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User Interface and AI Navigation System for Autonomous Vehicle

Aalhad Satav, Nishigandha Patel

Abstract**: The issue of vehicle accidents due to human error and behavior (rash driving, drink and drive, etc.) is on rising resulting into fatality and economical loss. In order to overcome these issues, the autonomous vehicle is being explored as a probable solution. Driver will be replaced by AI based autonomous system; The main objective is to convert the manual operated EV into autonomous vehicle. The project work is divided into three main parts i.e., Control System for Vehicle Control, AI (Artificial Intelligence) and UI (User Interface). The main objective of User Interface is to give information regarding vehicles health i.e. battery remaining, charging time, distance to be covered, etc. AI will be use as decision making system or we can say brain of the autonomous vehicle. System Control or Vehicle Control System is to control the vehicle's steering, acceleration and braking system with the help of PID controller while the vehicle is being operated in autonomous mode. The main purpose is to make an autonomous EV for the passengers to go to their selected destination with a single click by selecting destination on display (UI). So the vehicle control is responsible for the vehicle's steering i.e., at what desired angle the vehicle need to turn, during acceleration the factors that are considered are; at what speed the vehicle needs to move in an straight path or during a turn and the braking system is operated with the help of LIDAR where if it detects an object at what distance it needs to apply the brakes and when to release the brakes. All the factors and conditions required in developing the autonomous vehicle will be considered, as use cases to improve the accuracy of autonomous vehicle, resulting into achieving desired objective of safe travel.

Keywords: EV, UI, LIDAR, Autonomous Vehicle, AI, Vehicle control

I. INTRODUCTION

An autonomous vehicle (robotic car, driverless car) is an automobile capable of transporting passengers without the need for human direction or interaction. through ability to sense its surroundings. An autonomous vehicle utilizes a fully automated driving system in order to allow the vehicle to respond to external conditions that a human driver would manage. There are five different levels of automation and, as the levels increase, the extent of the driverless car's independence regarding operation control increases. [2] [3]

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* Correspondence Author
Aalhad Satav*, M.Tech Student, Department of Mechanical Engineering, MIT ADT University, Pune (Maharashtra), India.
Nishigandha Patel, Assistant Professor, Department of Mechanical Engineering, MIT ADT University, Pune (Maharashtra), India.

The type of automation which is used in this vehicle is "Level-3" automation. In the truest sense of the term, it is at Level 3 when cars should be prefixed with autonomous. In Level 3, vehicle monitors and controls itself using advanced sensors, algorithms, and LiDAR. But there is still a need for human-driver in the worst-case scenario or emergency, or to apply brakes or halt the car. An automated vehicle basically can be divided into three broad categories i.e. (UI) User Interface, Navigation system and vehicle control. The role of vehicle control is to control the vehicle's steering, braking and acceleration. Where the visual part of the application i.e., User Interface plays very important role when it comes to any automated system. This project focuses on User Interface and the hardware components (sensors) and Navigation system of the automated vehicle.

A. Basic Knowledge

The user interface (UI) is the point at which human users interact with a computer, website or application. The goal of effective UI is to make the user's experience easy and intuitive, requiring minimum effort on the user's part to receive maximum desired outcome. Image result for what is the help of user interface in vehicle. [2] Generally, the goal of user interface design is to produce a user interface which makes it easy, efficient, and enjoyable (user-friendly) to operate a machine in the way which produces the desired result (i.e., maximum usability). The UI is basically integrated with the hardware components which monitors the surroundings such as different kind of sensors which gives the output to the UI which can provide information the user. The main components of the User Interface are as follows:

a. User Interface Elements:

Figure 1 UI Elements

For the vehicle user interface elements, the elements can be toggles or indications which show the information about what's going on inside the vehicle for example temperature inside the cabin or navigational information, other than that information related to the infotainment system.

b. Integration of Sensors:

The output of the sensors for which a user can see the elements of the different parts of the system. Navigation System, Navigation is the process or the activity of accurately calculating and planning a route to take or a direction to travel starting from one's position or location. [1] Finding your way around. Getting from point A to point B. Navigate is to direct and guide something or someone carefully and safely. To plot or plan the path and position of something that serves as a means of transportation. To act as the navigator in a car, plane, or vessel and plan. The act of moving something from one location to another. Coordinate is a number that identifies a position relative to an axis. Course is a general line of orientation or a line or route along which something travels or moves. Steering is to direct and guide a desired course and determine the direction for travelling. Position is a certain place or abstract location in a portion of space where something is situated. Place is a point located with respect to surface features of some region. [5]

A navigation system is a computing system that aids in navigation. Navigation systems may be entirely on board the vehicle or vessel that the system is controlling (for example, on the ship's bridge) or located elsewhere, making use of radio or another signal transmission to control the vehicle or vessel. In some cases, a combination of these methods is used. An automotive navigation system is part of the automobile controls or a third-party add-on used to find direction in an automobile. [4] [5] It typically uses a satellite navigation device to get its position data which is then correlated to a position on a road. When directions are needed routing can be calculated. On-the-fly traffic information (road closures, congestion) can be used to adjust the route. The AI-based autonomous navigation system software enhances the autonomy level and capability of platforms to achieve their mission through helping them to understand their environment, even in GPS-denied locations, allowing them to respond to changing conditions in real-time without any need for human intervention.

II. LITERATURE REVIEW

For this paper, through various literature searches it is found that many researches are going on with different technologies. Electrical vehicles are the future of the automobile industry. [10] Good amount of development has happened in the field of electrical vehicles. However, still there are very few companies which have been working on field of autonomous vehicle technology. The main advantage of this User interface is that user can easily monitor the status of the vehicle's performance and other parameters which comes under health monitoring system etc. It can help user to interact with different training tools. With the help of Navigation system, vehicle can go to different places without human interaction by generating the coordinates using GPS modules.

Scope of Work:

- To develop a User Interface for the Autonomous vehicle with the integration of hardware sensors.
- To Implement sensors in the autonomous vehicle which can help in monitoring the parameters of the vehicle according to the surroundings.
- To implement a GPS navigation system and fuse it with the AI module.

III. METHODOLOGY

After reviewing all the research papers related to the project or in work scope of User Interface and Navigation System, for autonomous vehicle is dispensed and therefore the basic information needed to implement in the system is obtained. The vehicle operates with the help of three system i.e., vehicle control, artificial intelligence and user interface. [3] Through the vehicle control system, the vehicles steering, braking and acceleration can be controlled so that the vehicle would safely reach the destination even though if any obstacles come in between and also the passengers can also enjoy their ride. [7] The User Interface gives all the technical information on the screen regarding vehicles different parameters which are very easy to use while starting the ride and for showing vehicle information. The navigation system helps to generate the path which will be followed by the path planner of the vehicle to maneuver the vehicle to the selected destination. After these studies, detailed information has been obtained about variety of sensors, camera, radars, etc., which obtains raw data and information from the surrounding environment. These data would then serve as input for software which would recommend the appropriate courses of action, such as acceleration, lane changing, and overtaking.

A. Proposed Methodology;

A self-driving car, also known as an autonomous vehicle is a vehicle that is capable of sensing its environment and moving safely with little or no human input. [11] This operation of the self-driving vehicle has been divided into three parts so that understanding of the whole vehicle becomes easy. The three parts are Vehicle Control, AI (Artificial Intelligence) and User Interface (UI). The vehicle control is responsible for controlling the vehicle's overall acceleration, braking and steering. The vehicle's acceleration and steering are calculated based on the desired angle which has will be generated with the help of PID and encoders. [9] Second main part of the autonomous vehicle is human and machine (vehicle) interaction unit which is User Interface which is fused with hardware components i.e., sensors. The output of these sensors will be visible on the screen which is integrated to the UI. [12] The navigation system uses GPS module to generate the coordinates. The coordinates then generate the trajectory points where the vehicle control sends signal to follow the path, hence the vehicle moves from one place to another. These trajectory points are mainly responsible for the vehicle's steering and acceleration because based on these points the path will be generated.

