Advanced Real time IoT Eco-Driving Assistant System

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Summary
Eco-driving of vehicles today presents an advantage that aims to reduce energy consumption and limit CO2 emissions. The application for this option is possible to older vehicles.
In this paper, we propose an efficient implementation for IoT (Internet of Things) system for controlling vehicle components that affect the quality of driving (acceleration, braking, clutch, gear change) via Smartphone using Wi-Fi and BLE as communication protocol.
The user can see in real-time data from sensors that control driver action on vehicle driving systems such as acceleration, braking, and vehicle shifting through a web interface. Thanks to this communication, the user can control his driving quality and, hence, eco-driving can be achieved
Keywords: *Eco-driving, IoT, EDAS*

1. Introduction

Over the past decade, engine technology and vehicle performance have improved dramatically. Polluting emissions of CO, HC and NO have been reduced with the introduction of catalytic converters **[1]**. Fuel consumption and CO2 emissions can also be reduced through technological innovations, but this is only partially effective under real traffic conditions. This is because most people do not drive their vehicles as the engine design and calibration would require. Manufacturers calibrate vehicle engines to strike a delicate balance between optimum handling and optimum exhaust emission levels. Thanks to eco-driving, it is possible to get closer to these optimal conditions.

The concept of eco-driving responds to the implementation of certain basic principles **[2]**such as:

1. Shift into high gear as soon as possible.
Shift up a gear between 2000 and 2500 rpm.
2. Maintain a constant pace.
Engage as high as possible and drive at low engine speed.
3. Anticipate traffic.
Look as far as possible and anticipate the surrounding traffic.
4. Gradually decelerate.
If you need to slow down or stop, gradually decelerate by releasing the accelerator in time and leaving the car in gear

2. Related works and contribution

Ming Li, Xinkai Wu, Xiaozheng He, Guizhen Yu, Yunpeng Wang proposed a system to ensure economical driving that provides congestion detection using infrared sensors, fuel detection, and gear shift assistance [3]. The main disadvantage is that infrared sensors are used to determine the presence of other vehicles, pedestrians and certain other objects in order to avoid collisions and accidents. In case of reliability, ultrasonic sensors are better than IR sensors and the maximum range of an ultrasonic sensor is around 20 meters, while for IR sensor it is only 1-5 meters and depends on the type of IR sensor used. Range will also vary.
Zhengwei Bai, Peng Hao, Wei Shangguan, Baigen Cai, Matthew J. Barthhave proposed methods for eco-driving using the Pi camera module which is useful to avoid collisions between vehicles and with some other objects [4]. But in smoky and dusty conditions, the Pi Camera will not be suitable for capturing images due to poor visibility, it will result in blurry images which are not good enough for object detection while driving and render driving more difficult.
Yen, Meng-Hua, Shang-Lin Tian, Yan-Ting Lin, Cheng-Wei Yang, and Chi-Chun Chen have proposed an eco-driving system that reads existing information on the CAN Bus [5] . The only drawback is that CAN BUS cannot be used directly with smart phones, there may be a lack in the processing of information to drivers. And the other disadvantage is the cost, it is not profitable and compatible to make a modification in the electronic installation of the vehicle.

In others, most developed eco-driving systems have used wired links. Authors of [6] and [7] used CAN communication. Other authors used Ethernet [8],
In this work, we have developed an IoT driving assistance system called EDAS (Eco-Driving assistant System) which is an ADAS that advises the driver to follow a called Eco-energy instruction. These eco-driving assistance systems determine acceleration, braking and clutch profiles,

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the aim of which is to minimize fuel consumption. These profiles are determined using Iot sensors, etc.
The developed system is based on IoT WLAN Esp32 modules. We have also developed an IoT web interface to display these parameters measured while driving.

3. Proposed IoT architecture for eco-driving system

• The Internet of things (IoTs) can be defined as connecting the various types of objects like smartphones, personal computers, and Tablets to the internet.
• The aim of the IoT is that it enables things to be connected anytime, anywhere with anything and anyone
• With the introduction of IoTs, the research and development of home automation are becoming popular in recent da

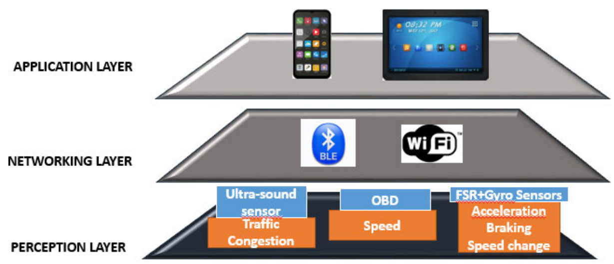

Fig1: Iot Eco-driving assisting system

• The perception layer consists of the Vehicles component and parameters, which are to be monitored.

