Internet of Things 18 (2022) 100213

Contents lists available at ScienceDirect

Internet of Things

journal homepage: www.elsevier.com/locate/iot

An IoT-enabled intelligent automobile system for smart cities

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ARTICLE INFO

Article history:
Received 19 August 2019
Revised 9 March 2020
Accepted 29 April 2020
Available online 3 June 2020

Keywords:
Artificial intelligence
Intelligent automobile system
Internet of Things
Smart Cities
Smart System

ABSTRACT

In our world of advancing technologies, automobiles are one industry where we can see improved ergonomics and feature progressions. Artificial Intelligence (AI) integrated with Internet of Things (IoT) is the future of most of the cutting-edge applications developed for automobile industry to enhance performance and safety. The objective of this research is to develop a new feature that can enhance the existing technology present in automobiles at low-cost. We had previously developed a technology known as Smart Accident Precognition System (SAPS) which reduces the rate of accidents in automobile and also enhance the safety of the passengers. Current research advances this technique by integrating Google Assistant with the SAPS. The proposed system integrates several embedded devices in the automobiles that monitor various aspects such as speed, distance, safety measures like seatbelt, door locks, airbags, handbrakes etc. The real-time data is stored in the cloud and the vehicle can adapt to various situations from the previous data collected. Also, with the Google Assistant user can lock and unlock, start and stop, alert and do various automated tasks such as low fuel remainder, insurance remainders etc. The proposed IoT enabled real-time vehicle system can detect accidents and adapt to change according to various conditions. Further, with RFID keyless entry authentication the vehicle is secure than ever before. This proposed system is much efficient to the existing systems and will have a great positive impact in the automobile industry and society.

1. Introduction

The automobile industry is in a path of technological advancement. The latest cars have advanced security features, but they are costly. So, the common man who can afford low-end automobiles needs to compromise on the latest features such as advanced safety, voice commanding, connected cars, etc. Due to this, road safety and user-friendliness are decreasing, which is having a substantial adversarial impact on our society [1–2]. Further, physically disabled people find it very difficult to use facilities in a budget car. If we take a closer look, most brutal accidents happen with low-end car users. Also,

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https://doi.org/10.1016/j.iot.2020.100213
2542-6605/

most of the luxurious advantages that connected car owners experience is not enjoyed by common car owners. And voice commanding is still a dream for a common man. No live feed details are displayed in budget cars. Also, in existing budget cars, there are no applications available to see car diagnostics or for controlling the lane collision detection system [3].

The primary objective of this research is to develop a new feature that can enhance the existing technology present in automobiles at a low cost. Nowadays, every budget car owner has smartphones. The proposed method utilizes the advantages offered by the Google Assistant available in smartphones and integrates it with the automobile system. The proposed system consists of embedded devices in automobiles connected to the Internet that will continuously monitor various aspects such as lock, AC status, media, headlights, wiper, etc. The significant advantage of the proposed system is in its lower cost of development and deployment, which would enable low-end car users to enjoy these advanced features.

We have already developed a previous system, Smart Accident Precognition System (SAPS) that reduces the chances of accidents in automobile and also enhance the safety of the passengers. SAPS system consists of an ultra-sonic based obstacle detector in the vehicles. This sensor detects the distance to an object (maybe another vehicle on the road) and reduces the speed of the vehicle if the distance falls below a certain set threshold, which prevents accidents. The proposed method is integrated into this technology and offers much better results. The new system integrates the Google Assistant with SAPS. Using the advantages offered by Internet of Things, the entire system is connected via the Internet, and this technology will have a tremendous impact on the society. Devices embedded in the system will continuously monitor the automobile's aspects such as speed, distance, safety measures like seatbelts, door locks, and media unit, etc. The real-time data is stored in the cloud, and the vehicle can adapt to various situations from the previous data collected. Also, with the Google Assistant, user can lock and unlock, start and stop, alert and, do various automated tasks such as low fuel remainder, insurance remainders, etc. Further, with RFID keyless entry authentication, the vehicle is secure than ever before. The contributions of this research can be summarized as,

- An efficient, low-cost system using SAPS and Google Assistant technology along with smartphones for advanced safety, voice commanding, networking in automobiles.
- An effective accident prevention system using ultra-sonic based obstacle detector.
- Automated system with user application to check real-time conditions of the car and to control it according to need and desire.
- Secure system with authentication provided by the combination of RFID tag value and intelligence data from sensor.

The paper is organized as follows. Section two describes the background and the related works with initial investigation, facts and figures and, design specifications. Section 3 presents the proposed system with the methodology used and the working of the system. Theoretical analysis of the system is also discussed in this section. Discussion of results is presented in the next section. Finally, the paper concludes in Section 5.

2. Background and related works

2.1. Initial investigation

Initially, a survey was conducted on smart features and facilities in automobiles and some of the existing technologies. One such electronic system allows the vehicles to reduce speed while approaching another vehicle and accelerate again to the preset speed when traffic is cleared. It also warns the driver and brake if there is a high risk of a collision. This is a microcontroller based automatic vehicle speed control system. Nowadays, it is observed that a significant number of accidents happens in highways. Most of the accidents are due to the drivers' mistake. To avoid this situation, an adaptive cruise control system which consists of an ultra-sonic based obstacle detector was developed. Whenever the system detects the obstacle automatically, speed will be reduced, and when the distance of the obstacle increases automatically, speed gets increased. Also, the driver doesn't need to give acceleration and the break, which is entirely controlled by the system [4]. The study also analyzed the safety impacts of this system [5 6]. The research also studied the positive features of some of the latest existing systems that provided the necessary background towards the development of the proposed technology [7–16]. After investigating through the current systems, it is found that there is enormous scope and opportunity to the economically smart vehicle theme proposed in this paper. Further, there are also numerous opportunities to enhance the existing smart system.

2.2. Facts and figure

According to the latest survey, the number of smartphone users in India is 337 million. The number of smartphone users is increasing at a faster rate and, if this trend continues, it is estimated to reach 800 million by 2022 [17-18]. This marks a 60% increase in users. Fig. 1 shows the smartphone user statistics.

