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A low-cost localization method in autonomous vehicle by applying light detection and ranging technology

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ABSTRACT

The autonomous platform uses global positioning system (GPS) to localize the vehicle. In addition, light detection and ranging (LIDAR) and the high precision camera help to identify the turns in the road. The proposed system can help to determine the road turns with higher accuracy without utilizing LIDAR and high-precision camera technology. This research aims to implement a cost-effective simultaneous localization system that can reduce the cost by half for any autonomous vehicle. The existing system is more complex due to the inclusion of LIDAR technology. In contrast, the proposed approach uses beacon communication between vehicles and infrastructure and long-range (LoRa) for vehicle-to-vehicle (V2V) and vehicle to infrastructure (V2I) communication. The simulation result illustrates that the proposed approach provides better performance.

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1. INTRODUCTION

The light detection and ranging (LIDAR) was not introduced in cars until the 2000s. In 2005, during the Grand Darpa challenge, 5 LIDAR sensors were mounted on top of the car along with GPS, accelerometer, and camera. Velodyne was the market leader in LIDAR [1]. David hall from Velodyne has invented 3D based real-time scanning system. In 2007, most of the teams in the Darpa challenge started using LIDAR for 3d visualization. This laid the foundation for the autonomous vehicle. But the, autonomous vehicles are not affordable for public transportation due to their price. It was initially used for competition purposes [2]-[5]. The existing autonomous architecture consists of LIDAR and a high-resolution perception –Localization camera [6]. The major role of LIDAR for localization is to identify the sharp curve turns since the GPS data has accuracy +- 10 meters [7]. Due to the inclusion of many higher-cost components, the autonomous architecture can't be affordable for public transportation [8].

Low-cost vehicular positioning systems that are connected to continuous global coordinates are needed for the independent path planning and movement control of vehicles. A method of position determination that utilizes multi sensors, including a GPS, a camera, and in-vehicle sensors, with the assistance of kinematic and dynamic vehicles. At the beginning, it will reject any image blurring and get eliminate of any erroneous feature correspondences in to ensure the correctness and stability of the visual simultaneous localization and mapping (SLAM) algorithm in the surrounding vicinity. After that, the GPS coordinates are converted to an accurate local coordinate system that may be used for the visual SLAM technique. At the final, an inverse coordinate approach is used in order to determine the position using the global coordinate system. The data from the in-vehicle sensors are combined with the data from the cooperative multiple-model extended Kalman filter by the kinematic and dynamic vehicle models. This is performed to enhance the positioning accuracy [9].

The GPS positioning errors are reason by several components like multipath, impressive delays, clock-offset errors, and signals reflection from adjacent building walls. K-means clustering and quartiles to minimize the mistakes because of it using multipath. In addition, a geometric approach uses a laser range sensor on the top of an autonomous vehicle. It recognizes the reflected GPS signals as accurate for placing errors because of reflections from the building facades. It improves localization accuracy in urban environments [10]. A typical software framework and set of rules for the execution of autonomous vehicles in order to localize and map its locations. The concept behind the automotive open system architecture, which is a standard software platform for automobiles, provides support for the general software platform that is used for localization and mapping. The method of developing software makes use of the execution guidelines provided by the software used for localization and mapping. For the objective of intending the general software platform, localization and mapping graph structure has been applied [11].

The objective of the tracking platform solution for an autonomous vehicles localization programme is to analyze and arrange machine and deep learning methods with the aim of enhancing and achieving the consistency, accuracy, and robustness that is required at low-cost GPS/IMU devices [12]. The objective of cooperative routing is to extend the lifetime of the network and reduce the cost of route detection. To enhance energy efficiency and provide a way to solve the issue of dead nodes, this technique makes use of the fresher encounter algorithm [13].