• The networking layer consists of IoT gateway router, device manager and various communication protocols.

• The ESP32 is used as the IoT gateway, which communicates, to Tablet or smart phone by using WLAAN and BLE communication.

• The application layer consist of a web interface, which is nothing but designing a web page by which we can control the various driving systems.

4. Proposed system

To have an eco-driving it is necessary to apply certain habits when driving:

1. Shift up gears quickly. We know that the engine tends to lose energy due to friction (mechanical friction). So the faster the engine runs, the greater the friction, hence the advantage of reducing the engine speed or speed. The solution then is to upshift quickly so that you are at a lower engine speed even if you have to drive in high gear for a low gear as shown in Figure 7.

2. Maintain a constant speed using the highest gear possible: When driving a lot of energy is used in acceleration to move the car. In addition, some of that energy is lost every time you brake. Consequently, repeated acceleration and braking requires a lot of energy and therefore fuel. It is, therefore, recommended to adopt a fluid and constant driving style, avoiding unnecessary braking and acceleration. In addition, by keeping a high gear ratio and maintaining a constant speed, fuel consumption savings can reach 38% depending on the type of vehicle compared to using a lower gear ratio (see Figure 8).

3. Anticipate traffic and drive slowly: In order to drive at as constant a speed as possible, it is important to anticipate as much as possible and choose the speed according to the environment and not to the limitations to avoid unnecessary braking and acceleration.

4. Gradually decelerate and use the engine brake.
Diesel and gasoline vehicles manufactured since 1990 are generally equipped with an electronic fuel injection system, which cuts off the fuel supply to the engine when the engine brake is used, in other words, the wheels drive the engine.

The advantage of engine braking is that it can be used to save fuel by releasing the accelerator as soon as possible when slowing down or stopping. It also reduces the use of brakes and thus reduces maintenance costs.

To achieve the eco-driving objectives described above, we have designed a low-cost IoT eco-driving assistant system that is capable of controlling most of the vehicle systems related to driving style. The system contains a great elasticity by using wireless reliable technology to interconnect various modules to the webserver. This in turn reduces the deployment cost; will add to the flexibility of advancement, and system reconfiguration. The projected system can make use of BLE (Bluetooth Low Energy) connections between various sensors, hardware modules, smartphones, and various communication protocols between users and servers [4].

The block diagram of the proposed system is shown in Fig2.

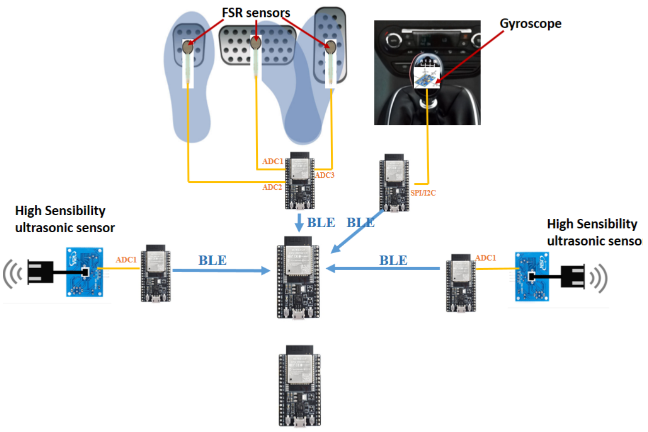

Fig2: system architecture

4.1 Data processing

There are multitudes of microcontrollers. The choice of the microcontroller for proposed system in this paper was based on the following characteristics:

- the number of analog / digital converters (A/D),
- the availability of a UART port (Tx, Rx) ,
- the programming language ,and access to the programming software (compiler),
- compatibility with the Bluetooth or Wifi module
- Data storage capacity.

The microcontroller had to control three FSRs hence a need for three input / output ports and 3 A / D converters, an SPI port to detect the gear change information, an SPI port for the transfer of data from the gear lever position. A Bluetooth module, a compiler accessible in a familiar programming language.