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For the vehicle's braking system, a single turn encoder and a DC Motor will be used because the encoder after generating the values in pulses (0 & 1) will send it to the motor so that the motor can process it further. The braking system works similarly to the pulley system. For the angle generation two PID's will be used because the job of first PID is to generate an desired steering angle and the second PID will calibrate that value comparing it with the trajectory points which have been plotted and also the vehicle's acceleration is been controlled with help of PID and the trajectory points. The overall tuning of the PID is done based on Kp (proportional gain), Ki (integral gain) and Kd (derivative gain) values. [5] [6]

B. Components of Vision System:

There are 4 major sensors being used in the navigation f vehicle. Sensors are the most required part of our system. We have used multiple powerful sensors which sense the real-world data and provide consumable data to process and generate output to take an action process it, so the encoder does the job by converting the data into readable format so that the DC Motor can process it.

Sensors:

- Stereo Depth
- Camera
- 3D Lidar
- Dual GPS
- Speed Sensor
- IMU
- Compass
- Steering Rotational Encoder
- Brake Rotational Encoder

a. ZED2 Stereo Camera

Figure 2 Zed Camera

We have used a ZED2 stereo camera to understand the real-word as humans can see. This camera works like the human eye, which will take real-time video feed and is passed by an AI engine. The camera started using ROS pipeline and data transfer using ROS topics.

b. LiDAR

Figure 3 Ouster Lidar

A typical lidar sensor emits pulsed light waves into the surrounding environment. These pulses bounce off surrounding objects and return to the sensor. The sensor uses the time it took for each pulse to return to the sensor to calculate the distance it travelled. We have used 3D lidar which is capable of working in any weather conditions. Basically, this lidar helps with obstacle detection and avoidance based on generated point clouds.

c. GPS

Figure 4 GPS Module

The Global Positioning System (GPS) is a U.S.-owned utility that provides users with positioning, navigation, and timing (PNT) services. This system consists of three segments: the space segment, the control segment, and the user segment. GPS satellites circle the Earth twice a day in a precise orbit. Each satellite transmits a unique signal and orbital parameters that allow GPS devices to decode and compute the precise location of the satellite. [4] GPS receivers use this information and trilateration to calculate a user's exact location. We have used Pixhawk GPS to get the current location, so we understand the current location of our vehicle and validate that vehicle driving on the track.

d. Speed Sensor

Figure 5 Proximity Sensor

The speedometer sensor is located in the transmission of your vehicle and is designed to register the drive shaft's rotational speed. The sensor delivers this information through the speedometer cable and to the vehicle's computer, which converts electrical pulses into a numerical speed. To track the current speed of the vehicle, a speedometer is the best option. [6] We have used it to get the current speed and, on that basis, we maintain the speed of our vehicle.

Models:

Perception Engine (Road Detection System)

Road detection is one of the preliminary tasks for intelligent and automated driving vehicles and has been richly studied in the past 2 decades. [10]

Finding out the drivable area is a complex and very crucial task. We have used **instance segmentation computer vision** techniques to get the drivable area from the different roads. We train and tested multiple instance segmentation state-of-the-art deep learning models like **Detectron 2, Mask-RCNN** and come up with a very accurate and real-time state-of-the-art instance segmentation model that is **YolactEdge.**

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Figure 6 Output of YolactEdg Model (Road Instance Segmented)

Working of Perception Engine (Road Detection System): The backbone of the perception engine is the YolactEdge model. We take the real- time video input from the ZED2 camera using ROS topics then it is consumed by the YolactEdge pipeline. This pipeline detects the road and finds the road mask and gives the output as a bounding box and instance segmented mask on a real image. This output is transferred to the trajectory model and we find the polygon list from the output mask and pass to the occupancy grid to generate the cost map.