Also, in 2015, there were about 5 lakh road accidents in India, which killed about 1.5 lakh people. Road accidents are not decreasing, even though strict traffic rules were implemented. The first quarter of 2018 shows a 1.68% rise over the corresponding previous quarter. Low-end car users suffer most of the accidents. Such budget cars don't have advanced safety features such as collision detection system. Fig. 2 shows the road accident statistics. The number of road accidents per lakh population has been increasing since 1970, with an 84% increase from 1980 to 1990

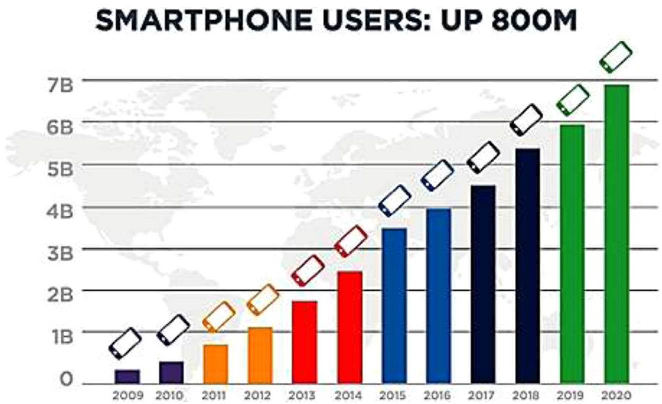


Fig. 1. Smartphone users' statistics [19].

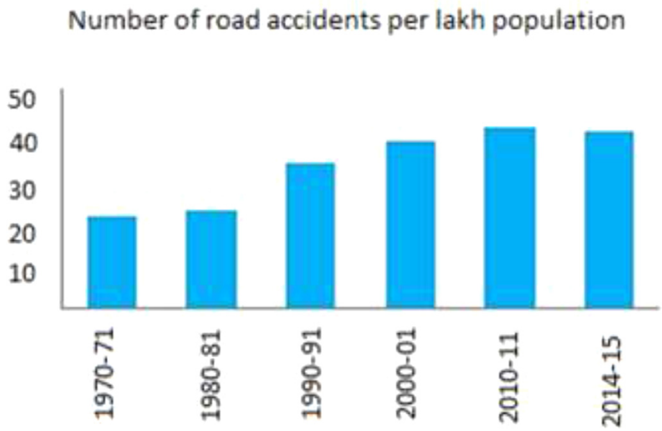


Fig. 2. Road Accident Statistics [20].

2.3. Technology and design

Some of the existing systems utilize the significant advantages offered by the voice recognition technology through which automobile systems are controlled remotely or autonomously using controllers and sensors embedded on them [21-24]. In our proposed system, a vehicle that can be controlled by voice commands via smartphone using Arduino Mega processor and Bluetooth sensor is developed. The Google Voice and VoiceBot [25–27] application is used for voice commands. Since, Bluetooth is a short-range technology, its application is not suited in the current system. In order to provide a real-time response, better technology than Bluetooth is required. So, Internet of Things (IoT) technology [28–31] is the next best option. Many IoT based efficient schemes have been proposed for advanced sensing with security in vehicles and vehicular networks [32–35]. The proposed system needed automation in order to make the vehicle smart. One of the automation technologies that existed was based on a web service called IFTTT [36]. This technology currently used in-home automation [37] and is quite efficient in our proposed system. All the above-mentioned technologies along with applications from Artificial Intelligence (AI) and IoT with real-time data base is combined to form a unique product which satisfies the needs of low-end car users.

The study on IFTTT includes some interesting areas that can be presented with role-application-security models. Current technology adapts some existing models mainly for automation systems of home. Our proposed framework is completely different from the past frameworks as per the integration of a simplified core script and a collection of trigger/action scripts. In fact, our proposed prototype integrates Google App Engine platform, a Raspberry Pi board, and the Arduino boards as I/O units.

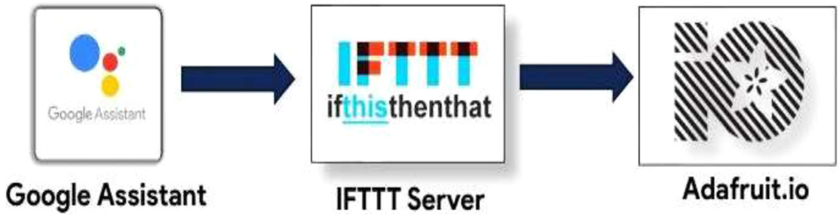


Fig. 3. Block diagram of working at user end.

3. Proposed System

3.1. Methodology and working

This section discusses the methodology used by the proposed system. Fig. 3 presents the block diagram of the working of the system at the user end.

The basic block used in our project consists of three main components at the user end. The first component is Google assistant, which is a virtual assistant powered by artificial intelligence. It is developed by Google and mainly available on mobile and smart home devices. The company previously had a virtual assistant called Google Now. But it doesn't support a two-way conversation. Here, Google Assistant can engage in two-way conversations. Assistant was introduced initially in May 2016 with Allo, which is a messaging app of Google and its voice-activated speaker Google Home. First, it was deployed on Pixel and Pixel XL smartphones. Later it was used on other Android devices in February 2017, including third-party smartphones and Android Wear (now Wear OS), and was released as a standalone app on the iOS operating system in May 2017. The software development kit was announced in April 2017. Along with this, the Assistant was developed and extended to support various devices such as cars and third-party smart home appliances. Third-party developers can enhance the functionality of the Assistant. Google Assistant was installed over more than 400 million devices by 2017. Thus, this feature is available in almost all the smartphones, and an extra purchase is not required by common users.

In step 1, the Google Assistant is activated by an initial command of "Hey Google" or "OK Google". Then the instruction is given to Google Assistant by the user through previously saved command. This is recognized by Google Assistant and is sent to IFTTT server. IFTTT (IF THIS THEN THAT) is a free web-based service to create applets. IFTTT server lets us exchange data between multiple applications. It can also make changes in other applications based on the values and command of another connected app. In step 2, IFTTT receives the data from Google assistant and transmits a trigger data based on the command to Adafruit.io. Adafruit.io is a cloud service it is meant primarily for storing and then retrieving data. In step 3, the stored value in adafruit.io changes when the trigger data is received. This data is stored such that it can be retrieved upon connection to the internet and the changes can be read by the Node MCU. In step 4, Node MCU constantly observes for changes in the values in Adafruit.io, when the value in Adafruit.io changes Node MCU reads this data and perform the corresponding saved action in the vehicle and thus the action desired by the user is completed. In step 5, along with performing the desired actions Node MCU also updates the value in firebase server. Sunil-Auto, the application installed in the user's phone is set to read and display readings and corresponding values in firebase. Thus, the user can check real-time conditions of the car and control it according to desire.

Authentication and security are another major area of concern in vehicles, and most of the low-end cars don't enjoy high-security features [38-39]. In the proposed system, the combination of RFID tag value and intelligence data from the sensor improves the authentication. A corresponding authentication key is generated using a predictive decision system enabled with predefined authentication factor and intelligence information. The predictive decision system is enabled with passive class 2 RFID tag, considering various factors like sensor values, RFID Tag value with personal data, intelligence and, decision-making system. The intelligent authentication agent uses the sensors values for decision making. The node MCU manages the intelligent agent and RFID reader to generate the authentication key. The authentication key generation is done by combining intermediate steps in the Advanced Encryption Standard (AES) algorithm. The AES algorithm used is 14 round and 256-bit symmetric key size. The authentication key will have RFID Tag value, sensor value, environment and event information enabled with AES encryption. This logical combination is mapped into a standard format to generate the authentication key for adaptive authentication. The three-technology predictive decision system, RFID and AES encryption are combined together for the generation of the encrypted key. The functionality of each component is specified below. The passive type 2 RFID tag consists of tag number and personal information. The intelligence and sensor values are extracted, and a sensor array is formed. The sensor array and RFID tag are combined to make the decision on the generation of the key. The node MCU will have the movement information, and it generates the authentication key by combining it with sensor array. Assume an environment when RFIID user having the passive RFID tag is under surveillance with the RFID reader. The RFID reader is scanning the user periodically and keeping track of the users' movements. The objective is to combine the AES encryption with their free movement. Consider a matrix of G for the active tag in the restricted boundary as

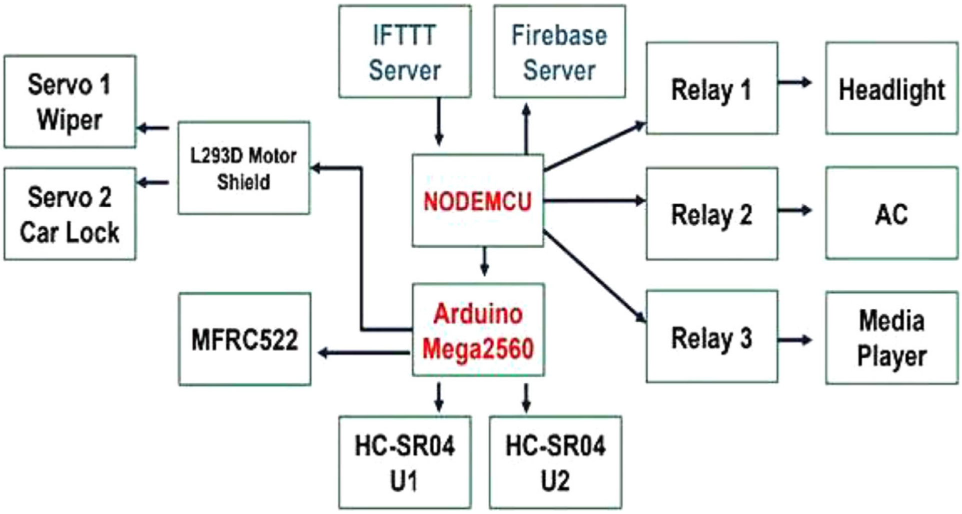


Fig. 4. Hardware block diagram (with embedded devices) of the proposed system.

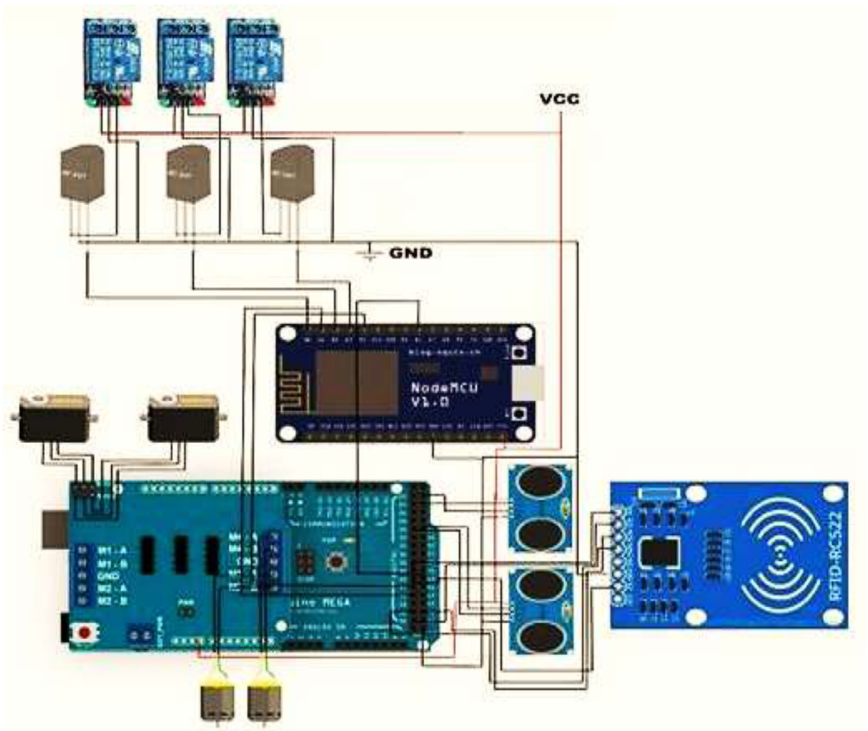


Fig. 5. Circuit diagram of the proposed system.

G={G1,G2……Gn}. The RFID tags are having individual information and sensors value *R*={R1,R2,…..Rn}. The AES encryption algorithm combined with the G and R matrix generates the ROUND KEY and SMART KEY and authentication key.

3.2. Hardware and circuit modules

Fig. 4 shows the Hardware block diagram (with embedded devices) and Fig. 5 shows the circuit diagram of the proposed system

In this circuit, the following components are used; Arduino Mega 2560, NodeMCU ESP8266, HCSR04 Ultrasonic Sensors, MFRC522 RFIDN Reader, Relays, Servo Motors, Gear Motors a Motor Shield (L293D). The NodeMCU is connected to the Adafruit.io and the Firebase Server. All the commands are given using the Google Assistant in the phone and modifying the

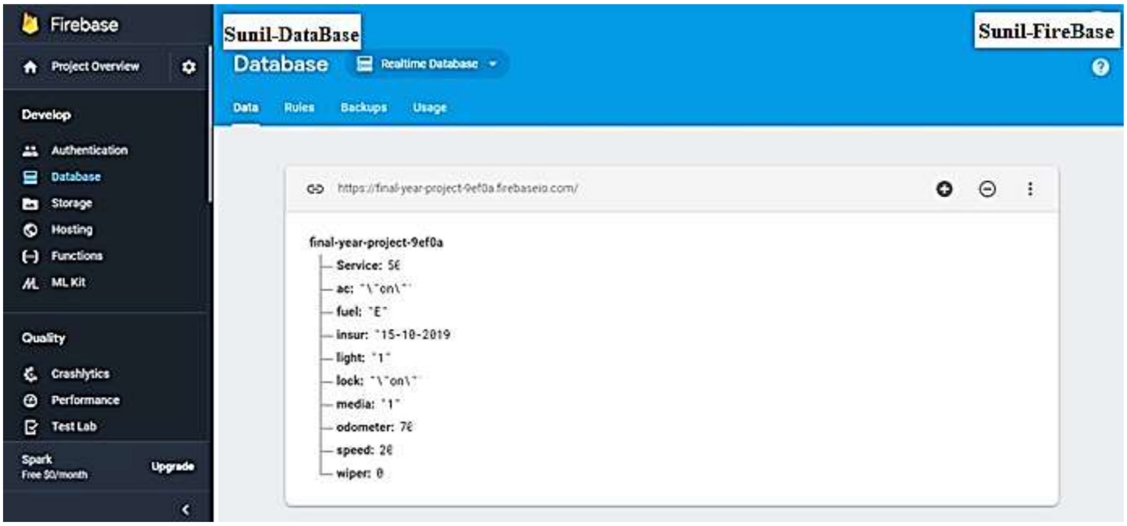


Fig. 6. FireBase console: real-time data entries in the firebase database.

Table 1
Real-time database details of fields.

Fields	Data provided by
service	Car Manufacturer
ac	Adafruit.io
fuel	NodeMCU
insur	Insurance Company
light	Adafruit.io
lock	Adafruit.io
media	Adafruit.io
odometer	NodeMCU
speed	Android App Via GPS
wiper	Adafruit.io

Table 2
Real-time feed details of Adafruit.io server.

Feed Name	Data Provider
ac	Google Assistant
light	Google Assistant
lock	Google Assistant
media	Google Assistant
wiper	Google Assistant

data in Adafruit.io server. The NodeMCU continuously monitors the data feeds in the adafruit server and responds to any data change. This node is directly connected to relays that can activate the headlight, AC, media player, etc. on command. Also, the node is communicating with Arduino Mega that transmits data in order to control door lock/unlock, wipers, etc. Once any change is made in the server of the adafruit, the node rewrites the data in the firebase server.

The Arduino, on the other hand, is controlling the motors via the motor driver. The motor is used to move the vehicle around. Also, the RFID authentication service is handled by the Arduino. The two HCSR04 ultrasonic sensors connected to the board calculates the distance of the vehicle in front and back. When the board receives a trigger from the NodeMCU, the board does the respective action. There are two servos used in the project representing the wiper and door lock system. These are triggered when the command is given using the google assistant. The entire system works using 12 V supply. Fig. 6 presents the Fire Base console with real-time data entries in firebase database.

Table 1 presents the real-time database details of the fields. Fig. 7 shows the real-time feed updating in the Adafruit.io server. And table 2 also shows the real-time feed details of the Adafruit.io server.

Fig. 8 presents the Blocks of the proposed application in the Android App with Thunkable.com and Fig. 9 shows the screenshot from the developed application.

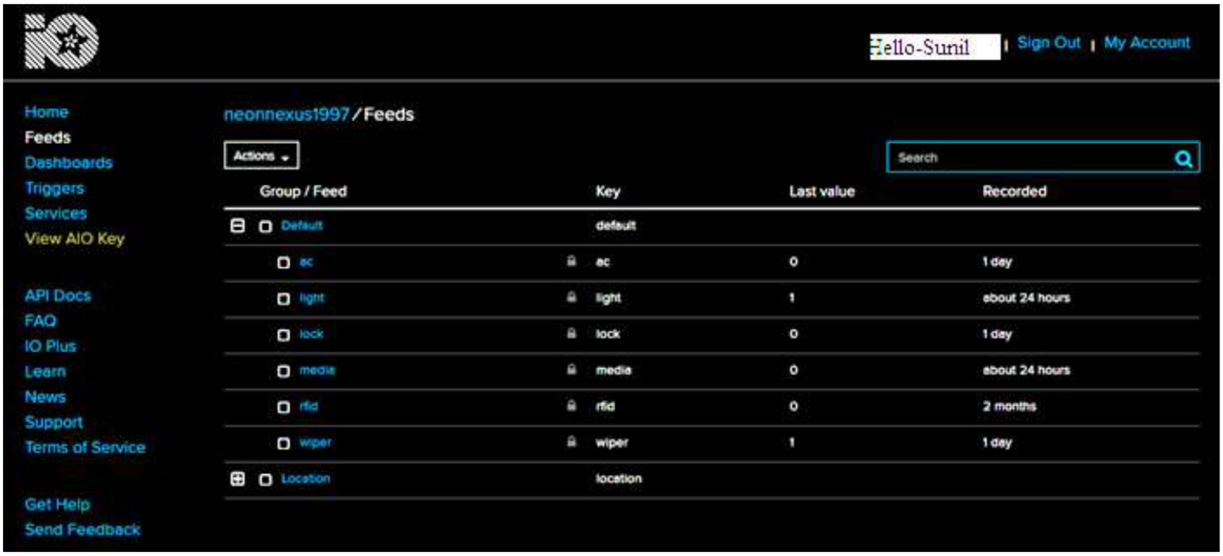


Fig. 7. Real-time feed updating in Adafruit.io server.

Table 3
Commands for Google Assistant and its actions.

Applet Google Assistant Command	Task Performed
car unlock, unlock car, unlock	Data ‘1′ is Saved in Adafruit.io feed lock
doors lock, lock doors, car lock	Data ‘0′ is Saved in Adafruit.io feed lock
turn on ac, ac on, switch on ac	Data ‘1′ is Saved in Adafruit.io feed ac
turn off ac, ac off, switch off ac	Data ‘0′ is Saved in Adafruit.io feed ac
turn on media, media on, switch on media	Data ‘1′ is Saved in Adafruit.io feed media
turn off media, media off, switch off media	Data ‘0′ is Saved in Adafruit.io feed media
turn on wiper, wiper on, switch on wiper	Data ‘1′ is Saved in Adafruit.io feed wiper
turn off wiper, wiper off, switch off wiper	Data ‘0′ is Saved in Adafruit.io feed wiper
turn on headlight, headlight on, switch on headlight	Data ‘1′ is Saved in Adafruit.io feed light
turn off headlight, headlight off, switch off headlight	Data ‘0′ is Saved in Adafruit.io feed light

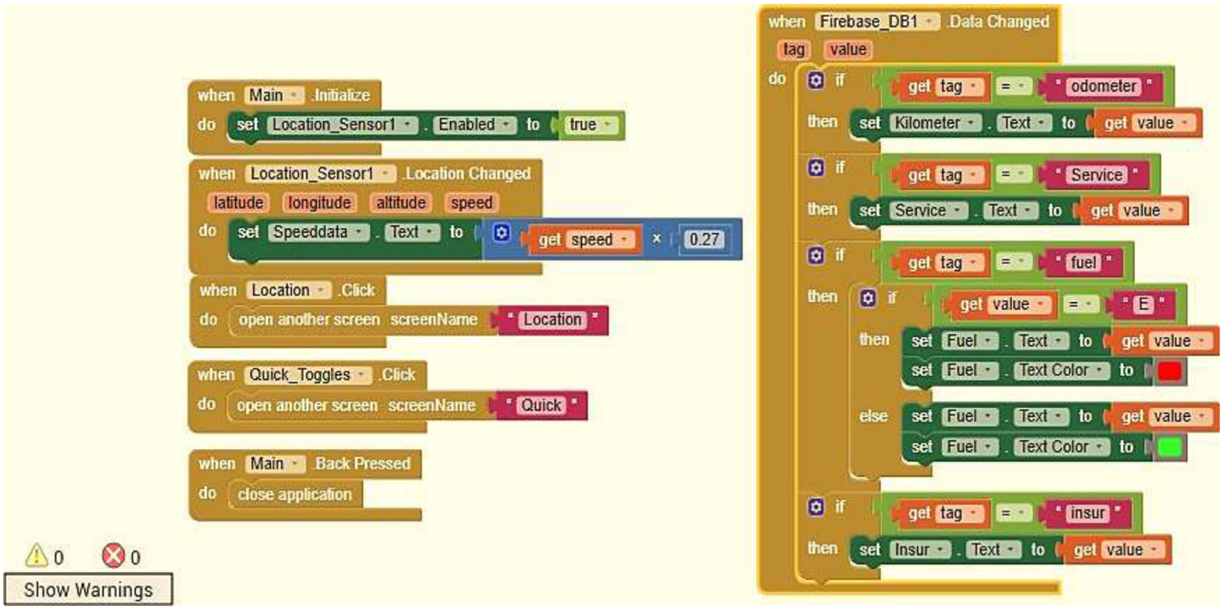


Fig. 8. Blocks of the proposed application in Android App with Thunkable.com.

Table 4
Comparison of the proposed system with existing systems.

System	Purpose	Node power	Protocol used	Communication	Mobility
BIADAS [2]	The parameters of interest are sensed in the environment and object under test	Source Sensor node, Relay and destination node (500mw)	Wi-Fi, ZIGBEE	Multi-hop delayed control	Sensor nodes are dynamic and tracking is difficult
REISE [3]	The tag object presence is detected	Source Sensor node, Relay and destination node (450 mW)	Wi-Fi, ZIGBEE	Multi-hop delayed control	Sensor nodes are static and tracking is instant
IMVC [4]	The tag object presence and location are detected	Source Sensor node, Realy and destination node(480mw)	Wi-Fi, ZIGBEE	Multi-hop delayed control	Sensor nodes are static and instant tracking
LSICACC [5]	The parameters of interest are sensed in the environment and object under test	RFID Tags and readers (50mw)	RFID Standard	Single-hop instant/intermediate control	Sensor nodes are static and instant tracking
Proposed System	The tag object presence, location, parameter of interest is sensed in the environment and object under test	RFID Tags and readers (10mw)	RFID standard	Single-hop instant control	Static/dynamic with respect to the attached object and instant tracking

Fig. 9. Screenshot of the application (Sunil-Auto-App).

3.3. Theoretical analysis

Let us assume that the relays and motor shield is driven by voltage of small-signal bias. The voltage of small signal is sinusoidal and have an angular frequency 'w'. In steady-state mode all the signals the relays will have same nature with same frequency. The voltage and current for the small-signal will be represented by a cosine function.

$$v_{R-S}\ (t) = \ K_{v_{R-S}} \cos\left(wt + \emptyset_{v_{R-S}}\right) \tag{1}$$

For the phasor representation of voltage & current of small-signal. The angle of magnitude is mapped to the phase and amplitude.

$$V_{R-S}\ = K_{v_{R-S}}\ e^{j\emptyset} V_{R-S} \tag{2}$$

We are interested in finding the effect of V_{R1}, $V_{R2,}$ V_{R3} & $V_{M\text{-}S}$ on the current $I_{R\text{-}3}$. There can be four possibilities. We will consider V_{R3} a small-signal voltage by keeping all the remaining three equals to zero. We can do the same operation by keeping other voltages as constant. In any possibility, the ratio of current phasor & voltage phasor is a complex admittance.

The small-signal circuits are linear. The amenities of I_{R1}, $I_{R2,}$ I_{R3} & $I_{M\text{-}S}$ are linear functions of V_{R1}, $V_{R2,}$ V_{R3} & $V_{M\text{-}S}$. We can use superposition theorem to find I_{R3}. This can be done by assuming one voltage as active & evaluating the total current.

$$\begin{aligned} I_{R_3}\ &= \ I_{R_3}\ \Big|\ _{V_{R_1}\ ,V_{R_2}\ ,V_{R_3}\ =\ 0} + \ I_{R_3}\ \Big|\ _{V_{R_2}\ ,V_{R_3}\ ,V_{m-s}\ =\ 0} + \ I_{R_3}\ \Big|\ _{V_{R_3}\ ,V_{R_{m-s}}\ ,V_{R_1}\ =\ 0} + \\ & I_{R_3}\ \Big|_{V_{R_3}\ ,V_{R_{m-s}}\ ,V_{R_1}\ =\ 0} + I_{R_3}\ = Y_{R_3\ R_3}\ V_{R_3} + Y_{R_3\ R_1}\ V_{R_1} + \ Y_{R_3\ R_2}\ V_{R_2} + Y_{R_3\ R_{m-s}}\ V_{m-s} \end{aligned} \tag{3}$$

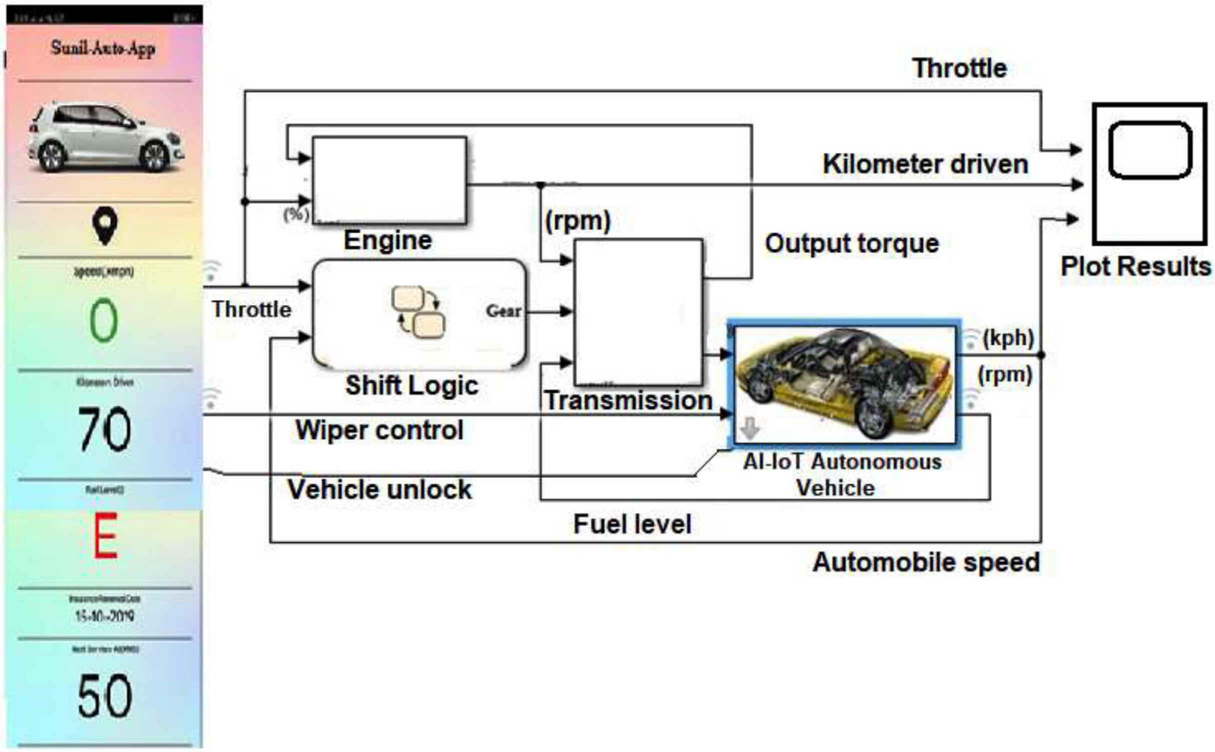


Fig. 10. Overview of the implemented system.

A similar analysis can be done to find the current through the remaining relay and motor shield. Where

$$Y_{KR} = \frac{I_k}{V_{I_R}} \mid V_m = 0, \; m \neq R| \quad (4)$$

4. Results and discussion

The proposed design was successfully implemented by integrating multiple internet services and applications to create a device with minimal hardware and maximum adaptability for modern cars. This section presents a discussion on the results obtained.

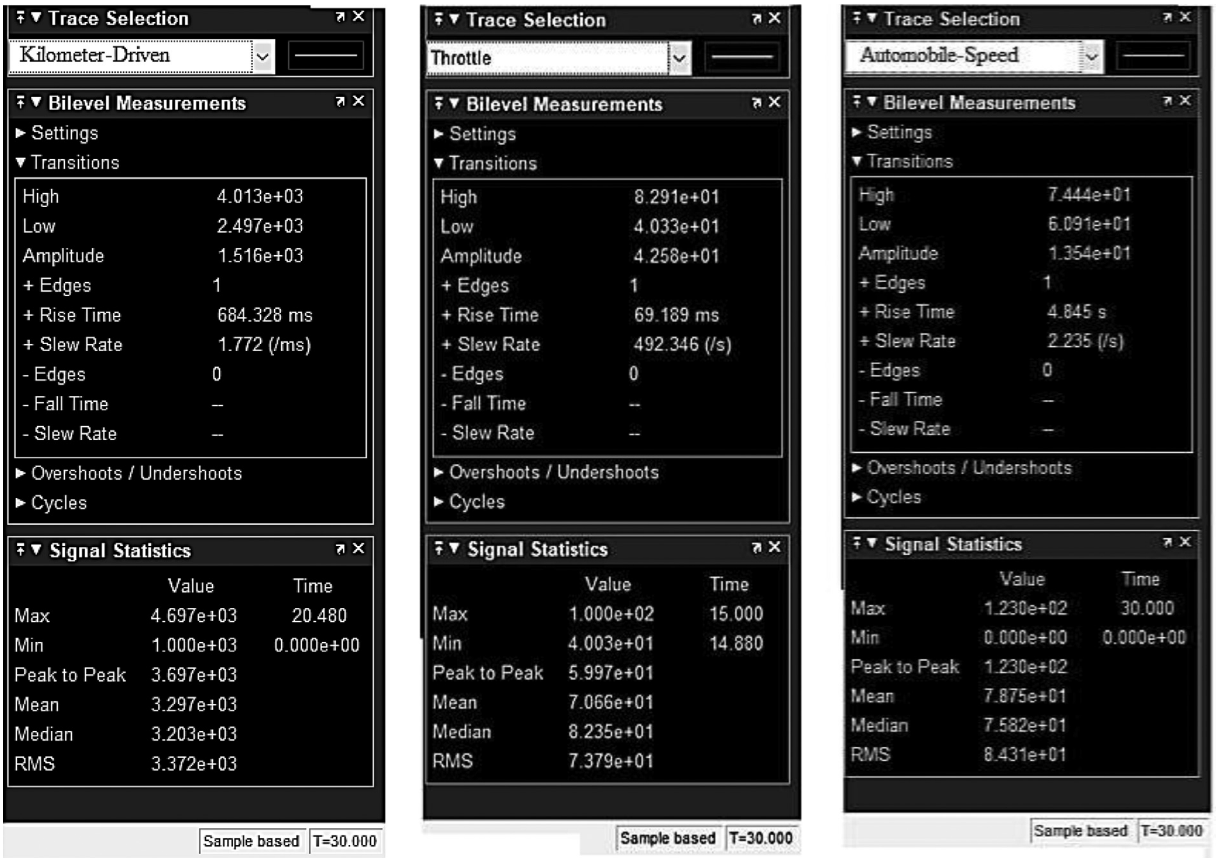
The following four objectives were satisfied with the current product,

- Voice Command Using Google Assistant: The actions of the car can now be controlled by just your voice remotely, whether you are in or out of the vehicle. Further, as Google Assistant has voice recognition, it also provides security to some extent.
- Live Vehicle Details on the Go: Real-time conditions of the vehicle like current location, fuel level, service updates on the user's smartphone. Sensors connected to different parts of the car keeps updating the status on a real-time basis and can be seen in the app
- In Lane Collision Detection: Accident prevention with safety of the passengers and speed control of the vehicle ensured.
- Security: As security is one of the most concerning factors, the lock and ignition are connected to personalized keycards and the real-time position and condition can be seen in the smartphone application.

Fig. 10 presents the overview of the inputs, outputs and working of the implemented system. The current research has implemented the capture of throttle, kilometer driven (drove) and automobile speeds statistics. Option is provided to the user for wiper control, vehicle lock and unlock, fuel level indicators. Additional features can be easily added to the system based on user requirements. All the data is available to the user using the application installed on the user smartphone.

Fig. 11 presents the live results obtained from the smart automobile system. The live feed on kilometer driven, throttle and speed are collected at the user end via the smart application. This data will be stored and used for many decision-making applications in the future via the application. Fig. 12 shows the live statistics of the system varying with time.

Fig. 13 presents the accuracy of voice command in real-time detection. Fig. 14 depicts the lower delay obtained by the system in comparison to the existing system. It is evident from the results that the proposed system thus gives good performance and accuracy in real-time.



a) b) c)

Fig. 11. Live results from the system a) Kilometer Driven b) Throttle c) Automobile Speed.

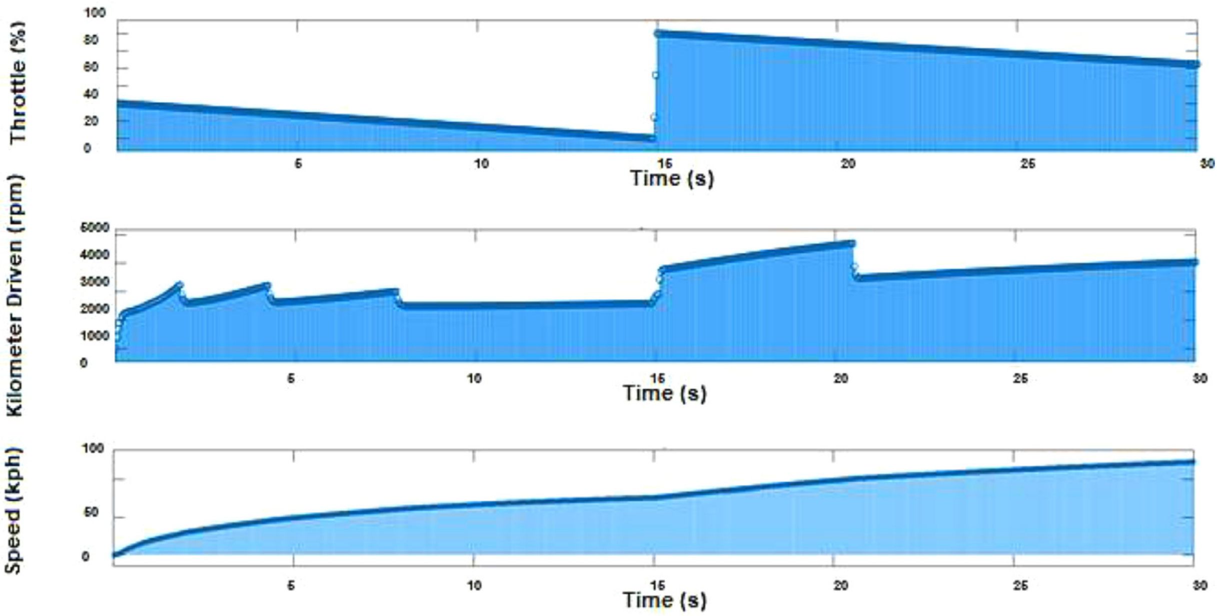


Fig. 12. Live statistics from the system varying with time.