Commutator for multiple path delays In order to increase both the throughput and the speed, the Fast Fourier transform has been suggested [14]. Satellite-based, radio frequency-based, radio wave-based, optical-based, and sound-based locating technologies are the five categories that make up the classification system for vehicle localization in intelligent transportation method locating technologies. Both technologies that are based on satellites and technologies that are based on cellular networks are occurring as potential solutions to the difficulties that are connected with vehicle positioning. Cellular-based systems can deliver accurate and reliable vehicle localization in an urban setting; they can support non-line-of-sight positioning and offer extensive coverage and high data communication [15]. Satellite-based systems can offer accurate positioning in an open outdoor setting, but cellular-based systems can deliver this in an urban setting. Platform that automatically adjusted itself and explained the self-balancing attitudes. The physical prototype of the self-balancing platform exhibits outstanding balancing accuracy and meets operational requirements despite the platform's simple design [16].

In this paper, we have developed a prototype for two applications. The first application was identifying the road turning using the camera alone. The second application was path following methodology using the Google map application programming interface (API). The environment should have the following setup installed, and the next steps should be followed for the new environment. It consists of an HM-10 beacon module installed at every road corner, turnings, and signal, with a unique address. The autonomous vehicle comprises of Beacon module with the raspberry pi and LoRa for V2V communication. The proposed system has been achieved in the form of a prototype model, which has an HM-10 module and operates at a voltage of 12 volts. By following to the procedures outlined in the flowchart, this entire architecture may be transferred over to any electric vehicle.

2. BACKGROUND OF TECHNOLOGIES BEHIND HIGHER ACCURACY LOCALIZATION IN CLOSED ENVIRONMENT

The closed environment will have a speed limit of 25 kmph (for all vehicles), and adequate lane marking should be established throughout the region [17], [18]. Examples include the surroundings of places like amusement parks, universities, and hospitals. Figure 1 demonstrates the placement of the beacon module in a closed environment map.

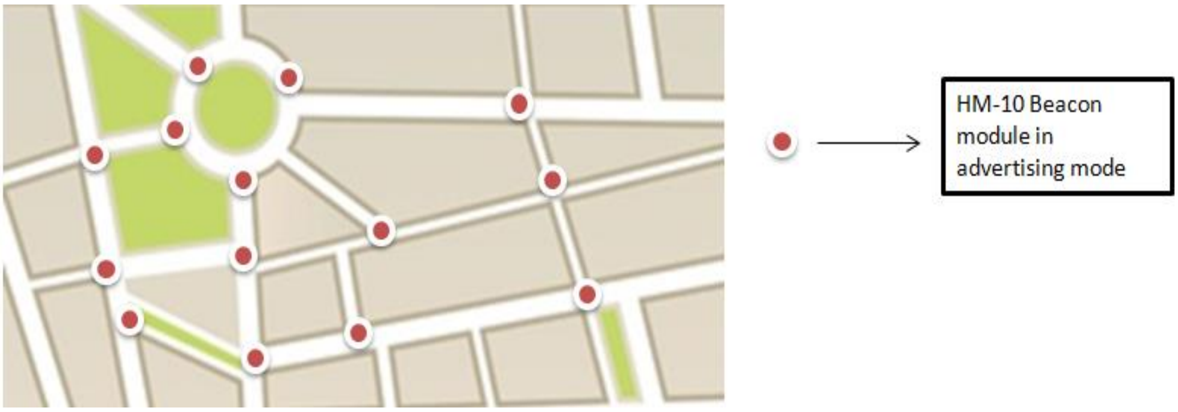

Figure 1. Placement of beacon module in the closed environment map

The HM-10 Bluetooth low energy module is used as a beacon module. It operates at 3.3 volts, and the maximum range is up to 100 meters in open space. It illustrates the placement of the beacon module in every road turnings and meeting point [19]. This module can be operated in standby mode, and with a power supply from a CR2450 battery, the operating life cycle for the battery is around one year. Figure 2 illustrates the steps to configure the HM-10 module as a beacon [20].

