iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: VII Month of publication: July 2021

DOI: https://doi.org/10.22214/ijraset.2021.36334

Anatomy of Self Driving Vehicle

Parth Ghube[1], Sachin N Patil[2]
Department of Mechanical Engineering, MAEER's MIT Polytechnic Pune, S.No.124, Paud Road, Kothrud, Pune, Maharashtra 411038

Abstract: The concept of Autonomous Vehicles portrayed in several Science Fiction mediums is now close to commercial reality. The new technology has the potential to change the conventional Transportation Industry. If implemented successfully, it will benefit society as a whole. As emerging as it seems; it also raises some serious challenges. This paper presents a systematic outline of the key components of Self Driving vehicles, current systems used, an overview of the Decision-making models, future scope and the practical challenges faced while developing and deploying the technology.

Keywords: AV- Autonomous Vehicle, SDV- Self Driving Vehicle, Driverless, Sensors, Central Processing unit, CAN- Controlled Area Network, Actuators, Vehicle Control, Localization, Deep learning algorithms, Mapping, Training, Testing, Integration, Safety-Critical Product.

I. INTRODUCTION

Self-Driving Vehicles referred to as SDVs is the buzzword in today's automotive and the Tech-World. The roots of technology go deep back in the 15th Century. A historical record belonging to Leonardo Da Vinci mentions the concept of a self-propelled programmable wooden cart. From then steady progress was made till the 20th Century. The development made in the last two decades on this technology is remarkable. The concept is now close to deployment in the upcoming years. Theory related to technology seems to be extremely complex. To simplify it, one can compare it with the human brain and its peripherals. SDV's are driverless vehicles commanded by a computer that procures data from sensory systems in real-world and time, to take relevant decisions; Similar to a person who decides a destination, visualizes the path and drives on road reacting to the real-time conditions, situations and surroundings. During this course, the vehicle comes across several static objects like roads, poles, signals and dynamic objects such as moving vehicles and pedestrians. The decisions and controls of the vehicle have no chances of errors while facing the conditions on an actual road. Deployed Driver Assistance Systems in the market have features such as lane assist, parking assist and self-driving combined with human intervention. Complete automation is yet to be deployed in the market. Organizations around the world have framed new guidelines and standards for this system. Society of Automobile Engineers (SAE) International has stated six levels of automation in vehicles. From level zero i.e., complete human-driven vehicle to level 5 fully automated vehicles.

TABLE 1 SAE LEVELS OF DRIVING AUTOMATION

Automation Level	Short Name	Longitudinal/ Lateral Control	Driving Environment Monitoring	Fallback Situation Control	System Capability/ Driving Modes
0	No Automation	Human	Human	Human	None
1	Driver Assistance	Human & System	Human	Human	Some
2	Partial Automation	System	Human	Human	Some
3	Conditional Automation	System	System	Human	Some
4	High Automation	System	System	System	Some
5	Full Automation	System	System	System	All

A. Benefits of SDV Technology

Globally in 2018, there were 1.35 million deaths by road accidents. These figures were recorded by World Health Organization (WHO) in the Global Status report.

NHTSA (National Highway Traffic Safety Administration – USA) states that 94% of accidents are caused by driver faults. Human Driver conditions like distraction, fatigue do not come into the picture in the computer-driven system. This reduces the probability of accidents and errors; Hence making roads safer.

It will increase uniformity in traffic behavior and ease vehicle congestions.

SDVs will mostly be adopted in EV's hence lesser pollution. Other than Private transportation it can be also implemented in various sectors like agriculture, logistics, paramedic operations, disaster management, industries, surveillance and security.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

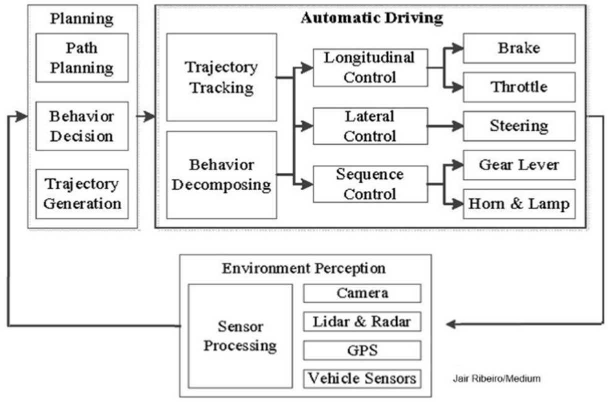


Fig. 1 Autonomous Driving System framework

II. HARDWARE

Being a safety-critical product, hardware design and selection is sensitive. Hardware required for SDV's is divided into the following sections-