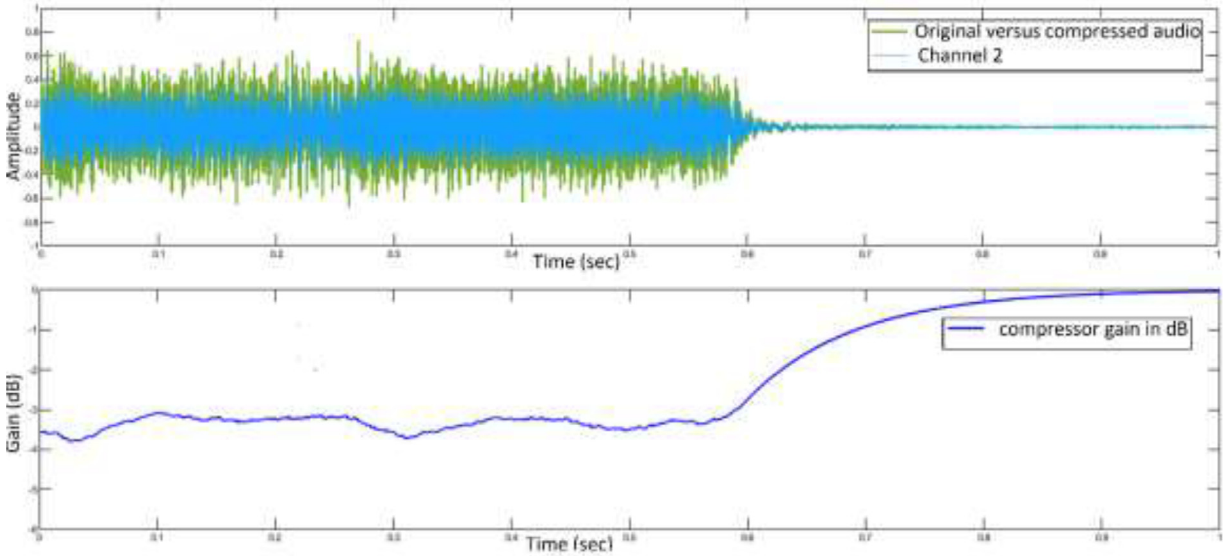


Fig 13. Accuracy of voice commands.

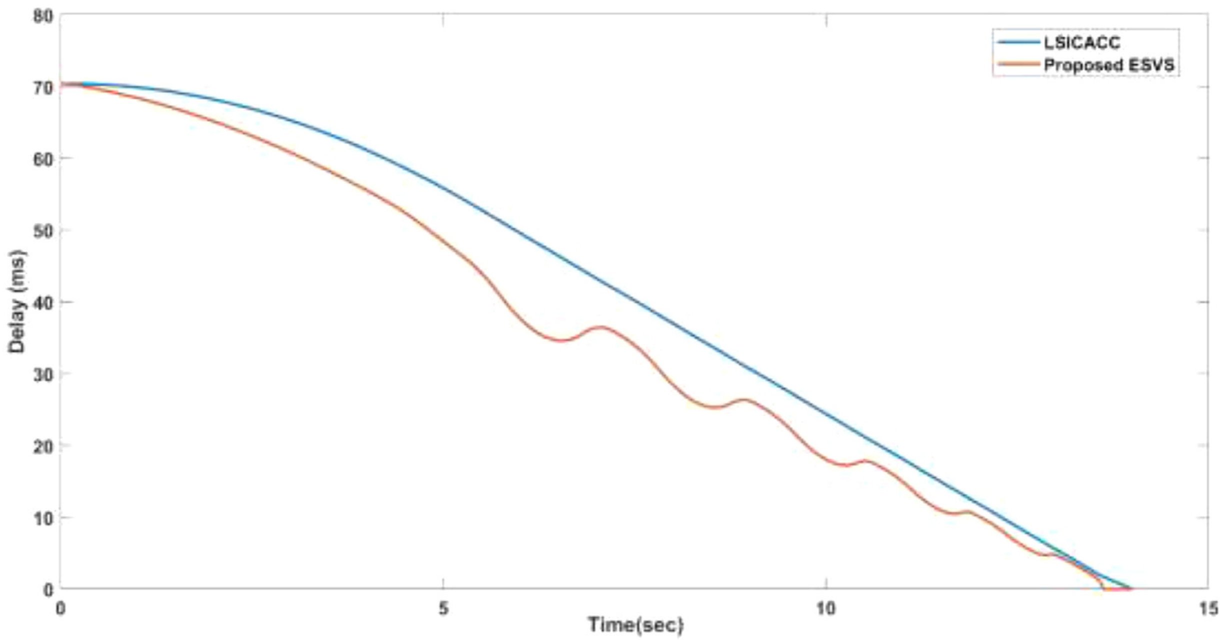


Fig 14. Delay vs time.

5. Conclusion

There have been numerous advancements in the automobile industry that have made various vehicles popular that we know today. Automated functions and voice commanding are the highlights of such vehicles. Fully automated functions are mainly present in high-end cars, which are not easily affordable for all. Voice commanding is not possible in low-end cars. Budget car users have to compromise with various safety features. Our technology helps integrate high-end features to a budget car, thus making its functions remotely accessible by smartphones from anywhere according to the user's desires; this technology also provides the user with the real-time status information and location of the car. The voice command recognition is done by integrating with the Google Assistant. Google Assistant is an artificial intelligence-powered virtual assistant developed by Google. It can engage in two-way conversation. The automation technology is based on a web service called IFTTT. These technologies along with the latest IoT, and real-time database are combined to form a unique product, which can satisfy the needs of low-end car users. NodeMCU (ESP8266), Arduino mega 2560, Hc-Sr04-Ultrasonic Sensors, MFRC522 are used here. This provide better security and make it more user-friendly, as the technology is evolving and number of smartphones are increasing exponentially every day, the implemented concept can help everyone simplify life without carrying any extra equipment and everything is just a click away. So, the headlights, media, AC, etc. can be turned on and off by voice commands. Thus, the features present in high-end cars can be brought in budget cars with the user's smartphone.

Declaration of Conflict of Interest

None

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