety. While fully automated vehicles haven't been commercially adopted yet, many cars today are equipped with sensors and advanced systems that alert drivers to dangers. Self-driving car technology, such as connected cars, may offer a solution to clogged roads. Connected cars can communicate with each other can help optimize routes for each individual vehicle, creating a network of information that helps distribute traffic flow.
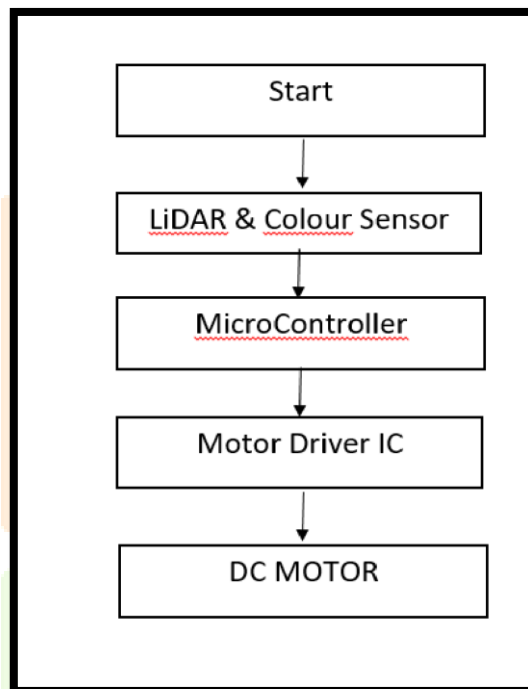
IV. FLOW CHART

Figure 4.1: Flow Chart Of The Self-Driving Car Using Lidar.
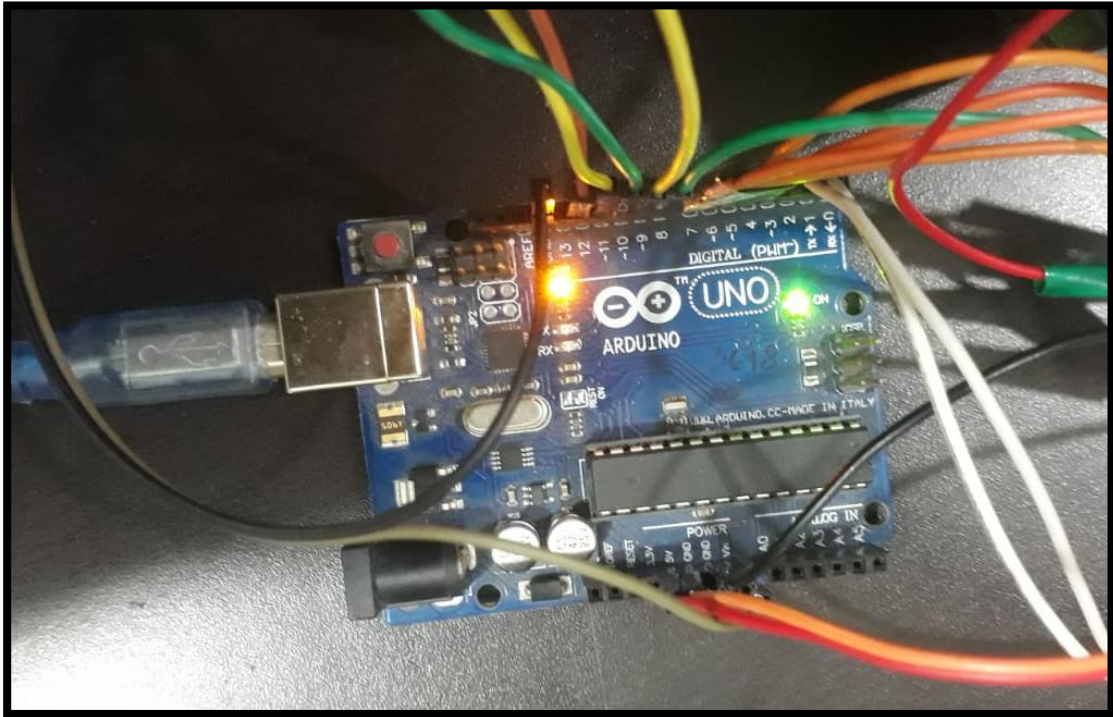
V. PHOTOGRAPHS OF CIRCUIT BUILD