A. Sensors

Sensors make the vehicle aware of its environment. Their data is extremely crucial for decision-making algorithms. Sensors used in Autonomous vehicles can be divided into 2 types based on working.

1) Active Sensor: Release energy to retrieve data from detected signals (LiDAR, Radar)
2) Passive Sensor: UTILIZE available energy to sense (Stereo Camera)

Based on the type of vehicle state a sensor measures, they are classified as

a) Proprioceptive Sensors (measure internal conditions)
b) Exteroceptive Sensors (measure external state).

The selection of Sensors mainly depends on the following factors
Accuracy- Sensor accuracy is vital as the data directly affects decisions.

- *Functionality*- Every sensor has particular features. Most of the AVs adopt multi-sensor fusion for maximizing functionality and safety.
- *Ruggedness*- It's the ability to work in adverse conditions without affecting accuracy. Most of the sensors are mounted externally on the body hence they need to withstand rough conditions.
- *Sensing Range*- The operating area of a sensor wherein it can measure the specified events with precision is the sensing range. Long-range sensors are mounted on the hood and are used in highway driving. Short-range are installed for close-range traffic, emergencies.
- *Cost of technology*- Lidar vision is sophisticated but costly, cost affects safety. Sensors mustn't hamper aesthetics.

Sensor Data passes to the Car Computing Platform via Middleware wherein it is processed, analyzed & necessary decisions are taken and signals are sent to actuators. Considering all the mentioned factors, a combination of sensors is selected.

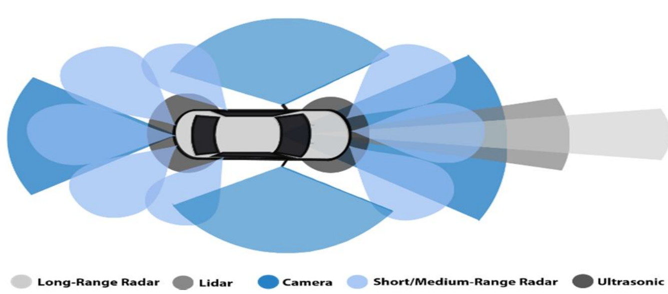


Fig. 2 Example of SDV sensors configuration.

B. Overview of Sensors installed in SDV's

1) *Radar (Radio detection & ranging)*- Radar emits electromagnetic waves that sense items and gauge their distance and pace with regards to the vehicle in actual time. 24 GHz, 77 GHz based Radars are used in AV's.
2) *LiDAR (Light detection and ranging)* - Principle same as Radar. Operate on laser instead of radio waves. LiDAR system has four major components: laser pulse emitter, a retro reflected light receiver, sensor and signal processing software. It is used for Short Range applications. LiDAR generates Point Cloud for mapping the environment. Technology was costly when introduced in the 20th century. Today's price is significantly lower. Features include 360° coverage, better precision than Radar, faster response.
3) *Ultrasonic Sensors* – Sonar uses soundwaves inaudible to the human ear. Distance is measured by Trilateration. They operate above 20 KHz. Used in Gesture control, parking sensors and close-range sensing. Above mentioned sensors are also called Time of Flight Sensors.
4) *Visual Stereo Cameras (Passive Sensor)*- Used in computer vision, ADAS, Cruise control. Design has dual cameras of the same focal length which simulate human binocular vision.
5) *Global Navigation Satellite Systems*- GNSS provides autonomous geo-spatial positioning with global coverage. Earlier only available with Military and Government. Now Commercial Mapping Satellites available in space- Galileo (European Union), GLONASS (Russia) BeiDou (China). They assist in Digital Mapping, Onboard navigation, Path prediction, Vehicle to Vehicle, Vehicle to satellite connectivity. Drawback- Limited positioning accuracy (1-3m), Unreliable. Minimum 24 satellites are required for global coverage and 3 or more are required for localization. Need a clear line of sight for communication.
6) *Inertial Measurement Units (IMU)* - Accelerometer, Gyroscope and Magnetometers integrated into Single units. They Detect motion, position, Cartesian coordinates and Nine degrees of freedom. IMU sensors can be mechanical, electromechanical, or laser-based.
7) *Odometry Sensors*- The sensors measure Distance and vehicle Orientation using wheel rotation.

