

Recent developments on driver's health monitoring and comfort enhancement through IoT

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Abstract. At present, many automakers are paying attention to develop vehicles with IoT enabled including healthcare, accident prevention, vehicle safety, driver safety, driver and passenger comfort, vehicle monitoring, etc. This paper focused on reviewing the recent developments in driver's health and comfort monitoring through IoT. The literature review was performed with popular search engines/databases like PubMed, ScienceDirect, Elsevier Science, Scopus, and Google Scholar. The search was based on keywords like "Healthcare Monitoring", "Seating Comfort", "IoT developments", "Smart Sensing", "Embedded Sensors", "Wearable Sensors", "in-vehicle smart assistance", "Autonomous Vehicle/Car". Later, the articles were sorted out according to the relevance of this paper's focus (i.e., driver's health and comfort monitoring through IoT) by reading title, abstract, and full article. The results show that there have been many IoT based health and comfort monitoring developments concerning the vehicle. We have classified and summarised the developments as health monitoring through seat pan, seat back, seat belt, steering wheel, eye tracking and face tracking, and comfort monitoring/enhancement through smart seating, smart seat cushion, smart door module, smart air-bag, smart seat belt buckles. This survey would be giving in-depth knowledge on recent developments in the field of automotive and IoT.

1. Introduction

Driving is a complex activity performed in a continually varying and stimulating environment. The coordination and execution of various skills like cognitive, sensory, psychomotor and physical are extremely necessary to drive safe [1, 2, 3]. Most of the studies related to driving highlighted that 75% of traffic accidents occurs due to human factors including driver's fatigue, deprived health condition,



attention loss, bad emotional state, and lack of skills [4]. Most of the developed country is ageing. Hence, the drivers above 60 years is also increasing [5]. Ageing results are weakening in cognitive function and threaten driver safety. The aged drivers (age above 60 years) have a comparatively more significant risk of accident due to medical emergency [6] than other factors like bad emotional state and lack of skills. The wellness of drivers' is considered as a key factor of traffic accidents. Heart failure and non-traumatic disease (i.e., stroke) are the main risk factors for drivers' death. Many of the victims have no prior knowledge of the presence of the condition. Stroke is a disease caused due to the disturbance in blood supply to the parts of the brain. After experiencing stroke, a driver's ability to drive is generally affected by the visual, perceptual, motor, and cognitive deficits [7]. Stroke leads to arm weakness, facing dropping, blurred vision, dizziness, coordination issue and speech difficulties of victims which are essential for driving. It is necessary to protect the driver's those are possibly be the victims for stroke. Since, stroke onset during driving lead a serious threat to the other drivers and the general public [8]. Now-a-days, there are lots of automotive industry competing not only to provide better performance in terms of the vehicle but also to provide the driver with better comfort even in long rides. Automakers are developing vehicle that could provide health monitoring service with Internet of Things (IoT). In IoT, an automobile or vehicle-treated as a "thing". IoT plays an important role in connected vehicles development. It provide us cloud connectivity, smart phone integration, health monitoring, safety and security [8, 9]. Automakers are developing vehicles with IoT enabled including healthcare, accident prevention, vehicle safety, driver safety, driver and passenger comfort, vehicle monitoring, etc. The paper aimed on summarizing the current developments in driver's health and comfort monitoring through IoT.