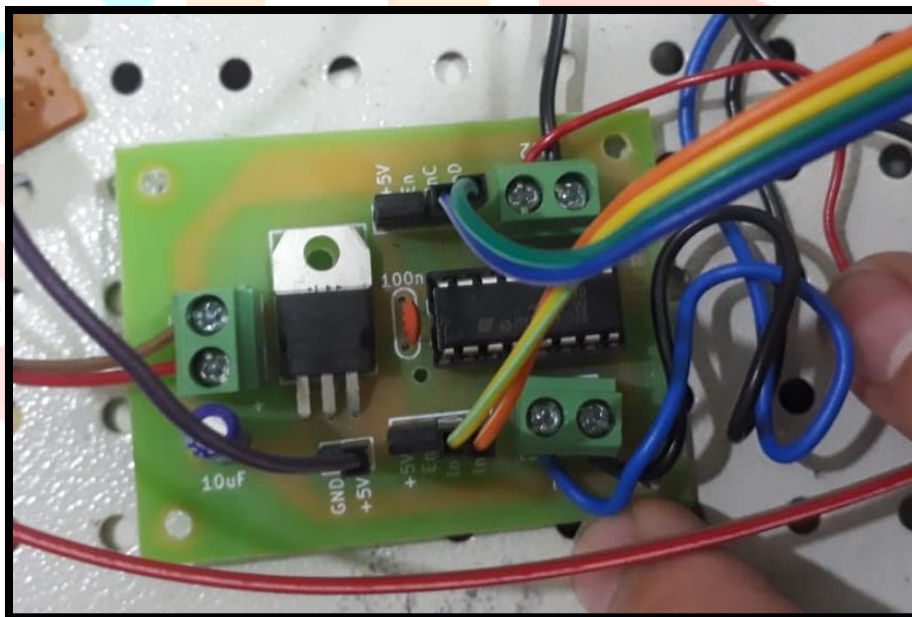**Figure 5.1: Arduino Uno & Microcontroller ATMEGA 328ino Uno & Microcontroller ATMEGA 328.**
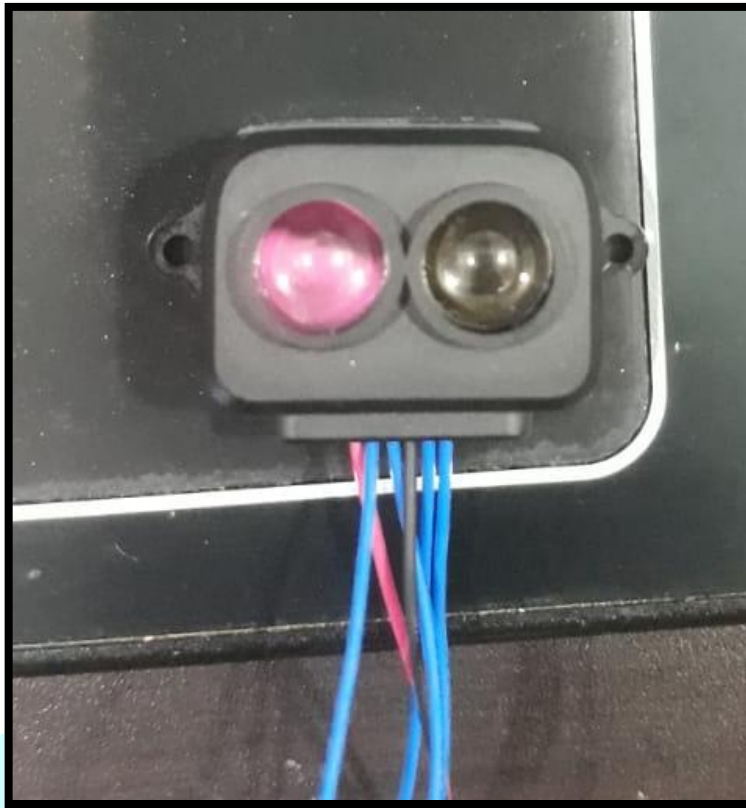