C. Middleware

Sensor Data is Unfiltered and Raw. It requires screening and processing; This is done by Components & tools referred to as Middleware. It consists of an Operating System and Runtime Infrastructure. Middleware acts as a bridge between the SDV Application layer and the hardware layer. E.g., Robot Operating System (ROS), Automotive data and time-triggered framework (ADTF- developed by Audi Electronic Venture), Automotive open system architecture (AUTOSAR).

D. Computing platform

After sensor selection, the major component is the computational platform. It is necessary to choose a system that can multitask efficiently with a fast response time. Humans perceive their surroundings using specific organs and take relevant decisions similarly, the computer platform has to map the environment in three dimensions to process data from the sensory systems. For this Integrated Platforms called HPC's (High-Performance Computers) are used. Autonomous vehicles continuously collect, analyse and transmit massive volumes of data; standard vehicle systems cannot handle this data. SDV's need High-Performance Onboard Computer Platforms. HPC Selection criteria depend on,

1) *Data Transfer rate*: Speed of Interna Data transmission.
2) *Computing power:* Calculation time affects situations directly. e.g., a vehicle moving at 100 kph i.e., 28 m/s faces a 1sec delay to take a decision that costs 28 m extra distance for braking. Hence Multitasking with high efficiency requires large computing power.
3) *Energy consumption:* As this technology will be implemented mostly in Electric Vehicles. The HPC's must be energy efficient.
4) *Robustness:* The platform needs to be Operational in a wide delta of conditions and temperatures.

Different computing platforms have been tested and implemented in AVs. Chip developers usually combine the following processors for building a redundant design. This ensures the safety and operational reliability.

a) CPU- Central Processing Unit.
b) GPU- Graphics Processing Unit
c) FPGA- Field Programmable Gate Array
d) ASIC- Application Specific Integrated Circuit

E.g., NVIDIA DRIVE AGX Developer Kit, Tesla FSD chip, Arm Cortex-A76AE, Intel SICSNXP BlueBox, Intel AthosMotion.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

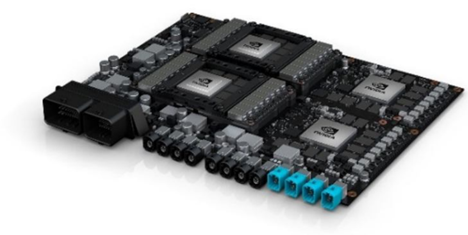


Fig. 3 NVIDIA DRIVE AGX Pegasus computing platform.

E. Actuators and mechanical systems

1) *Actuator Interface:* It is a low-level control kit which translates platform decision to physical components. It is the layer between the Computing Platform output signal and the mechanical actuation. Vehicle Dynamics states 2 main Axis Movements. Lateral motion Steering (Y-axis), Longitudinal motion Acceleration (X-axis).
2) *Drive by Wire Technology:* An SDV can use an Internal Combustion Engine or Electric vehicle platform. Vehicle control and Actuation are different in IC Engine vehicles than in EVs. The drive-by-wire is a technology that is adopted for converting Gas propelled vehicles into autonomous vehicles. The technology uses electrical and electromechanical systems for controlling vehicle systems. It eliminates the use of mechanical linkages and hydraulic systems for actuation. Drive-by-Wire technology is subdivided into four subsystems that control vehicle dynamics-

a) Throttle-by-Wire - Throttle Pedal control
b) Brake-by-Wire - Braking System control
c) Steer-by-Wire - Steering System control
d) Shift by-Wire - Transmission System control.