Based on the above-mentioned characteristics, the choice was made on the ESP32 microcontroller (Figure 13) which has a Bluetooth and Wifi module, a 2.3 Volts to 3.6 Volts power supply, a storage capacity of 256 kB, 34 input / output ports, 8 A / D interfaces, 3 UART ports ,and 2 I2C ports, and one USB connector [9].

In addition, it is programmable in C on Arduino IDE, python, and Matlab. The ESP32 microcontroller was paired with a tablet for data collection. WIFI communication was established between the ESP32 microcontroller and the tablet, the data was transmitted in real-time.

Actions on pedals sensing:

The Force-sensitive Resistor Sensor (FSR) is a low-cost detection unit that allows detecting physical pressure on the three pedals' acceleration, braking and clutch.

FSRs are a resistor that changes its resistive value (in ohms Ω) depending on how much it is pressed.

When the sensor is squeezing (V_{in}) its resistance changes, which causes the variation of the voltage (V_{out}) measured by the ESP32 through its analog to digital converter (ADC).

$$V_{out} = V_{in} \frac{R2}{R1+R2} \tag{1}$$

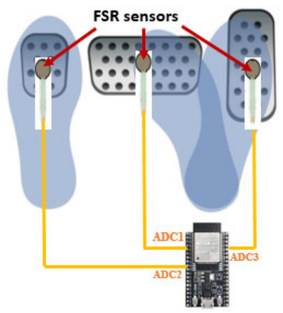

Fig3: pedals sensing

4.2 Acceleration Sensing

The quality of the acceleration is measured using an FSR sensor placed on the accelerator pedal. The top surface of the probe is spherical, centralizing the impact force.

To know the acceleration profile we propose the following calculation algorithm.

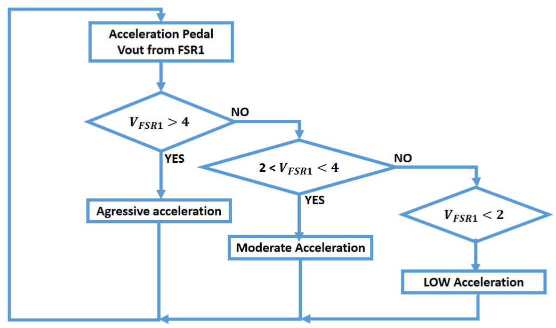

Fig4: Acceleration pedal sensing

The integral of the square of the acceleration is defined as follows

$$\frac{1}{n} \int {V_{FSR1}}^2 dt \tag{2}$$

With n=number of time intervals

This indicator increases when a lot of acceleration characterizes driving.

4.3 Braking Sensing

When the brake pedal is actuated, the calipers apply Pressure to the pads, which then use the brake discs as resistance to stop the vehicle. The car's brake discs are only applied when the brake pedal is engaged.

Mounted directly on the vehicle's brake pedal, the FSR force sensor measures and records the forces applied while braking.
The followed algorithm to quantify the braking is

