Driver monitoring system for automotive safety

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Abstract. The lifestyle of a person is a very active one from all points of view. He travels great distance every day, with car or on foot. Tiredness and stress is found in every person. These can cause major problems when driving up and driving in small or big distances by car. A system developed to prevent the dangers we are prone to in these situations is very useful. System that can be used and implemented both in the production of current cars and the use of those not equipped with this system.

1. Introduction

The systems used today by different car manufacturers include sensors or video cameras that analyze driver behavior [1].

Spanish scientists have created a system of four sensors that monitor different physical parameters and the steering position of the driver. As a result, a series of sound signals are issued in order to warn the driver. Toyota prepares projects that include, among many others, a system that contains a steering wheel sensor that analyzes the heartbeat of the driver to avoid accidents caused by heart attack while driving [2]. The engineers from Jaguar work to develop an active safety system to detect whether the driver is careless or is about to fall asleep by reading his brain waves [3]. Bosch Group has created a system that identifies signs of fatigue. They designed a function that computes the driver's fatigue level, depending on the frequency of the steering movements and other parameters, including the duration of the trip, the use of direction indicators and the time of day [4].

In recent years, there has been an increase in car accidents caused by drivers who fall asleep due to fatigue, or because of spontaneous manifestations of some disease. To prevent such accidents, there is an increased need to monitor the health of drivers, as well as to detect anomalies at an early stage. Non-contact sensors can estimate sleepiness of drivers based on pulse measurement.

Omron Corporation has announced a non-contact pulse sensor prototype. It can accurately measure heart rate inside the vehicles, where measurements are difficult to perform. The bio-detection technology prototype is able to measure the driver's pulse using radio waves and a dedicated algorithm.

The device transmits radio waves against driver and uses the return waves to detect a variation of about 100 micrometers of the blood vessels when the heart beats. The deviation is then converted into
a pulse signal, which OMRON's algorithm uses to calculate heart beats. This contactless sensor allows real-time monitoring of driver health without discomfort and without affecting driving.

With this type of contactless sensor combined with other technologies such as Cut-Edge AI On-board Sensor that measures real-time driver status and Wearable Sensor (worn on the wrist) which measures blood pressure continuously, anomalies of the state of the driver will be detected with greater accuracy and certain decisions can be made to prevent problems.

OMRON combines several detection technologies that can accurately detect and estimate the risk of abnormalities before they appear. Using such a sensor inside the car can be very useful for quickly detecting driver's cardiac problems that could cause accidents if he has a crisis for some reason. OMRON wants to be the first company to create an on-board health system capable of preventing accidents caused by the driver's state of health and contributing to a safe and comfortable driving oriented society [5].

![Contactless sensor](image)

**Figure 1.** Contactless sensor

2. **System architecture**

Wearables offer great opportunities to intensify our driving experience. Wearable devices like smart glasses and smartwatches are mainly used to enhance the driver's experience and improve safety. More specifically, Mercedes, BMW and Nissan have built special applications that monitor the speed and fuel efficiency via on-board sensors and even the driver's fatigue level via heart rate sensors.

Ford S-Max Concept provides the ECG Heart Rate Monitoring Seat, which continuously monitors and records the driver’s heart rate. S-Max Concept promised to enable the function of heart attack detection. Then, it will notify emergency services as well as a notification to the driver to safely come to a stop. Beyond heart monitoring, S-Max Concept is able to monitor the Blood Glucose Level. Sensors and transmitter fob are equipped to continuously measure blood sugar levels in the driver. A notification will send an alert if the level of glucose becomes dangerously low.

2.1. **Selection of sensors**

Sensors used to detect driver behaviour changes may be of different type and functioning principle.

The criteria for choosing these sensors are:

- Power supply voltage
- The current used
- Dimension
- Working temperature
- Case
- Mode of operation
- Output configuration
- Force sensitivity range
- Response time
- Lifetime
- Vibration / Noise Sensitivity
2.1.1. Pressure sensor FSR400. These sensors provide a simple way to sense the force that acts on it. The operation of this sensor can be compared with the operation of a resistive potentiometer that changes its proportional value to the force applied to it. It can be connected together with a resistor with a value of 10K and using the principle of the voltage divider to read the voltage drop across the resistor. Thus, the sensor changes its resistance and with this it changes the current through the circuit and also the voltage drop across the 10k resistor. This resistor’s value is read by the microcontroller on an analogic input with a 10-bit resolution. The sensor has a 10% precision.

The sensor shows a decrease in resistance when the applied force increases.

![Image of FSR sensor layers](image)

**Table 1. Performance specifications: [6]**

| Parameter                              | Value                                               |
|----------------------------------------|-----------------------------------------------------|
| Force Sensitivity Range                | ~0.2 to 20N                                         |
| Break Force (Activation Force)         | ~0.2N min                                           |
| Part-to-Part Force Repeatability       | ± 6% of established nominal                         |
| Single Part Force Repeatability       | ± 2% of initial reading                              |
| Hysteresis                             | + 10% Average                                       |
| Long Term Drift                        | < 5% per log₁₀(time)                                |
| Force Resolution                       | Continuous                                          |
| Stand-Off Resistance                   | > 10MΩ                                              |
| Switch Travel                          | 0.05mm                                              |
| Device Rise Time                       | <3 microseconds                                     |
| Maximum Current                        | 1 mA/cm² of applied force                            |
| Hot Operation                          | -15%                                                |
| Cold Operation                         | -5%                                                 |
| Hot Humid Operation                    | +10%                                                |
| Hot or Cold Storage                    | -10%                                                |
| Hot Humid Storage Temperature          | + 30% of established nominal resistance              |
| Thermal Shock                          | ± 2% typical                                        |
| Tap Testing                            | -10%                                                |
| Constant Load                          | -5%                                                 |
| Chemical Resistance                    | The following chemicals do not affect the operation when applied to the outside of the sensor: cola, coffee, isopropyl alcohol, soap solution, household cleaners. No others tested. Application is a single drop on the exterior of the sensor that is allowed to |
soak until evaporation and does not enter the sensor.

| Property                      | Specification                                      |
|-------------------------------|----------------------------------------------------|
| Sensitivity to Noise/Vibration| No effect                                          |
| Positional Resolution         | 0.075 to 0.5 mm (0.003” to 0.02”)                  |
| Positional Resolution         | Better than ± 2% of full length                    |
| Force Sensitivity Range       | ~0.2 to 20N                                        |

2.1.2. **Bending sensor FS7548.** Bending sensor provides a simple way to grasp the degree of bending of an environmental element. One side of the sensor is printed with a polymer ink that has conductive particles embedded in it. When the sensor is straight, the particles give the ink a resistance of about 30k Ohms. When the sensor is bent away from the ink, the conductive particles move further apart, increasing this resistance (to about 50k-70K Ohms when the sensor is bent to 90°, as in the diagram below) [7].

![Figure 3. Conductive particles further apart – 70k](image1)

When the sensor straightens out again, the resistance returns to the original value. By measuring the resistance, you can determine how much the sensor is being bent [7].

![Figure 4. Conductive particles close together – 30k](image2)

It changes its value depending on the degree of bending it is subjected to.
Table 2. Performance specifications [8]

| Parameter                  | Value                                                                 |
|----------------------------|-----------------------------------------------------------------------|
| Life Cycle:                | >1 million                                                            |
| Height:                    | 0.43mm (0.017")                                                       |
| Temperature Range          | -35°C to +80°C                                                        |
| Flat Resistance:           | 10K Ohms ±30%                                                         |
| Bend Resistance:           | minimum 2 times greater than the flat resistance at 180° pinch bend  |
| Power Rating:              | 0.5 Watts continuous; 1 Watt                                          |
|                            | Peak                                                                  |

2.2. Hardware design

The system includes three pressure / touch sensors that are located in the vehicle, a light sensor, a microcontroller that receives sensor data, interprets and memorizes it, fills in from the vehicle's battery, and a graphical display that alerts the driver and also a buzzer.
The three pressure sensors are located on the steering wheel, gearshift and armrest. They transmit data regarding the driver's position if the positioning of both hands is on the steering wheel and if the left hand is on the steering wheel and the right hand is on the gear selector or on the armrest.

The light sensor has a very important part in the system, it detects whether the vehicle is driving at night or during the day. Driving at night is much more exhausting and driving time is lower than driving if it is daytime.

Figure 7. Circuit diagram

2.3. Software design

When the vehicle's engine is started, the system's power supply is generated and the pressure sensor, light sensor and time variable are read out. The entire driving time is counted by the microcontroller and, depending on the light sensor value, it generates decisions regarding the driver's warning. Night driving time should be shorter than daytime driving time, because the driver's sight weakening is faster when the road illumination is lower.

If no one of the sensors is active after starting the engine, the system will send only one warning after that it will consider that the engine is turned on for heating or for maintain. If the system is in this situation, driving time is not counted. The system will send again warnings only when at least one of the sensors from the steering wheel and the gearshift will be reactivated.

Time spent driving is stored by the central unit (microcontroller) and memorized before the engine stops (power off). At startup, a check is made if the driver has taken a long break or a few minutes. If the break was a few minutes then the timing continues (it adds to the previous driving time) and if the break exceeds a few hours then the variable will reset (time_driving = 0).
The pressure sensors are read every second and the driver's position is monitored if at least two sensors (one mandatory on the steering wheel) are not activated for 10 seconds then the driver is warned. This is the most common occurrence when the driver speaks on the phone, changes the radio channels, search for something in the car, etc. This means an imprudent drive and a certain degree of danger to it. If no sensor is activated then the alert is on (the driver does not hold his hands on the steering wheel). This case is monitored even when the car is passed to the automatic pilot.

During this time, the CPU registers the activity of the sensors and the average duration of their operation. The average calculated by the algorithm is the driving mode of the vehicle owner and is stored. This average is continuously compared to the driving style and when changing the driver, it can be reset or the change is made in a few hours.

The pressure sensors are read and, if the value is variable over a short period of time, then the driver is warned. Usually when the driver falls asleep at the wheel, he weakens the grip of the steering wheel, and in a short time the grip is strong (when he falls asleep). If this behavior is detected the system immediately warns the driver to stop the vehicle.

In Figure 5 is shown the entire algorithm as presented above.

![Algorithm diagram](image_url)

**Figure 8. Algorithm diagram**

3. Conclusions
Due to the fact that we are very busy every day, we get to spend a lot of time driving most of the time without realizing that we are tired and this can be a danger to us or other traffic participants. This kind of system will certainly improve traffic and life safety.
Using this system means easy mounting inside the car of several sensors together with the processing and alarm device (microcontroller and buzzer). The differences between vehicles having different manufacturers do not affect the implementation of this system, as is for the implementation of other systems.

The cost of purchasing the components/devices is very low and also the cost of implementing the system into the car is small.

The driver alert mode is adjustable to the user needs, can go from silent and only visual but it can be also loud. The buzzer used in this system produces a low frequency sound, which is not disturbing for the car passengers.

The system can detect the driver’s drowsiness from the steering wheel sensors and warn the driver in this case to take a driving break. Attention to traffic, correct steering position are also monitored and, if necessary, alerted by this system.

References
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