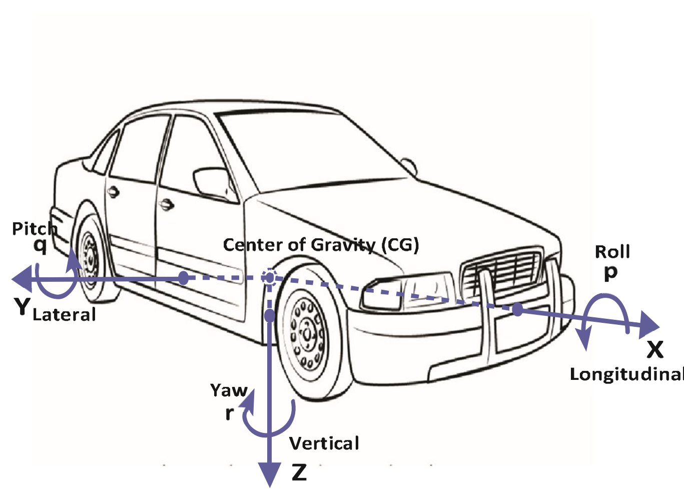


Fig. 4 SAE J670 vehicle axis system.

III. SOFTWARE

The core of most of the Software models used in Autonomous Driving Vehicles is Machine Learning algorithms particularly Deep Learning Neural networks- a Subset of Artificial Intelligence. Developing Deep Learning Models for SDV's could be broadly classified into two major paradigms

1) Semantic Abstraction Learning
2) End to End Learning

Achieving Level 5 Automation will be the benchmark for the two approaches. Software components are divided into Perception & Architecture.

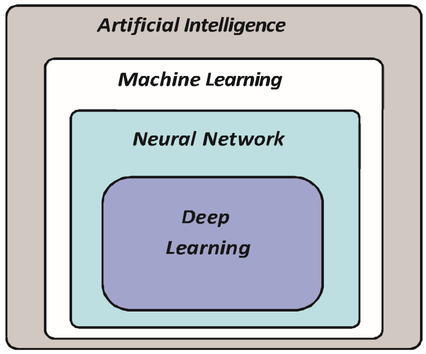


Fig 5 Relationship between deep learning, neural networks, machine learning and artificial intelligence.

A. Perception

Is the organization, identification, and evaluation of sensory information to represent and interpret the surrounding environment or information. Human perception is superior and complex. Perception in SDV is the replication of surroundings in a digital environment, calculating the values and answering the logical questions for decision making. Reproducing this ability in SDV technology needs a huge volume of data and coherent algorithms. The decisions taken by the models must be safe, valid and quick. All the processes are in a fast-paced dynamic environment. Perception can be categorized into 2 main subsets namely Simultaneous Localization and Mapping (SLAM) and Detection and Tracking of Moving Objects (DATMO).

1) *Localization:* "Localization" refers to determining the vehicle's exact location on a map. The vehicle may identify its precise relationship to all of the components on the map by localizing itself. Vehicle position & orientation on the map. Relative localization Using the TOF sensor data set is faster than global localization (GSS). Techniques include gathering data from GNSS, Wheel Odometry, Inertial System, Sensors, Lidar (Scan matching by ICP algorithm), Camera Vision System (Depth Maps) SLAM- (Simultaneous Localization and Mapping) is a method for autonomous vehicles that combines localization and map building. Using it the car can map out unknown environments using SLAM methods. The map data helps to perform activities such as route planning and obstacle avoidance. The algorithms used to perform Visual SLAM are ICP and ORB. For Appearance-based localization Large-Scale Direct Monocular SLAM (LSD-SLAM) and Stereo Large-Scale Direct SLAM (S-LSD-SLAM) can be implemented.
2) *Mapping:* Developing an accurate 3-Dimensional Map is only possible when the exact position and direction of the vehicle is known i.e., when Localization results are precise. Generation of the three-dimensional environment from Multi-sensor data is an important stage in perception. Different types of maps generated for perception by vehicle computer are,

a) Occupancy grid maps.
b) Feature, or landmark maps.
c) Relational map
d) Point Cloud Map

3) *Object Detection:* In a Safety-Critical Product, object detection has to be precise. Humans can detect and decide objects even in an Unknowing state. The computer has to rely on massive datasets for this operation. Computer Vision Model can be divided into 3 primary parts-

a) Object Classification
b) Object Detection
c) Semantic Segmentation

General Pipeline of Object Detection Models is - Preprocessing--Feature Extraction—learning algorithm-- Label assignment. Feature Extraction is crucial.