Neural Path Planner (Trajectory):

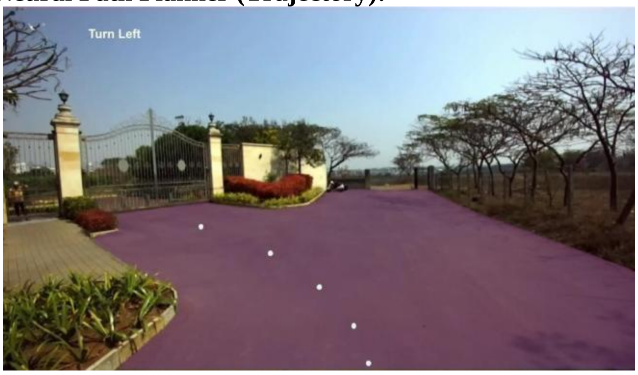

Figure 7 Output with 5 trajectory waypoints

The trajectory model generates 5 decision points that help to locally navigate the vehicle by providing the direction left, right or straight.

Trajectory model takes input (mask with original image consumed from ZED2 camera) from the perception engine and predicts the given 5 points which are in the sequence. Basically, we used the middle point that is the 3rd point to calculate the steering angle and that angle calculated by the path planner model.

Also, this model gives the direction of the vehicle. These are generated by 5 points consumed by the cost map model.

GPS Module

We have mounted a Dual GPS module on top of the vehicle which gives the current direction, latitude, and longitude continuously that passes to the Path Planner and Mission Planner for further process.

Mission Planner

After selecting the destination from the user, Mission Planner will use its mission file and get the current vehicle direction, latitude, and longitude from the GPS module and then generates a global map which sends to UI & path planner to track the vehicle position every time.

Lidar Intelligence

There is a 3D lidar mounted on top of the vehicle and in front, which collects the 3D point cloud data which is passed to the Occupancy Grid & Obstacle detection model.

Occupancy Grid Generator

The Occupancy Grid Model plays a very crucial role which takes 3 models' data and does sensor fusion. Basically, it takes a polygon list, trajectory points & lidar data then generates a cost map which shows the drivable area for the vehicle.

Obstacle Detection System

We understand that security is the main priority of our intelligence system. For that reason, just relying on vision sensors, we also used lidar data for obstacle detection. Lidar is the most powerful sensor because it works in different weather conditions. We stop the vehicle if the obstacle is in front of the vehicle that has a range of approximately 2.5 meters.

Path Planner

We can say the Path Planner model is the brain of our systems. It has the main role in this ecosystem. It collects all models data and takes the decision on that data and gives the task to the different models.

Health Check Master

When our system gets started, the health check master checks the health of all sensors and S/W. If everything looks good then it gives the green signal. But the job of this model does not stop yet, it keeps checking the status of each model.

Feedback & Control

This model takes the feedback from different sensors & models which helps to take the action in terms of control.

DWA Collision Avoiding Algorithm

DWA is an algorithm that takes the data in terms of the array generated by the cost map and also gives the speed, direction to navigate the vehicle.

Navigation System:

For the navigation system, we have used the Here3 GPS module with Pix Hawk Orange Cube Controller to get coordinate points

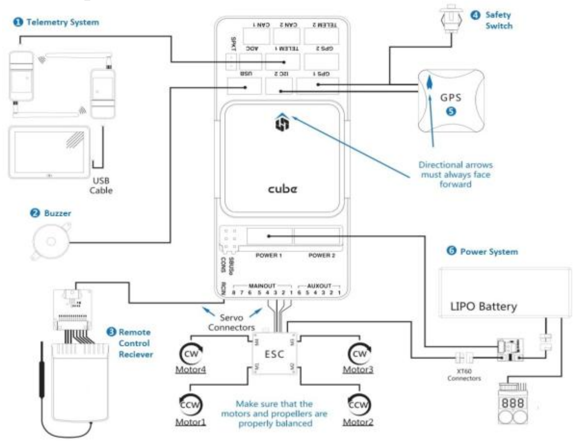

Figure 8 Pix Hawk Controller Ecosystem

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Features of Pix Hawk Orange Controller:

- Built-in IMU Heating system, allowing flights at extreme temperatures (below freezing).
- Robust DF17 Interface connectors give enhanced drop and shock resistance.
- Airframes: VTOL, Plane, Multicopter, Traditional Heli, Rover, Boat, Sub, General Robotics.

Connections for the GPS module:

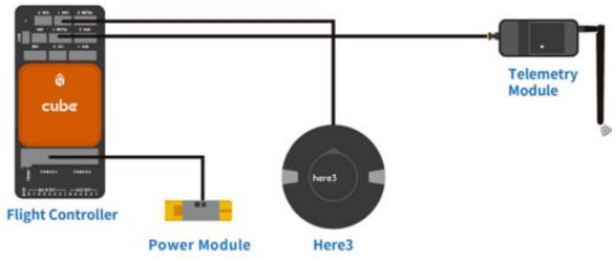

Figure 9 GPS module connections

Software Part of the GPS Module has been done using Mission Planner software.

Mission Planner is a ground control station for Plane, Copter and Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for the autonomous vehicle.

IV. RESULT AND DISCUSSION

From the UI (User Interface) point of view, the backend sensors must be implemented to get the appropriate output about the sensors. That's why a number of sensors have been implemented to keep track of all activities of the vehicle.

- Battery Health Monitoring
- Temperature Monitoring
- Near Distance Measurement
- Steering angle Detection
- TPMS
- Vision system implementation using a stereo camera with the help of an artificial intelligence
- Training of AI system
- Object Detection using LiDAR
- GPS implementation and calibration
- UI/UX with the integration of maps

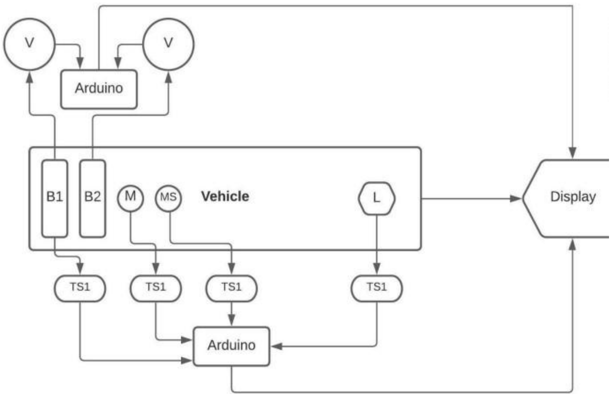

Figure 10 Block diagram of Sensors

For the above block diagram:
V - Voltmeter
B1- Battery 1
B1- Battery 2
M - Motor
MS - Motor Sensor
TS - Temperature Sensor
L - Lidar Sensor
Output at UI (User Interface):

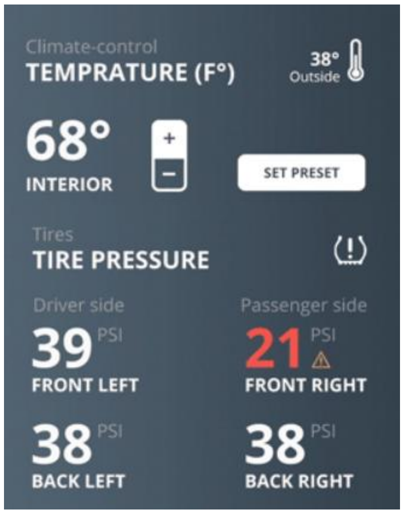

Figure 11 UI Output

Lidar and Camera Implementation and Validation:

From the Vision system point of view, the Lidar and the camera have been implemented on the front side of the vehicle where the lidar can detect the object as well as the camera.