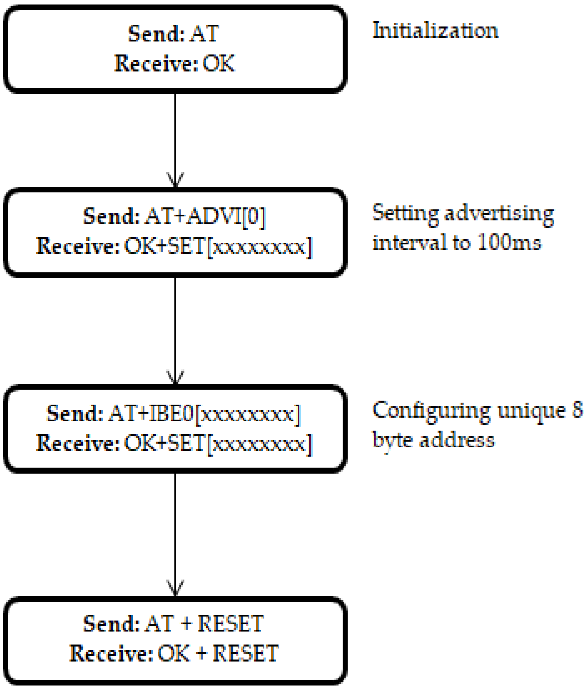

Figure 2. Configuration of HM-10 as Beacon

Every HM-10 module has unique 24 bytes UUID address. These addresses are split into three segments. Every segment is configured by command AT+IBE0 …IBE2. The Raspberry Pi is used as a vehicle controller and has a Google map API package [21]. When the user wants to go to a destination point in a closed environment, the user can enter the destination location in GUI. From Google maps API, the controller receives the path to the destination in JSON format. Figure 3 indicates the JSON format for the goal [22].

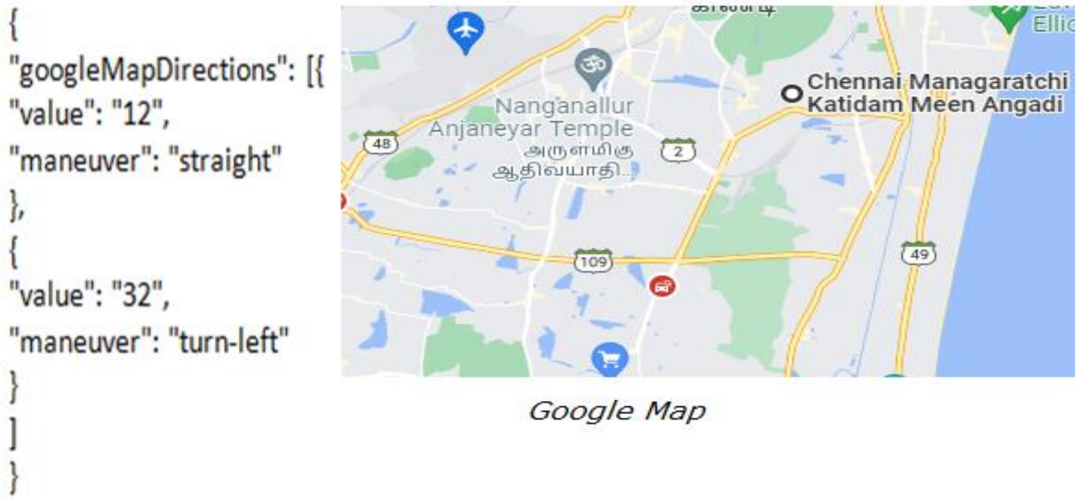

Figure 3. JSON format for the destination from Google maps API

2.1. Algorithm for beacon mapping

Every corner and crevice has a beacon module installed, which sends out its own unique value. At the initially, the vehicle is driven manually while in the learning mode so that the controller can count the specific number of beacons located in each of the corners. When the mapping has been completed in its entirety, the car will be put into an automatic driving mode [23]. Figure 4 shows the learning mode, which allows the observer to monitor the beacon values.

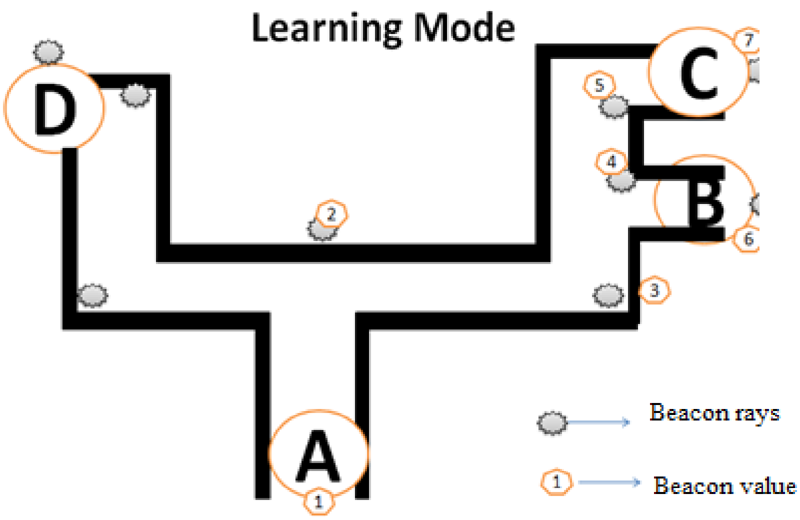

Figure 4. Learning mode to observe the beacon values

2.2. Data fusion between Google maps and beacon module emission

In our research, higher accuracy can be achieved by data fusion between JSON from Google maps API and the beacon module. Figure 5 explains the localization of the vehicle in a normal scenario. Figure 5 denotes the scenario where the vehicle is moving towards the destination point, and it needs to go straight for 44 meters in straight and takes a left turn to reach the destination. Figure 6 Illustrates the data mapping algorithm for a vehicle to reach the destination place [24]. The vehicle has a beacon receiver and transmitter in the corner of that road. The beacon transmitter is in advertising mode and emits a unique UUID number [25].

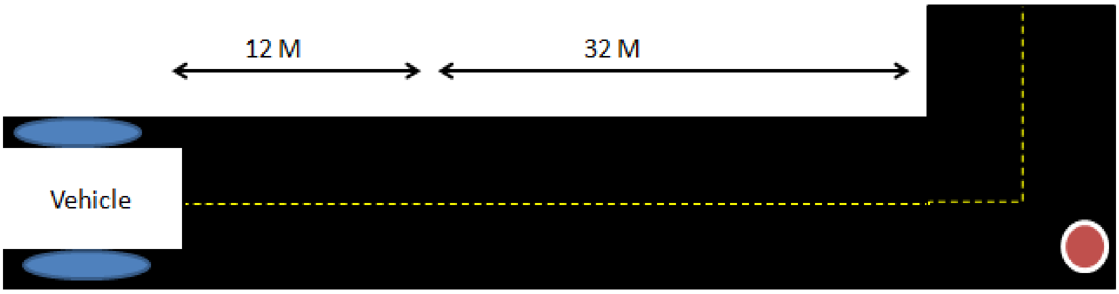

Figure 5. Localization of vehicles in a normal scenario

From the above condition mentioned in figure, the controller receives the destination path data in JSON format like in Figure 6. Since the GPS accuracy is +- 10 meters, the vehicle calculates the distance covered in parallel [26]. From JSON, it parses the first key, where the vehicle needs to move 12 meters straight, and it keeps measuring the distance covered by getting the data from the tachometer. Once it reaches the 12-meter coverage, it processes the following key. The next key denotes that the vehicle needs to turn left after reaching 32 meters [27].

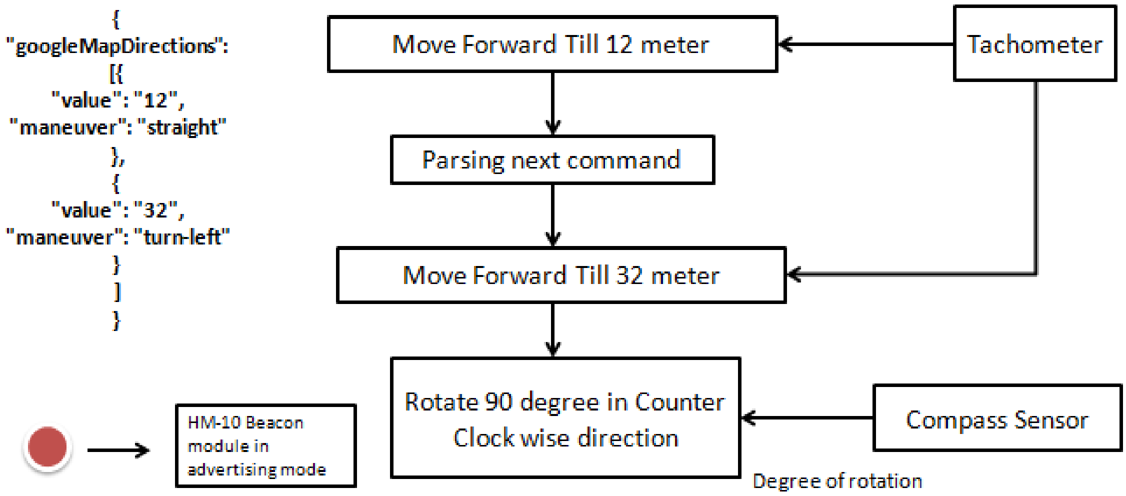

Figure 6. Data mapping algorithm

Once it reaches the turn, it receives the signal from the beacon module. Based on received signal strength indicator (RSSI), it calculates the distance between the vehicle and the beacon transmitter. So, the vehicle will correct the tachometer measurement error and GPS error. Using this method, the vehicle can take a left turn without any failure [28], [29].

3. ARCHITECTURE OVERVIEW

The main objective of sensor fusion in architecture is localization with very less error. The controller is programmed to have a different call thread for each sensor input so that it can be run parallel. Figure 7 denotes the prototype of an autonomous vehicle.

In a closed environment, an electric vehicle station box consists of beacon and GPS with a 32-bit Microcontroller. The station box is installed at various places in a closed environment; the EV server tracks the GPS location of the vehicle. The vehicle moves in automated driving mode with the help of the Beacon. Figure 8 denotes the components present in the prototype model. Raspberry Pi 3 is used as a vehicle controller and is powered by a 5 V power bank. It has eight megapixel Raspberry Pi version 2 cameras. A 10 Amps dual channel motor controller controls the two DC motors.

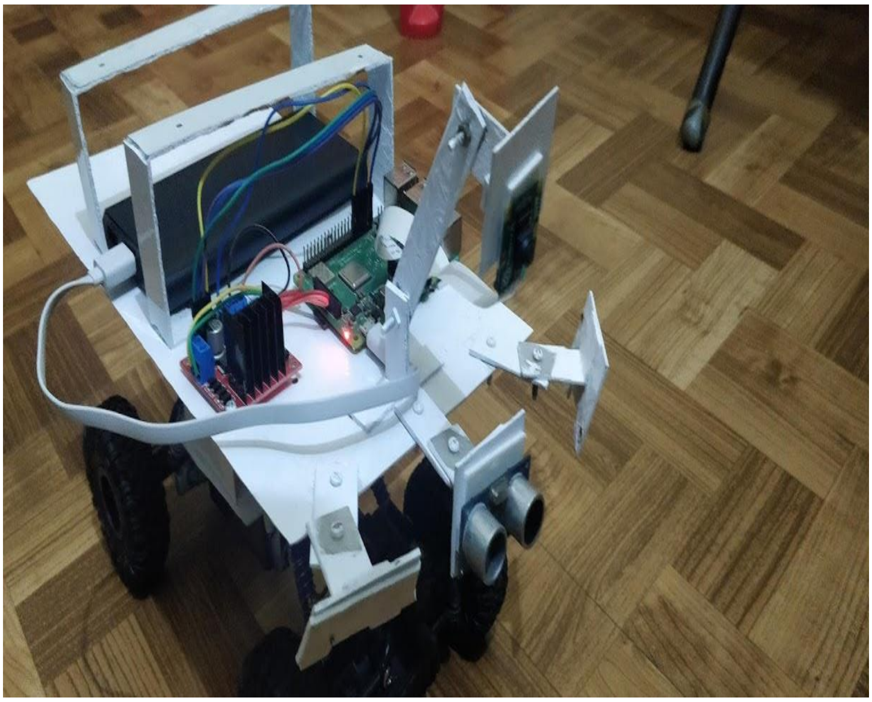

Figure 7. Prototype of autonomous vehicle

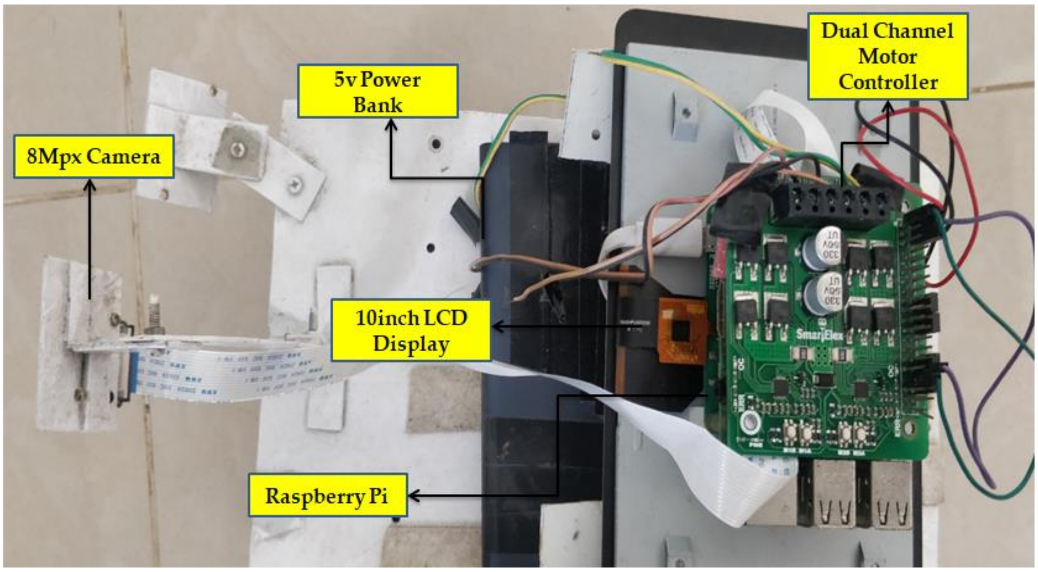

Figure 8. Components in the prototype model

Figure 9 is the complete functional overview of our research. We have simulated each beacon module from the android app. These applications are commonly available in the android play store to transmit data to another Bluetooth module. In a simulation, we have generated a different message with a unique ID that indicates the UUID [30], [31]. Here the master controller is Raspberry Pi 3, and the secondary controller is Atmega 328. The secondary controller measures the distance using a series of ultrasonic sensors. If any obstacle is detected, the secondary controller sends a warning message to the main controller, and based on the various patterns, the main controller takes the decision [32], [33].

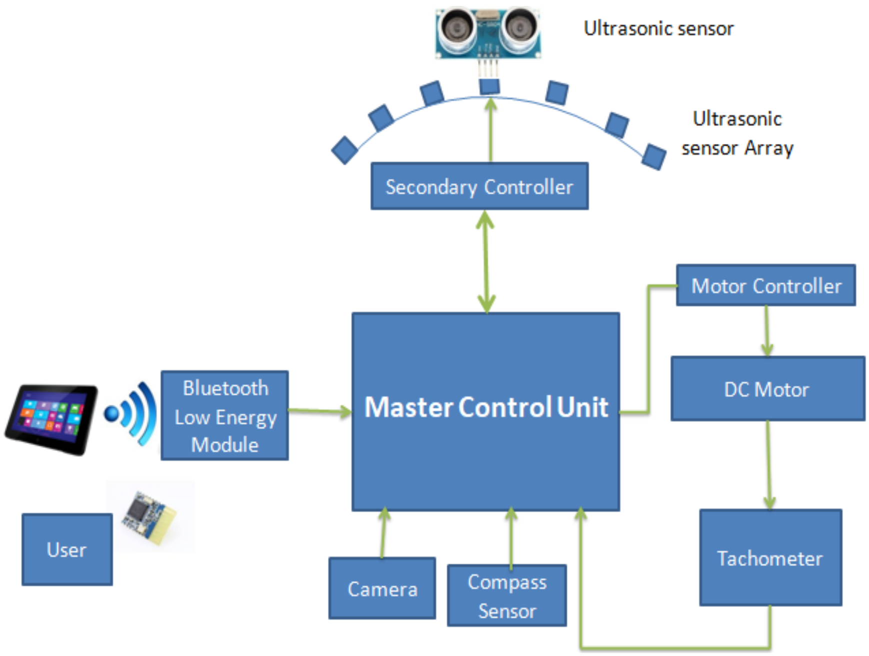

Figure 9. Functionality overview

4. DISCUSSION

In further research, vehicle localization can be implemented in normal road conditions where the number of vehicles will be high and the vehicle speed is limited to 60 kmph, as shown in Figure 10. V2V communication and vehicle-to-infrastructure communication is implemented across the region to make faster response. V2V communication and rearview cameras shall be made mandatory to achieve a cost-effective autonomous architecture in normal conditions [34]. The Raspberry Pi will not be sufficient for processing the image at a higher speed rate. Processors like Nvidia Jetson should be used instead of raspberry. Table 1 represents the comparison between the three processors. Based on GPU capability, the processor should be decided.

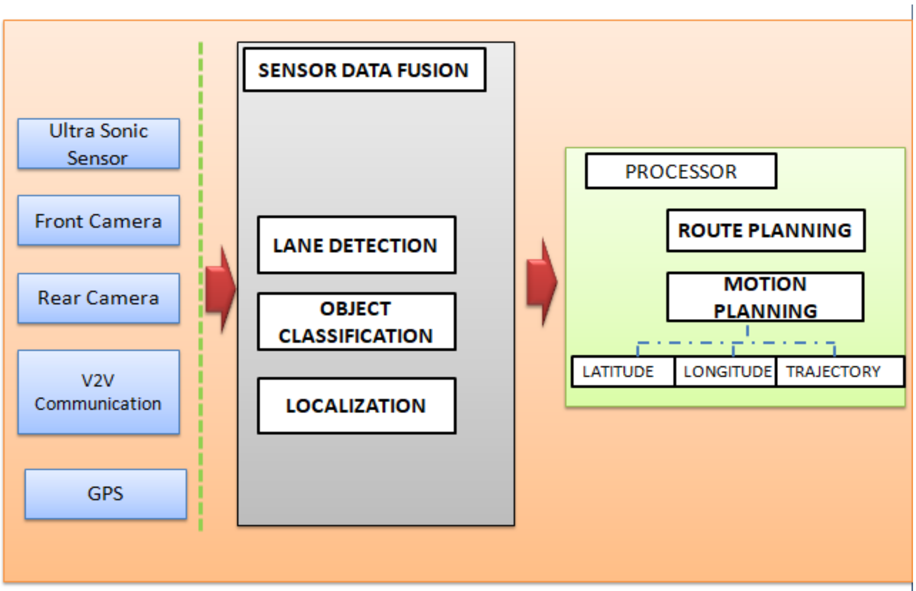

Figure 10. Architecture overview for vehicle speed limited to 60 kmph

Table 1. Processor comparison

Parameters	Rock Pi N10 (Model A/B/C)	Raspberry Pi	Jetson Nano
CPU	Quad-Cortex-A72@1.8 GHz & quad-Cortex-A53 1.4 GHz	Quad-ARM Core-A72@1.5 GHz	Quad-ARM Cortex-A57 64 bit@1.42 GHz
GPU	Mali T860MP4	Broadcom VideoCore VI(32-bit)	NVIDA Maxwell w/128 CUDA cores @ 921 Mhz
NPU	3.0 TOPS computing power	-	-
LPDDR	4/6/8 GB LPDDR3	4 GB LPDDR4	4 GB LPDDR4
eMMC	16/32/64 GB eMMC5.1	-	-
Networking	Gigabit Ethernet only	Gigabit Ethernet only / Wi-Fi 802.11ac	Gigabit Ethernet only/M.2 key E(for Wi-Fi support)
Display	HDMI 2.0	2xmicro-HDMI(up to 4Kp60)	HDMI 2.0 and eDP1.4
USB	1xUSB 3.0,2xUSB 2.0	2xUSB 3.0,2xUSB 2.0	4xUSB 3.0,USB 2.0 micro-B
Video Encoder	H.264(1080p30) and VP8	H264(1080p30)	H264(H.265(4Kp30
Video Decoder	H.265(4Kp60) H.264(1080p60) VC-1,MPEG-1/2/4,VPS	H.265(4Kp60) H.264(1080p60)	H.264/ H.265(4Kp60,2x4Kp30)

Table 2 represents the average cost of LIDAR technology implemented in the autonomous vehicle. Where the proposed low-cost localization will cost around 500$ to implement in 50 Street turns in an area. This implementation cost is for the infrastructure, not for the individual car. So, this will be marginally less in an autonomous vehicle.

Table 2. Average cost of LIDAR

LIDAR model	Channel	Range(m)	Data Rate	Cost($)
Velodyne LIDAR- HDL64	64	100-200	13,00,000	75,000
Velodyne LIDAR- HDL32	32	80-100	7,00,000	35,000
Velodyne LIDAR- VPL16	16	100	3,00,000	8000

5. RESULTS

To test the efficiency of our proposed method, we placed the HMC5883L module on top of the prototype and recorded the angle in the degree unit. The HMC5883L is an I2C interface type, so we collected the data through the I2C bus and saved it with a timestamp. Initially, we drove the prototype in manual mode and collected the data. Then we changed to autonomous mode and collected the data in the same format. Figure 11 shows the deviation between the autonomous mode and manual mode. The graph clearly shows the variation is less than +-5%.

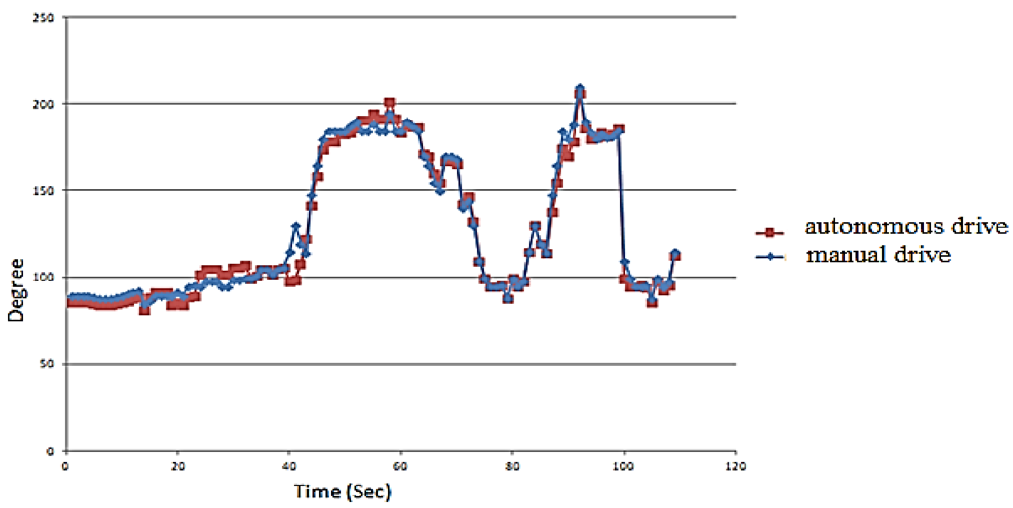

Figure 11. Compass reading between manual and autonomous mode

6. CONCLUSION

This paper presents an autonomous driving architecture with higher accuracy curve detection that helps to avoid unnecessary turns and accidents with low-cost implementation. This architecture can be ported into any existing electric vehicle model by implementing a standard beacon module in every street corner and using Raspberry Pi 3 with an 8 mpx camera for lane detection. Only the motor controller has to be connected with the existing motor controller in an Electric vehicle this system would benefit the end users like Industries, university campuses, and amusement parks. The technology used in a vehicle supports green transportation with affordable cost in public transit. The results demonstrate the deviation between autonomous mode and manual mode, and it clearly shows the variation is less than +-5%.

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