Multi-Sensor Data Fusion – SDV's have different sensors installed on them. Data from multiple sensors has to be interpreted by the models. The models3 types Complementary, Redundant, and Cooperative. (e.g., AV company Mobileye uses a Redundant approach in their SDV technology)

To conclude Software output from perception has to answer Two basic questions; Where am I? and What direction am I facing?

B. Architecture

Planning- based on Prediction Planning follows a Three-Layer Inverted Pyramid approach. Layers include,

1) *Path Planning:* Aided by built-in navigation systems (Google maps, TomTom, etc.), In automobile systems, shortest pathfinding algorithms like Dijkstra's Algorithm are implemented. Route planning functionality, Routing Kit (CPP library)
2) *Behavioral:* This stage has to make critical predictions on road. Several external factors like perceived obstacles, road geometry, pedestrians, actual traffic rules, speed limit, other vehicles, natural occurrences, stray animals come into the picture here. As mentioned earlier they can be static or dynamic. Dynamic is challenging to predict here. One of the Approaches used is Prediction and Cost-function Based (PCB)Architecture.
3) *Motion Planning:* The Outputs from the behavioral model are used here. Calculations like steering wheel angle, throttle level, braking are performed. The combined calculations determine the velocity, steering trajectory, acceleration of the vehicle. Well-known path algorithms used in SDV's are Rapidly-exploring Random Tree (RRT) and Probabilistic Roadmap (PRM).
4) *Vehicle Control:* In this Layer Signals for actual system actuation are executed. Decisions are taken only after safety screening. Thus, it is a highly vulnerable module as the decisions implemented directly affect the on-road action. Due to this the module is separated and given 'Freedom from Interference' and 'Override Decisions Lacking Safety'. The module controls the longitudinal lateral movement by considering the mentioned parameters. Features like Adaptive Cruise control, Lane changing, Braking, Turning, etc. are performed by this module. All Software layers require efficient coordination and communication to achieve the desired outcomes for safe and secure automated driving.

IV. INTEGRATION AND TESTING

Hardware and Software integration is the next step after the development of individual modules. For Prototyping several open-source frameworks are available. Numerous experiments of converting Modern Manual cars to autonomous cars have been done successfully by different Universities and Automakers. Implementing SDV technology in EVs is easier than in IC Engine Vehicles.

A. Integration

Hardware- Software integration includes the following layers-

1) *Securing Vehicle Network:* Sensors and Central Processors generate huge volumes of data, using a highly efficient communication network is a key part of Integration. The Ethernet and CAN-based networks have been implemented in SDV's. The chosen network has to have a minimum delay, maximum transfer rate and should not generate noise and latency. The common way of laying the network is by connecting all components to a central gateway.
2) *Sensor Calibration and Testing:* Sensor calibration and testing are Intensive. It has to be performed for millions of cycles, in varied environments and conditions. Tests include Lab Simulations and Ground runs. Labs conduct Visual tests, feedback reports, Parameter Accuracy and Validation. For validating 3D reconstruction accuracy of Visual Stereo Camera systems parameters such as height, pitch, roll, focal length, skew have to be calibrated.

Fig. 6 Example of sensor calibration.

3) *Installation of Middleware and Device Drivers:* Driver packages of all components have to be installed on the processor and configured with the systems.
4) *Software Implementation*: Generally, two approaches are seen here. Hand coding and Model-based (using MATLAB and ASCET). Actual deployment may have both workings redundantly or in a combination.

B. Testing

To make a car 95% as safe as an experienced driver, 275 million failure-free autonomous miles (400 M km) are needed while several billion miles (or kilometers) are needed to make them 10% or 20% safer than humans [6].