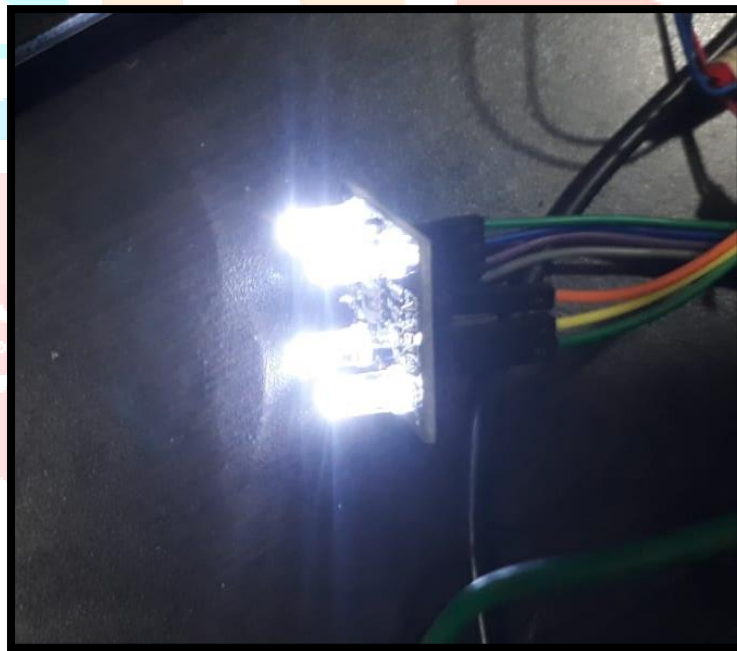**Figure 5.2: Motor Driver IC L293D.**

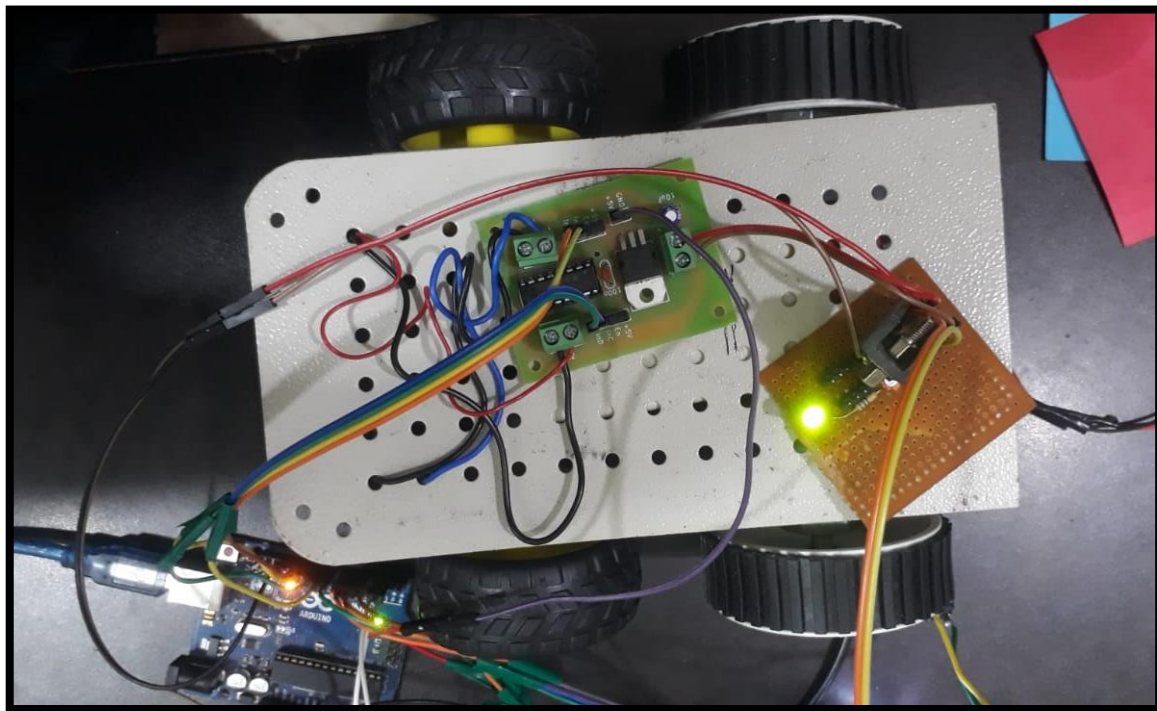**Figure 5.3: LIDAR.**

Figure 5.4: Colour Sensor

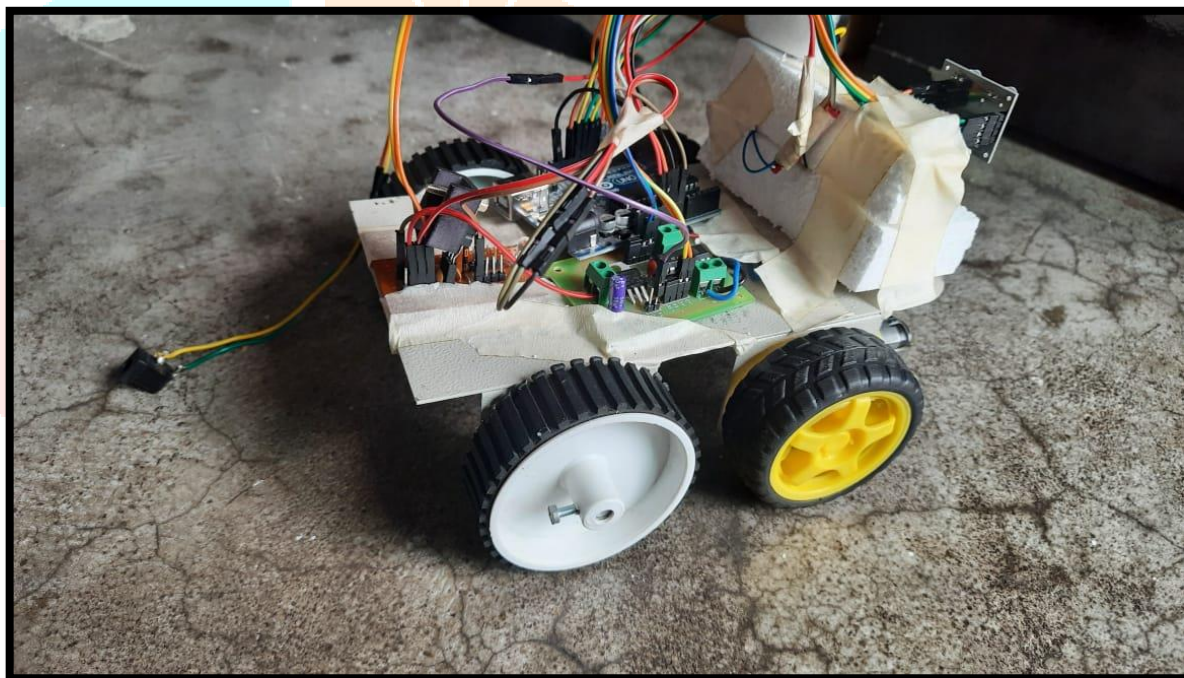**Figure 5.5: Vehicle without Assembly**

Figure 5.6: Assembled Vehicle

Figure 5.6: Final Model of Self-Driving Car

VI. RESULT

When Car start Lidar and Colour Sensor send their input to microcontroller. With the received information from Sensors, microcontroller decide to take next decision like Start, Stop, Move Forward, Move Backward, Turn Right, Turn Left, etc. Microcontroller end instruction to the motor driver for controlling motors with respective input taken from sensor.

VII. CONCLUSION

This is an advanced step for autonomous driving vehicles. With the help of this algorithm, vehicles can be set to automatically navigate to the destination location by continuously receiving the direction from another vehicle moving ahead to the same destination. The robotic vehicle routes itself with the guidance of another vehicle moving ahead to the same destination, therefore, deviations in time can occur. The goal of navigation process for a robotic vehicle is to move the robot to a known destination in an unknown environment. The navigation planning is one of the vital aspects of autonomous systems. When the robotic vehicle actually starts to move towards the planned route it may find unknown obstacles from the existing location to the destined location, hence the robotic vehicle must avoid the obstacles and follow an optimal route to reach the destined position. The potential applications of this robotic vehicle are to use these types of autonomous vehicle on highways or heavy traffic roads. These types of autonomous vehicles can also be used when a driver travels to the new areas. It is an improved navigation system for autonomous vehicles.

7.1 FEATURES

Many drivers are ready for the arrival of self-driving cars, which will cut down on the frustration and annoyance of having to constantly pay attention in traffic or on long road trips, among other benefits. But while we all know a truly autonomous car could be a decade or more from arriving in dealerships, you might be surprised to discover just how many autonomous features are available right now — including some in your own car. If you're looking to maximize the autonomous capabilities of your next vehicle, make sure it has some (or all) of the features on our list.

1. Adaptive Cruise Control

Probably the most common feature on our list, adaptive cruise control has been available on some vehicles, in varying forms, for over a decade. Improving upon the first autonomous driving feature ever (cruise control), adaptive cruise control can adjust your vehicle's speed based on the speed of cars on the road in front you.In many cases, it can even set and maintain a desired following distance. And while some adaptive cruise control systems require vehicles to be traveling at a certain speed before they'll kick in, the best systems can bring a car to a complete stop and get it started again once traffic in front begins moving.

2. Automatic Forward-Collision Braking

Automatic forward-collision braking is perhaps the most rapidly proliferating feature on our list. While it was considered a novel (And unusual) feature just a decade ago, it's now offered in an enormous range of cars, including some compact and subcompact models with highly affordable price tags. So, how does it work? Although systems vary from automaker to automaker, most forward collision braking systems detect an imminent frontal collision, alert the driver to the possible accident ahead and quickly apply the brakes in order to ensure the car stops in time. Don't be fooled by forward-collision "warning" systems.

3. Automatic Parking

Automatic parking is the latest exciting self-driving feature to find its way into a wide range of vehicles. Like other technologies on this list, the actual workings of automatic parking systems vary from model to model and automaker to automaker, but the general gist is that these systems can decide whether a vehicle is large enough to fit in a certain parking spot and then automatically steer the car into the spot. While some versions only control the steering and require drivers to work the brake and gas pedals, other systems do it all for you — and some even work in perpendicular parking spots, in addition to parallel ones.

4. Autopilot

Tesla's Autopilot system is possibly the most advanced autonomous system on the market today. While many automakers are focusing on making sure vehicles remain in their lanes (lane-keep assist), avoid collisions (forward-collision braking) or slow down and speed up based on traffic (adaptive cruise control), Tesla has put together every piece of the puzzle in the best and most useful way possible. The result is near-full autonomous driving — though the system won't work in some conditions, and Tesla reminds drivers to always keep their hands on the wheel. Still, Tesla's Autopilot system is as close to autonomous driving as you're going to get for the time being.

5. Lane-Keep Assist

More and more automakers are rolling out lane-keep assist, a new feature that builds on lane-departure warning systems in older models. While lane-departure warning would sound an alert or flash a light to let you know you're drifting from your lane (if you're distracted, for example), lane-keep assist will automatically steer you back into your lane should you start to drift out. While there are a few limitations to lane-keep assist systems — they won't work if lane lines aren't easily visible, for example — the technology is an excellent example of increasing autonomous technology in modern vehicles.

6. Sign Recognition

If you don't know about road-sign recognition, you might be surprised to learn it exists — but it's available and surprisingly helpful. Road-sign recognition is a tool that automatically views signs on the side of the road and relays that information to the driver. Have you ever wondered what the speed limit is as you drive down the road? A car with a good sign-recognition tool will automatically capture the speed limit and display it for you, so you never have to wonder again.

7. Steering Assist

Several high-end luxury cars — like the BMW 7 Series, the Mercedes-Benz S Class and the Volvo S90 — offer full steering-assist systems in addition to more common autonomous technologies like lane-keep assist and adaptive cruise control. While steeringassist systems from these more traditional luxury brands aren't as comprehensive as Tesla's Autopilot system, and they usually only last a few seconds or a minute before handing control back to the driver, the idea is similar: The car uses all of its sensors and cameras to steer for itself for a certain period of time. While this feature is currently only offered on top-level luxury cars, we suspect it'll trickle down to lesser models in the next few years.

7.2 Application

1. For Using As a Self-Driving Taxies and Transportation Vehicle
2. For Personal Vehicle.
3. For Industrial Work and Transportation.

7.3 Advantages

1. Decreased the number of accidents

Autonomous cars prevent human errors from happening as the system controls the vehicle. It leaves no opportunity for distraction, not just like humans who are prone to interruptions. It also uses complicated algorithms that determine the correct stopping distance from one vehicle to another. Thereby, lessening the chances of accidents dramatically.