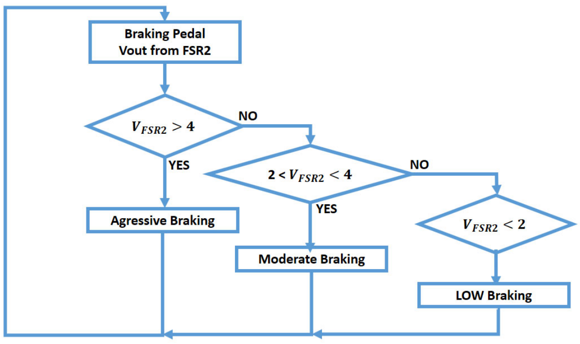

Fig5: Braking pedal sensing

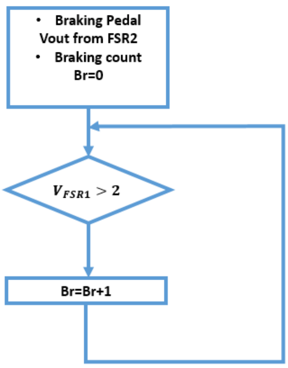

Fig6: system architecture

4.4 Speed variation sensing:

The MPU6050 sensor placed on the gear shifter is used in combination with the FSR sensor placed on the clutch pedal to detect the change of gear ratio.
The MPU6050 has both a 3-Axis accelerometer and 3-Axis gyroscope integrated on a single chip.
The gyroscope measures rotational velocity or rate of change of the angular position over time, along the X, Y and Z-axis. The outputs of the gyroscope are in degrees per second, so in order to get the angular position; we just need to integrate the angular velocity.
On the other hand, the accelerometer of MPU6050 measures acceleration. Briefly, it can measure gravitational acceleration along the three axes and using some trigonometry math we can calculate the angle at which the sensor is positioned.
Therefore, if we fuse, or combine the accelerometer and gyroscope data we can get very accurate information about the sensor orientation.
For our system, for each speed the Gear shifter has a position coordinates(X, Y, Z) that can be measured by the MPU 6050 placed on it.
When the driver acts on the gear shifter to change the speed of the vehicle, MPU6050 sends the coordinates of the new position towards the esp32 through I2c.

Fig7: system architecture

4.5 Traffic congestion sensing:

To know the level of traffic congestion, we used two high-sensitivity ultrasonic sensors. The first is placed on the front part of the vehicle and the other is placed on the rear part.

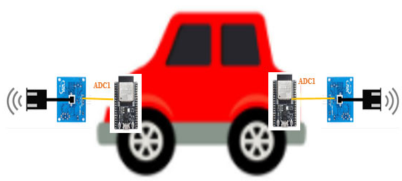

Fig8: Traffic Congestion sensing

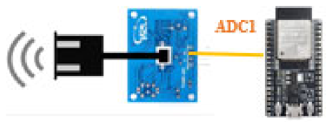

Fig9: Traffic Congestion sensing

Ultrasonic sensors consist of a transmitter and a receiver and use the ultrasonic telemetry method to calculate the distance between the transmitter and a distant object. This method measures the time it takes for an ultrasonic pulse to reach the object and return by reflection to its starting point. The sound wave used has a frequency of over 20 kHz. Knowing the speed of propagation of this type of wave, which is approximately 30 cm / ms, the distance crossed by the ultrasound, is given by the following formula [10]:

$$d = \frac{v.t}{2} \qquad (2)$$

Where d the total distance is traveled, v the speed of propagation and t the time elapsed.
Depending on the distance d of neighboring vehicles, the two sensors send two analog signals that they will subsequently be processed by esp32.

Table 1: Developed system variables

	Variable Name	Type	Description
Time	Time	INT	Time of driving in s
Acceleration pedal	V_{FSR1}	Real	Force applied on acceleration pedal
	T_{acc}	INT	Time of acceleration
Braking pedal	V_{FSR2}	Real	Force applied on Braking pedal
	V_{FSR2}	BOOL	
	T_{Br}	INT	Time of Braking
Clutch Pedal	X,Y,Z	M1x3	
	V_{FSR3}	BOOL	Force applied on Clutch pedal
Congestion	V_{CONGF}	Real	Front Congestion sensor
	V_{CONGR}	Real	Rear Congestion sensor

It is important to note that the time interval between two successive recordings is of the order of 50ms but is not constant.

5. Case study and discussion

To validate our developed system, we tested the proposed system on a Fiat punto 3-fuel consumption.

The chosen circuit is 14km distance. This route is inter-urban, rather rural, and includes an interesting variability of driving situations.

Fig10: test circuit

All parameters described are processed by the ESP32 modules and sent to the graphical interface included in the webserver and compatible with smartphones, PCs or tablets.

The IoT interface subsequently developed makes it possible to acquire all these measurements and analyze the data (Fig 11). This system can be used for the brake pedal, accelerator, clutch and hand brake pedal. The driver can then monitor the data via a calculated score.

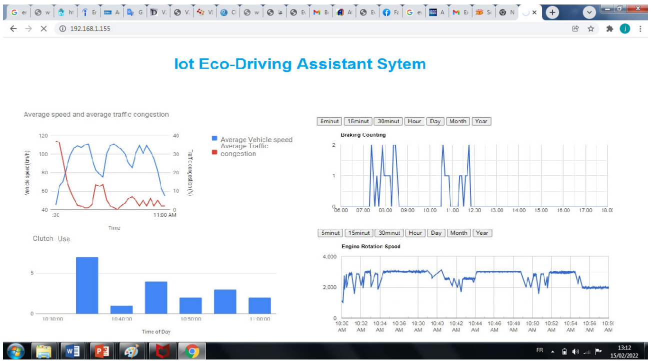

Fig11: Developed Interface

Figure 12 represents the action of the driver on the accelerator according to the type of driving. We observe a lower average speed in economical driving; however, this is not enough to conclude that driving slowly allows you to reduce fuel consumption, even if this is not false. Indeed, the average speed is very sensitive to stopping times, so stopping at a traffic light for a few minutes can lower the average speed but increase the average consumption.