1) *Unit Testing: Each component is isolated and tested individually in a virtual environment. For example, in localization unit testing, trials have to be carried for three types of occurrences,*
   a) Normal input values within boundary conditions
   b) Out of Boundary values
   c) Erroneous values
2) *Integration Testing*: The objective of integration testing is to validate the behavior of all systems when integrated. Test cases used are similar to Unit Testing.
3) *System testing*: Involves standard test procedures followed in automotive industries. The functionality of software with all the hardware components is tested in this stage. Tests include, Simulations of real-world scenarios, Accident/ Malfunction cases, Benchmarking and Stress tests. Testing Setup is known as Hardware-in-the-Loop (HIL) test environment. Generally, testing is done on dedicated servers.
4) *Ground Runs and Acceptance tests*: Include actual vehicle test drive on road. They can be pre-defined tests or random tests. Drives need to be done in varied weather conditions, geographical regions, extreme environments, at different times, on different roads. A massive amount of data is collected from such drives improves the functionality of the deep learning models.

V. APPLICATIONS AND FUTURE SCOPE

Autonomous Driving systems will create a massive impact in the transportation and mobility sector. The scope of SDV technology is huge. We can adopt SDV both in transportation and non-transportation areas,

1) Personal Mobility
2) Public Transportation and Shuttle Fleet
3) Logistics and Delivery
4) Automated Agriculture
5) Paramedic and Emergency-response Vehicles
6) Security and Surveillance Operations
7) Assistance and Service Vehicles
8) Autonomous vehicles for physically challenged

A. Automated Agriculture

Agriculture is a labor-intensive job. With the introduction of modern technology in farming, the agriculture sector has seen tremendous growth. The SDV technology can be employed in driverless tractors, autonomous harvesters, special purpose farming machines and high-tech tools. The Vehicle will not only be equipped with basic SDV systems but also with agriculture-specific systems such as ground moisture level sensors, pH level sensors, ground temperature sensors.

Fig. 7 Two autonomous tractors performing a spraying function. ASIrobots

B. Autonomous Vehicles For Physically Challenged

Nowadays several projects and products like Automated wheelchairs, Prosthetic arms, Exoskeletons have been introduced for physically abled people. The concept of "Inclusive design" can be applied in the development cycle. Autonomous cars for the challenged people can be coupled with healthcare technologies. The application in this sector has great potential and can bring a revolutionary change in the lives of disabled people.

VI. CHALLENGES

Safety-Critical Products need to overcome vital challenges. They need to prove their systems across multiple channels, in varied conditions. Every New Technology has to face resistance to change.

A. Noticeable Challenges faced while developing SDV's are as follows-

1) Functional Safety- Hardware Interference and Malfunctioning, ISO 26262 compliance.
2) Cybersecurity
3) Robust Design
4) External Vehicle Communication
5) Maps and Navigation Unavailability
6) Firmware Updates
7) Social acceptability
8) Accident Liability

B. External Vehicle Communication-

External communication between the SDV and Back-end servers is similar to general client/server communication in the classical IT world. V2X (Vehicle to everything) communication is based on communication protocols that are acceptable to industry standards. As a result, V2X communication security standards are required to assure security without compromising interoperability. Network coverage is one of the most significant V2X problems. V2X networks are typically limited to specific geographic areas due to significant investment (and sometimes bureaucracy) required by public road authorities or municipalities to upgrade existing road infrastructure with roadside units (RSU), intelligent sensors, communication backbones, and other technologies. The issue of interoperability is also a major concern. Historically, numerous standardisation groups around the world, mainly in the United States and Europe, created V2X communication standards in parallel. Parallel standardisation activities have resulted in a collection of standards that are incompatible with one another.

C. Accident Liability

Who is accountable for accidents caused by driverless vehicles? What about the Vehicle manufacturer? What about the human passenger inside? What about the insurance company? Who is responsible for the loss of property, life involved in the accident? The questions remain unanswered. According to the most recent design, a completely autonomous Level 5 automobile will not have a dashboard or a steering wheel, meaning that a human passenger will not be able to take control of the vehicle in an emergency. This is one of the biggest hurdles for the AV Industry. Liability for self-driving car accidents is a growing field of law and policy that will define who is responsible when a car causes bodily harm or property damage. Existing liability laws must adapt to adequately identify the necessary remedies for harm and injury when driverless cars shift the responsibility of driving from people to autonomous car technology. Consumers will likely develop the confidence to use this new technology if an appropriate legal framework is in place that ensures affected victim's legal protections.