2. Material and methods

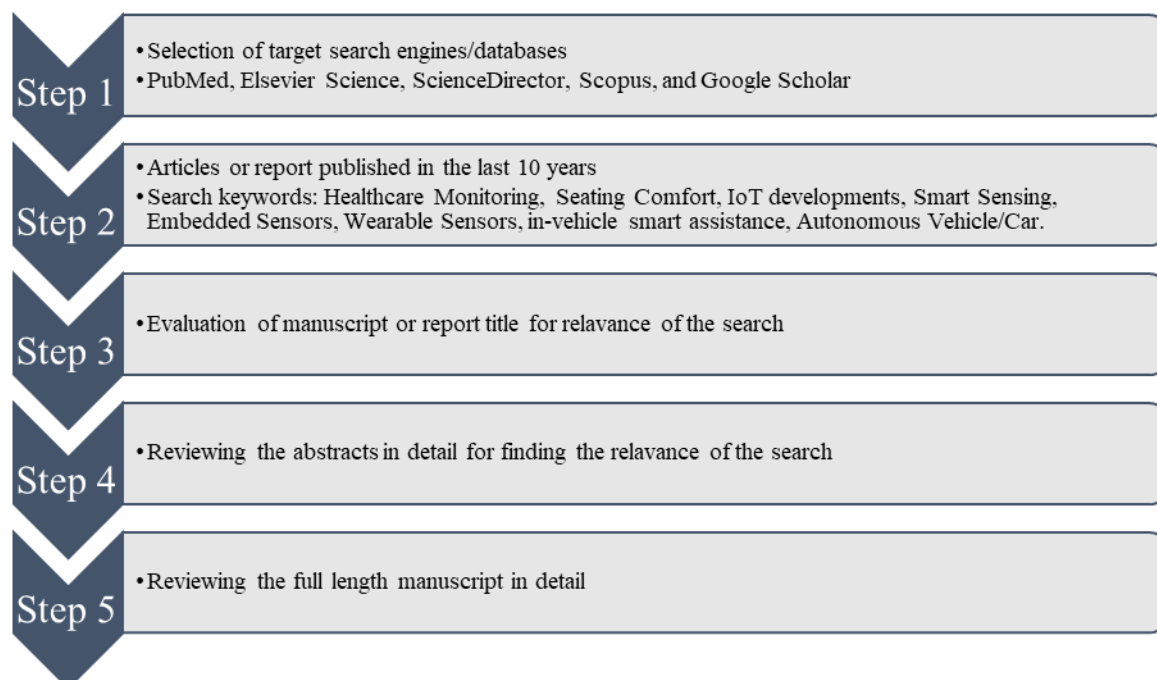


Figure 1. Methodology or Literature survey procedure

The literature review was restricted to following search engines/databases PubMed, ScienceDirect, Elsevier Science, Scopus, and Google Scholar. The search keywords are: "Healthcare Monitoring", "Seating Comfort", "IoT developments", "Smart Sensing", "Embedded Sensors", "Wearable Sensors", "in-vehicle smart assistance", and "Autonomous Vehicle/Car". Also, the search was restricted to the

period from 2002 to 2017 (15 years). The search was restricted to articles written in English. The items were shortlisted based on the title, abstract and finally by the full text (Fig. 1).

3. Summary of findings: IoT application on health monitoring

The results show that automakers and researchers have been developing many IoT based services including health monitoring, comfort monitoring, accident prevention, vehicle safety, driver safety, driver and passenger comfort, vehicle monitoring, etc. We have classified and summarised the developments as health monitoring through seat pan, seat back, seat belt, steering wheel, eye tracking and face tracking, and comfort monitoring/enhancement through smart seating, smart seat cushion, smart door module, smart air-bag, smart seat belt buckles. This summary might provide knowledge on the recent developments of IoT based automotive.

A full sort of applications for IoT-based smart health monitoring system is possible including smart vehicle, smart home, smart office, smart bed, smart shirt, etc. Concerning smart vehicle, including luxury automakers and key OEMs integrating health monitoring services into their next-generation products. Few studies [10-12] proposed textile-based wearable ECG devices. However, those devices suffered the difficulties from skin impedance, electrode position and driver body movement. Yang et al [4] developed the shirt embedded with electrodes which could measure heart rate variability and sitting posture of vehicle drivers. The electrodes in the shirt are washable, comfortable and easy sewed into a shirt. The signals from sensors (electrodes) are transferred to PDA device through Bluetooth. Also, this system includes a 3 axes accelerometer to measure road condition. These accelerometers were used to prevent false alarm when emergency stop or speed bump on the road.

Driver's stress and health state was monitored through U-car development [13]. The U-car, ubiquitous healthcare car was installed with a non-intrusive sensor on the steering wheel, seat and seat belt. This U-car measured GSR, PPG, ECG and respiration parameters through various sensors embedded. The results proved that through non-intrusive sensor it is possible to measure driver's biosignals and stress state. Most of the ubiquitous health monitoring system only tested under home environment by attaching sensors to home appliances. However, this study [13] developed U-car for health monitoring in the vehicle.



Figure 2. FAURECIA's Active Wellness 2.0 generation, Picture credit [14].

One of the leading automaker Faurecia [14], produced an active wellness seat (Active Wellness™ 1.0) used to monitor drivers heart rate variability and breath rhythm data. Faurecia claims that no smart car without a smart seat. This seat monitors both the mental and physical status of drivers and passengers via embedded sensors for heart rate variability and respiration rates. Those data were used to help alleviate stress or drowsiness. At present, Faurecia's Active Wellness™ 2.0 generation (Fig 2) incorporated an expanded range of biological and behavioural data including heartbeat, eye gaze, temperature, humidity, respiration rate, body movement, head tilt, facial expression, etc. This second

generation seat monitors the driver's data and recalls their behaviours and preferences, allowing it to predict how the driver will be most comfortable based on his physical condition, time of day, travelling conditions. Based on the health condition and status of the driver, this second generation seat alert the driver through a five-program massage capability, changes in seat ventilation, ambient lighting or audio environment [14].

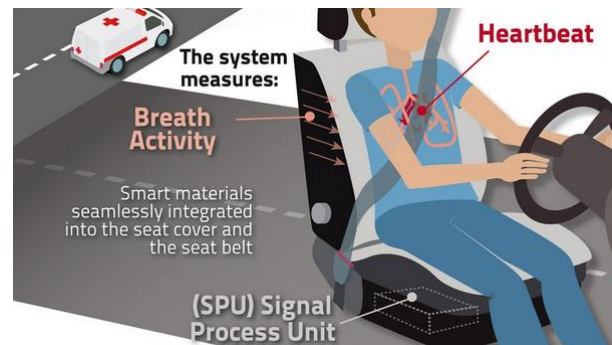


Figure 3. HARKEN Seat Concept developed in the Biomechanics Institute (IBV) in Spain. Picture credit [16]

The EU funded project, Harken [15], focused on developing smart materials and sensors for the vehicle to monitor physiological and mechanical activities. The respiration and the cardio activity were concentrated and they have utilised adaptive filters to reduce vibration and artefacts present in the physiological signals. The Harken project measured cardioactivity by ballistocardiography (BCG). BCG refers a measurement of the blood flow mechanically, which are driven by heartbeats. The BCG is different from ECG waveform. However, it provides heart rate variability. Also, Baek et al. [16] measured individuals BCG while they were seated in the standard chair. The Harken project embedded sensors in seat cover and seat belt and monitoring physiological and mechanical activities of drivers and their research further extended to drowsiness detection (Fig. 3).

Plessey's [17] WARDEN™ is a health monitoring system which can alert the driver based on heart-rate. With Electric Potential Integrated Circuit sensing technology, the WARDEN™ system detects electric potential changes in the human body without direct skin contact. This system uses an array of six sensors, it detects electric potential changes and returns only R peak signal from ECG. Further, this R peak signal is used to calculate the variability in heart rate. The picture of Plessey's [17] WARDEN™ seat and principle given (Fig. 4).

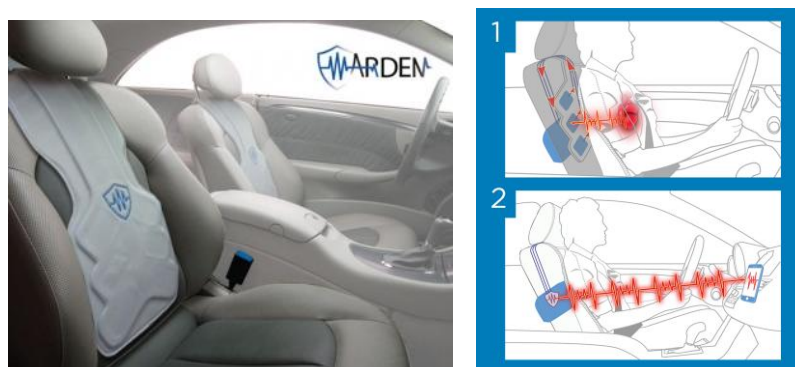


Figure 4. Plessey's EPIC Seat Sensor Technology. Picture credit [17]

A team of researchers at Washington state university developed [18] smart steering wheel which employed SensoFoil sensing technology. This steering wheel intended to detect grip lessens and hand movements. The team claimed that this technology overcomes many limitations currently available in

video-based driver drowsiness detection. Ford's European research and innovation centre initial worked on a car seat which could detect heart attacks by embedded sensors, later, they have stopped to continue their research [19].

For the automated driver-assistance system, the Detroit carmaker testing eye-tracking features. Also, GM proposed eye gaze monitoring technology to its supercruise cars. Furthermore, German automakers like Audi and Volkswagen expected to launch eye-tracking systems in quicker time. Most recently, IPPOCRATE [20] projected a steering wheel monitoring system (Fig. 5). This system could monitor body temperature, cardio activity, blood pressure, pulse rate, and eye movement. Similarly, BMW and Technische Universitt Muenchen (TUM) developed a smart steering wheel that monitors driver's vital signs [21, 22]. Toyota also developed a smart steering wheel to monitor the driver's ECG [23].



Figure 5. IPPOCRATE Smart Steering Wheel, Picture Credit [20]

4. Stroke prediction while driving

Stroke is a brain attack triggered by the unexpected disruption of blood supply to the brain and its parts [24]. Based on the area and side of the cerebrum affected by this attack, the victim may experience some of these effects: arm drift, movement difficulty, loss of vision or blurred vision, balance loss, severe headache. If someone is experiencing stroke while driving, it not only risks his/her life and safety, also decreases the safety of others on the road and increases the risk of an accident. Hence, prediction of stroke disease is essential. Many research studies developed models to predict stroke by considering medical records. The models are Bayesian list machine model, machine learning, Cox model (multivariate type), and Cox model (proportional hazard) [24-27].

We are developing a stroke prediction system (Fig. 6) by considering known and unknown factors. Our system is producing a super brain which has prediction intelligence (combination of the algorithm) and hyper-connected self-learning engine. Our system prediction intelligence would have medical record database where modifiable and non-modifiable risk factors incorporated. The non-modifiable risk factors or physiological/ activity parameters and its variables are listed (Fig. 7). All these variables go into the super brain, which identifies the best combination of medical sign, symptoms, physiological sign, biosignal, motion pattern and other findings in predicting the probability of stroke. Once the system predicts 90% of stroke symptoms, the system alarm the concern. And, will give appropriate medical aids to the stroke victims while driving; even it might prevent stroke occurrence.

5. Conclusion

This paper summarised the recent developments in driver's health monitoring and comfort enhancement through IoT. Also, introduced our developing stroke prediction system. This survey would be giving brief knowledge on recent developments in the field of automotive and IoT.

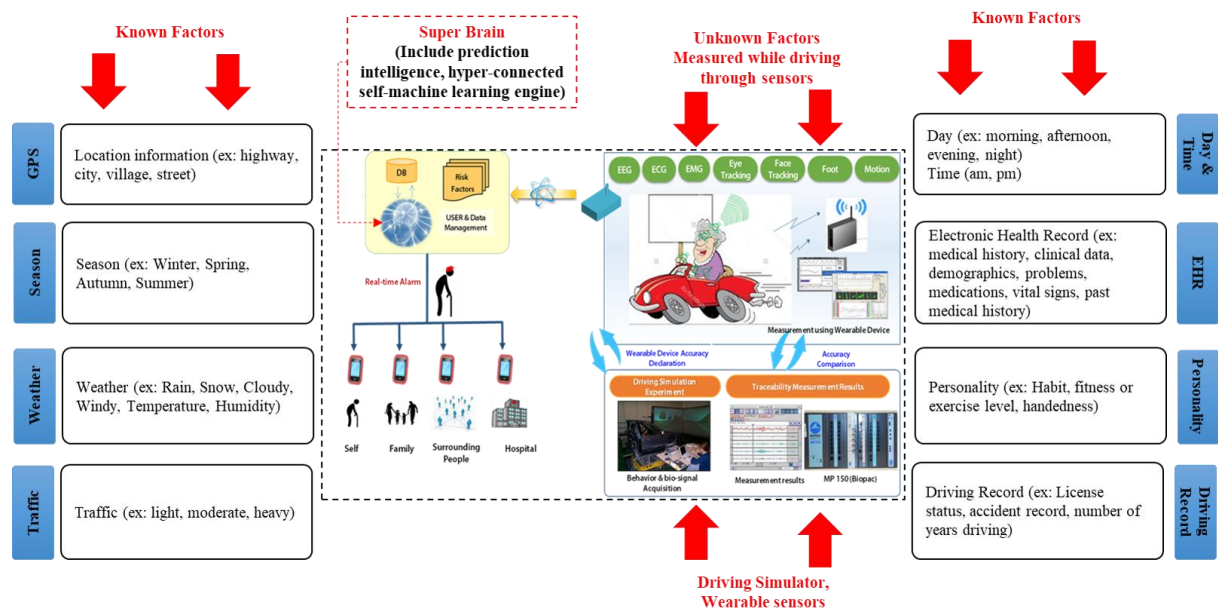


Figure 6. Outline of our developing stroke prediction system while driving. Known factors and unknown factors are detailed. Super brain predict and alarm to concern.

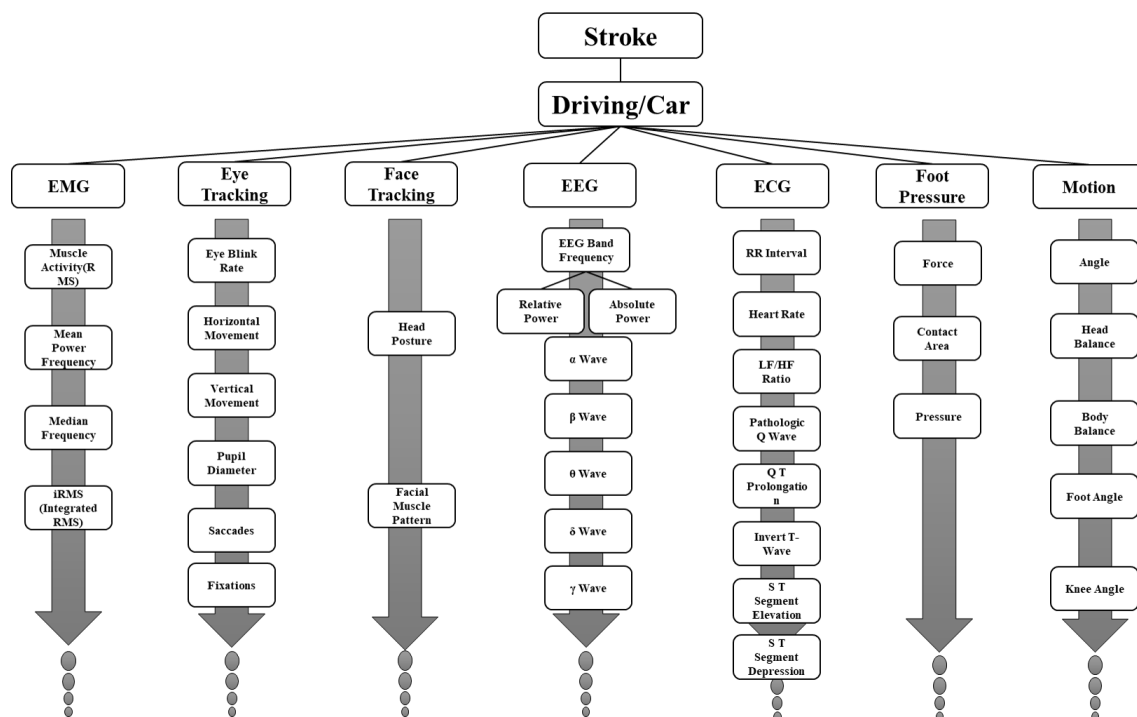


Figure 7. Physiological/Activity parameters and its variables monitored and calculated while driving for stroke prediction

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