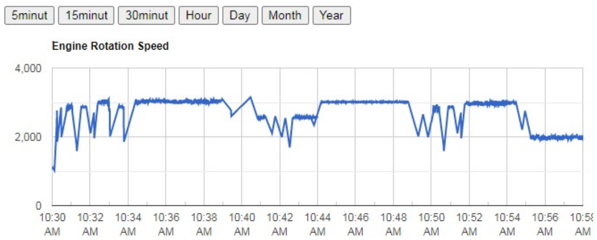

Fig12: acceleration sensor values over time

Braking management in economical driving is also very representative of smoother driving. Indeed, Figure 13 shows the number of braking operations.

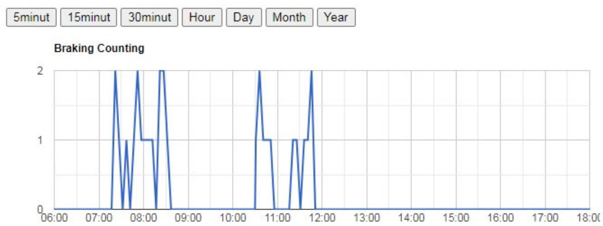

Fig13: Braking count

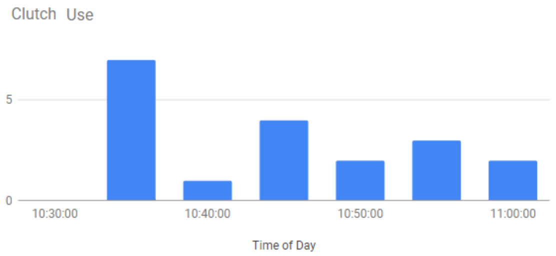

Fig14: clutch pedals actions counting

A technique associated with eco-driving and linked to traffic anticipation is the use of engine braking. Remember that when the vehicle is in engine braking, the fuel supply to the engine is cut off. The percentage of time spent in engine braking increased slightly in economical driving as shown in figure 15.

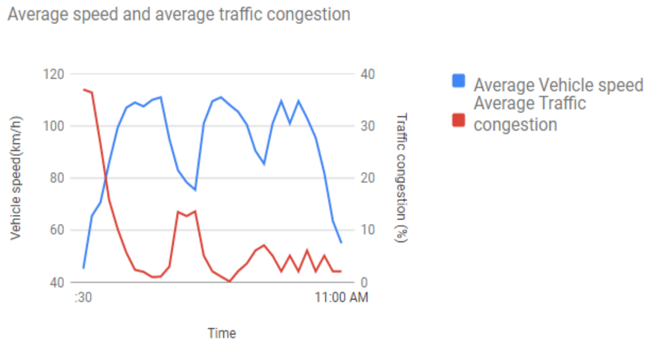

Fig15: average vehicle speed Vs Congestion

As shown in the plots in Figure 15 (pedal and traffic congestion), it can be seen that for minimum congestion sensor values are also translated into higher acceleration sensor valuesV_{FSR1} . This is true for the opposite direction (no congestion) the driver releases the accelerator pedal (resulting in lower V_{FSR1} values), V_{CONG} values decrease at these times. This validates our involvement for acceleration and congestion level in the eco-driving evaluation process since it is directly controllable by the driver and strongly affects fuel economy.

6. Conclusion

A real-time Iot EDAS system has been developed to promote more economical driving, using Iot sensors and without any intervention in the electronic installation of the vehicle. This system could also be beneficial for transport companies, fleet management.
The developed system provides the driver with direct recommendations when it detects events not related to eco-driving. This allows the driver to follow their driving style over long periods and adapt their driving to reduce fuel consumption and CO2 emissions. This direct link is taken from the analysis of the following entries; position of the accelerator pedal, brake pedal, clutch pedal, gear lever (gear changes) sensor. These variables illustrate the aggressiveness of a driver who consumes more fuel.
After a journey, the system interface provides the driver with a complete analysis of his driving style and a score between 0 (low eco-driving) and 100 (high eco-driving).
Our EDAS Iot System is still in the development phase. Future work consists in validating the effectiveness of the driving systems proposed by the test on several drivers under different driving conditions.

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