2. Lessens traffic jams

Driverless cars in a group participate in platooning. This allows the vehicles to brake or accelerates simultaneously. Platoon system allows automated highway system which may significantly reduce congestion and improve traffic by increasing up the lane capacity.

Autonomous cars communicate well with one another. They help in identifying traffic problems early on. It detects road fixing and detours instantly. It also picks up hand signals from the motorists and reacts to it accordingly.

3. Stress-free parking

Autonomous cars drop you off at your destination and directly heads to a detected vacant parking spot. This eliminates the wasting of time and gas looking for a vacant one.

4. Time-saving vehicle

As the system takes over the control, the driver has a spare time to continue work or spend this time catching up with their lovedones without the having the fear about road safety.

5. Accessibility to transportation

Senior citizens and disabled personnel are having difficulty driving. Autonomous vehicles assist them towards safe and accessible transportation.

7.4 Disadvantage

1. Expensive

High-technology vehicles and equipment are expensive. They prepare a large amount of money for research and development as well as in choosing the finest and most functional materials needed such as the software, modified vehicle parts, and sensors. Thus, the cost of having Autonomous cars is initially higher. However, this may lower down after 10 years giving way for the average earner people to have one.

2. Safety and security concerns

Though it has been successfully programmed, there will still be the possible unexpected glitch that may happen. Technologies are continuously updating and almost all of this equipment may have a faulty code when the update was not properly and successfully done.

3. Prone to Hacking

Autonomous vehicles could be the next major target of the hackers as this vehicle continuously tracks and monitors details of the owner. This may lead to the possible collection of personal data.

4. Fewer job opportunities for others

As the artificial intelligence continues to overcome the roles and responsibilities of humans, taxi, trucks, or even co-pilots may be laid off as their services will no longer be needed. This may significantly impact the employment rate and economic growth of a certain country.

5. Non-functional sensors

Sensors failures often happened during drastic weather conditions. This may not work during a blizzard or a heavy snowfall. Our technology still continues to develop and to be tested. Autonomous cars may provide a significant comfort we needed. However, we need to bear in mind that there are still disadvantages affiliated with it.

7.5 Future Scope

Vehicles last longer, cost more, impose larger external costs, and are more highly regulated than most other consumer goods. As a result, vehicle technologies take Longer to penetrate markets than most other sectors. It will probably take decades For autonomous vehicles to dominate new vehicle purchases and fleets, and some Motorists may resist using them. Optimistically, autonomous vehicles will be safe and reliable by 2025. A few more years will be required for testing and regulatory approval, so by 2030, autonomous vehicles may be commercially available and allowed to operate in many areas. If they follow the pattern of previous vehicle technologies, during the 2030s and probably the 2040s, they will be expensive and limited in performance, sometimes unable to reach a desired destination or requiring human intervention when they encounter unexpected situations. Customers will include affluent high-annual mileage motorists, and businesses that use vehicles to transport equipment and goods. For the foreseeable future most moderate- and low-income households will continue to use human-operated vehicles. It will probably be the 2050s before private autonomous vehicles are affordable to most middle- and lower-income motorists. Shared autonomous vehicles (self-driving taxis) and rides (micro-transit services) are being tested in some jurisdictions, but it will probably be the 2030s before they are widely available. Shared vehicles have moderate operating costs, and offer moderate convenience and comfort. They should be cheaper than current taxi and ride hailing services, but offer lower quality service since no driver will be available to assist passengers, provide security, or clean vehicles. Vehicle dispatching will sometimes be slow and unpredictable, particularly in suburban and rural areas. Shared rides will have the lowest costs but the least convenience and comfort since collecting passengers add delays, they generally cannot provide door-to-door service, and passengers will need to share confined spaces with strangers. Because of these limitations, shared vehicles and rides will primarily serve local urban trips and are unlikely to dominate suburban and rural travel. Because of their high labour costs and predictable routes, long-haul buses and freight trucks are particularly appropriate for autonomous operation, so self-driving buses and trucks may become common in the 2030s and 2040s. Many commercial vehicles will still need employees on board to provide passenger assistance, security, plus loading and unloading.

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