The lidar has 120m of range with 45 degrees of field of view and the camera has 120 degrees of field of view.

Figure 12 Lidar and Camera in action

Sensor Specification:
Range – 120m
Vertical Field of view - 45° (±22.5°)
Points per second - 655,360
Power Draw – 14-20 W
Weight – 447 gm

The Lidar uses lasers to create 3D perceptions of objects, which can then be used for things like object detection and mapping. The camera is being used for getting information about the surrounding. Based upon the output of Lidar and Camera, the CPU will take the decision about vehicle movement (direction, stop, etc).

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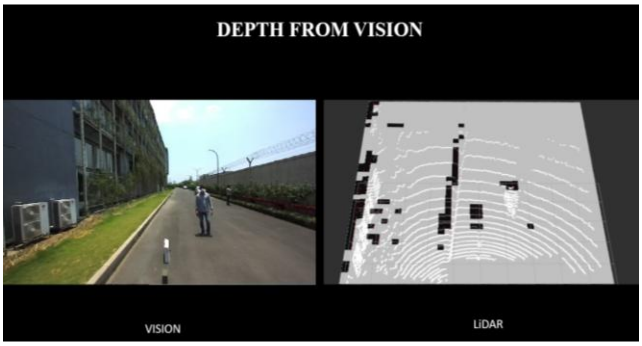

Figure 13 Lidar Object Detection

GPS Implantation and Calibration:

The Global Positioning System (GPS) is a U.S.-owned utility that provides users with positioning, navigation, and timing (PNT) services. This system consists of three segments: the space segment, the control segment, and the user segment. GPS satellites circle the Earth twice a day in a precise orbit.

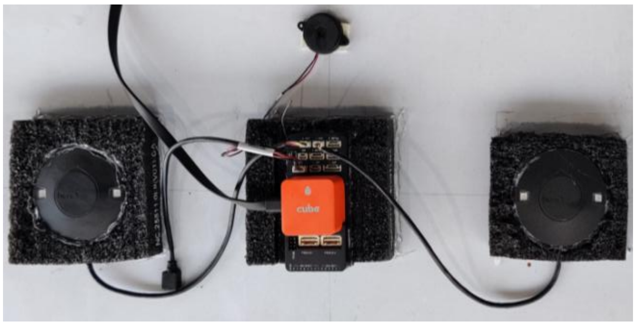

Figure 14 GPS Modules connection diagram

Figure 15 GPS Dashboard

GPS dashboard will display the parameters like real time location, direction, speed, time to reach the destination, and so on.

V. CONCLUSION

The User interface gives ease to the user to interact with the machine by showing all the important data on the display where hardware monitoring can be done very efficiently. AI navigation system helps to allow the coordinates of the location where the GPS signal is denied or unavailable without any human intervention. The vehicle uses different sensors for detecting various parameters and gets a vision of the surroundings where the scope of improvements is still there which can be improved by collecting more data and training the AI system for more precise maneuver of the autonomous vehicle

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AUTHORS PROFILE

Aalhad Satav is an M-Tech student, Dept. of Mechanical Engineering from MIT ADT University, Pune. He has done his M-Tech specialization in Mechatronics & Automation. He has done various institute-level projects relating to his background and completed his 1-year internship in Embedded Systems & Artificial Intelligence.

Nishigandha Patel is working in the capacity of Assistant professor in the department of mechanical engineering at MIT ADT University, Pune. She has completed her M.-Tech in Cryogenics and Vacuum Technology from NIT Rourkela and currently Pursuing a Ph.D. in the area of evaporative cooling. She has a teaching experience of 9 years and industrial experience of 3 years. Her area of interest is Refrigeration, Cryogenics, Hydraulics and Pneumatics, Fluid Mechanics, Thermodynamics, etc.

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