D. Events

1) Waymo's vehicles were engaged in 18 collisions with pedestrians, cyclists, drivers, and other objects, as well as 29 disengagements (where human drivers were forced to take control) that would have likely resulted in an accident.
2) In 2018 at Tempe, Arizona, Uber's self-driving Volvo hit a pedestrian at 39mph, despite the presence of a safety driver
3) On June 30, 2016, Joshua Brown, 40, was died while driving a Tesla Model S in Florida when the self-driving car collided with an 18-wheel tractor.

VII. CONCLUSION

Many problems remain unsolved because technology is still in its infancy. SDV Technology will take time to make the shift from self-driving cars with varying levels of autonomy to fully autonomous vehicles. Modern AI technologies and machine learning algorithms on the other hand are rapidly progressing and this is what is propelling the sector forward. With the development of new artificial intelligence models, powerful hardware, the decision-making ability of the vehicles has multiplied. However, the software faces challenges while facing accidental situations. Emotional intelligence is an area for further research. The situational and emotional awareness of humans in accidental conditions is yet to be seen in SDV's. Automakers and Tech Companies are investing heavily for achieving level five autonomy. The pace of research and testing is exceptional. Self-Driving Vehicles with level five autonomy are now close to reality.

VIII. ACKNOWLEDGMENTS

I would like to express my gratitude to my primary supervisor, Prof. Sachin. N. Patil, who guided me and offered deep insight into the study throughout this research. I am grateful to MAEER's MIT Polytechnic for providing me this opportunity and platform to present my research. I would like to express my gratitude to my primary supervisor, Prof. Sachin. N. Patil, who guided me and offered deep insight into the study throughout this research. I am grateful to MAEER's MIT Polytechnic for providing me this opportunity and platform to present my research. It was indeed a valuable experience to refer the information related to my topic from acknowledged testimonials that helped me to achieve my desired goal. I'm grateful to my family and colleagues who supported me throughout this work of mine.

REFERENCES

[1] Austin Brown, Brittany Repac, and Jeff Gonder. Autonomous vehicles have a wide range of possible energy impacts. Technical report, NREL, University of Maryland, 2013.

[2] Friedrich Fraundorfer and Davide Scaramuzza. Visual odometry. Part ii: Matching, robustness, optimization, and applications. IEEE Robotics & Automation Magazine, 19(2):78–90, 2012.

[3] H Durrant Whyte. Simultaneous localisation and mapping (SLAM): Part i the essential algorithms. Robotics and Automation Magazine,2006.

[4] Hanky Sjafrie Introduction to Self-Driving Vehicle Technology [Online] Boca Raton, Florida CRC Press [2020] Available from: https://lccn.loc.gov/2019026765 [Accessed 23rd May 2021] ISBN 9780429316777.

[5] Jair Ribeiro an-introduction-to-autonomous-vehicle [Online] Available from: towardsdatascience.com. [Accessed 25th May 2021]

[6] Laurène Claussmann, Marc Revilloud, Sébastien Glaser, and Dominique Gruyer. A study on al-based approaches for high-level decision making in highway autonomous driving. In Systems, Man, and Cybernetics (SMC), 2017 IEEE International Conference on, pages 3671–3676. IEEE, 2017

[7] Manfred Broy, Sascha Kirstan, Helmut Krcmar, and Bernhard Schätz. What is the benefit of a model-based design of embedded software systems in the car industry? In Software Design and Development: Concepts, Methodologies, Tools, and Applications, pages 310–334. IGI Global, 2014.

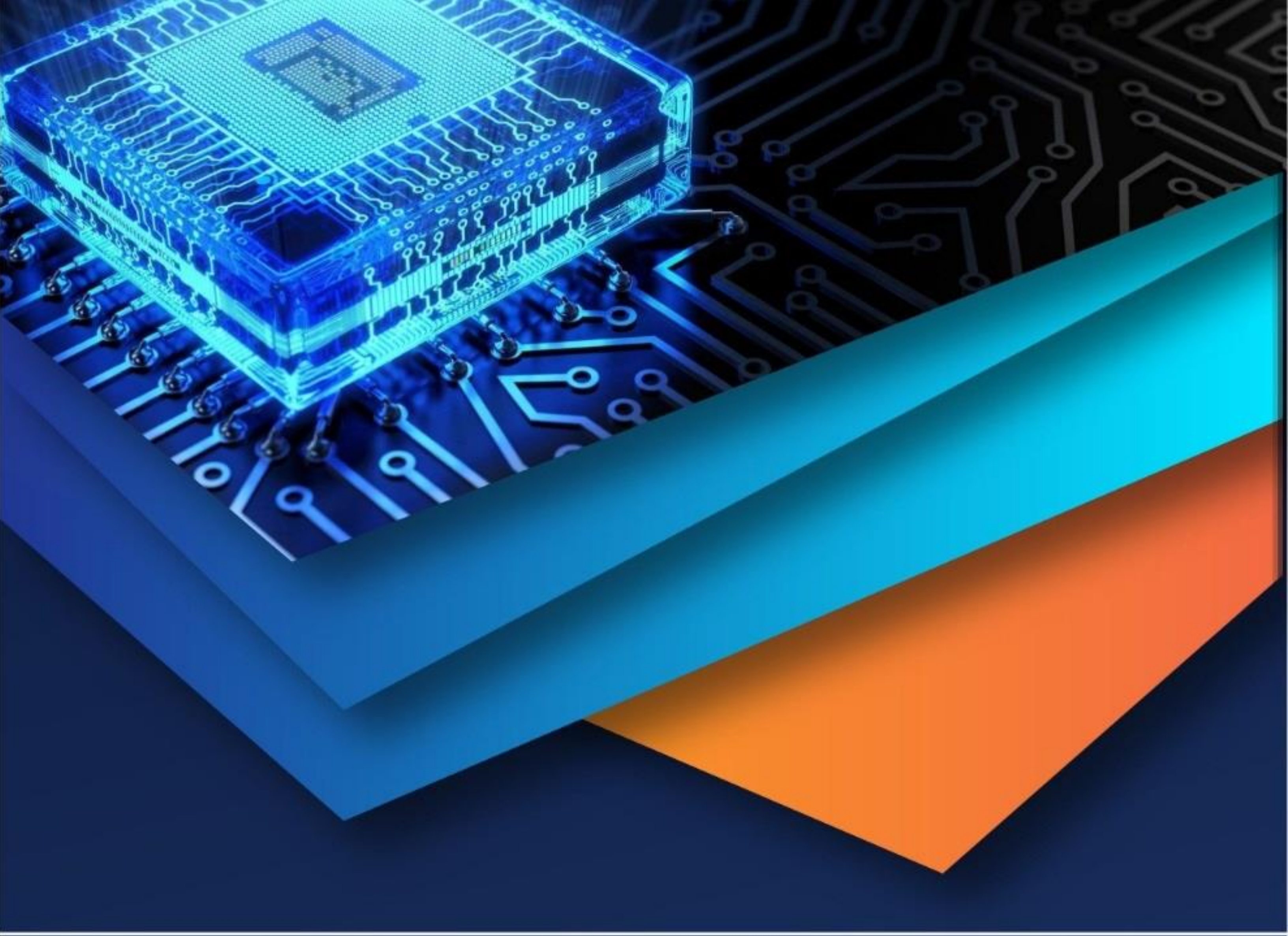
[8] Jennifer Shuttleworth SAE J3106 Levels of Driving Automation [Online]. Available from https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic [Accessed 27th May 2021]

[9] SAE Org J3061 201601 Cybersecurity guidebook for cyber-physical vehicle systems [Online] SAE International 2016-01-14

[10] Santokh Singh. Critical reasons for crashes investigated in the national motor vehicle crash causation survey. Technical report, National Highway Traffic Safety Administration, 2015.

[11] Society of Automotive Engineers. Vehicle Dynamics Committee. Vehicle dynamics terminology: SAE j670e: Report of vehicle dynamics committee approved July 1952 and last revised July 1976, 1978.

[12] Taxonomy SAE. Definitions for terms related to driving automation systems for on-road motor vehicles. SAE Standard J, 3016, 2016.



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY