Monitoring Biomarkers of Drivers with Medical Wireless Sensor Networks Deployed in Connected Vehicles

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Abstract

Millions of traffic accidents occur each year that negatively impacts the economy as well as the human lives. Human error is the principal cause of traffic accidents. Medical conditions of drivers that are not usually monitored have a significant role in accidents. Chronic illnesses have been shown to have reduced cognitive, visual and motor skills, which are the key driving requirements. In conjunction with the current wireless communication technologies and data processing capabilities, it is urgent that suitable sensors be deployed to perform non-invasive detection of objective biomarkers that state the driver's health. Cellular V2X communication provides the ability to share the information collected to the nearby driving vehicles for cautionary stance and to the hospitals for clinical validation. Dedicated short-range communication (DSRC) allows for the establishment of vehicle-to-vehicle communication (V2V) and vehicle-to-anything communication (V2X). This interconnected setup of Connected Vehicles (CV) would pave the way to establishment of smart city.

Keywords: Driving, psychomotor skills, psychological disorder, biomarker, array of sensors, DSRC, V2V architecture, low latency, smart city.

1 Introduction

Around 250 million vehicles are in operation in the United States of America [1]. Every year 6 million car crashes occur out of which 90 percent are driver related [2]. Moreover, 2 million drivers in car accidents experience permanent injuries every year [3]. These are some concerning statistics on lives of public. The fact that 90 percent accidents are due to human error of varied kinds is a matter of concern. Driving is a complex psychomotor performance [4]. Medically, there are multiple conditions varying from physical to psychological characteristics that impair driving ability dramatically. Only psychological disorder has been explored for the limitation of the long extensive research of other disorders. Psychological disorders such as schizophrenia and depression influence one's driving ability that include reduced vigilance, poor impulse control, poor judgment, and impaired visual-spatial functioning. Thus, every such disorder has objective biomarkers which can be detected using proper systems. Research [5] shows beat to beat variability of heart is a measure of cardiac autonomic innervation by the brain, which leads to death. Links have been established with heartbeat variability in depressive and anxiety disorders. Research carried out by University of Helsinki reveals that those with resting heartbeat greater than 82 BPM during youth are 69% more likely to be diagnosed with Obsessive Compulsive Disorder (OCD), 21% more schizophrenia and 18% more anxiety disorder than those with resting heartbeat less than 62 BPM [6]. Heartbeat becomes one of the key biomarkers. Ocular events (such as saccades, blink, vergence, and pupillary response) with certain metrics (such as duration, rate, and velocity) prove to be important biomarkers for predicting many such diseases (Parkinson's disease, Huntington disease, Alzheimer's disease, stress, anxiety) [7]. Thus, many such parameters can be assessed for various diseases upon extended literature survey. Currently, commercial vehicles with advanced driver assistance safety systems (ADAS) offer features like Forward Collision Warning, Automatic Emergency Braking, Electronic Stability Control, Road Sign Recognition and many more [8]. There exists an urgent need for the proposed research due to the lack of integration of medical biomarkers into the vehicle's ADAS. Therefore, sensors or an array of sensors which do not obstruct the normal functioning of the driver, can be deployed in the vehicle to predict these biomarkers and asses the

drivers' capacity to drive. Non-invasive technologies play a key essential role. Anomaly from the standard values would be picked up by these array of sensors. The processing of such data can be done onboard or on cloud with ultra-low latency connectivity provided by 5G. Any intravehicular communication is a part of the Intelligent Transport Systems. The main objective is to make road travel green, efficient and most importantly, safe [9]. DSRC could be deployed to allow the drivers' condition to be communicated to the nearby vehicles by the use of V2V communication architecture. Nearby vehicles can be warned to have a cautionary stance. Features of connected vehicles could pave the way for a community to switch to a smart city.

2 Statistics of Traffic Accidents

The statistics of every traffic accident demonstrate the true side of it heading to a very critical and deciding point. Road injuries reflect the darker side of reality, but they do happen. This review will provide the context for the need for technologies that would be necessary to ensure the safety of drivers and vehicles.

NHTSA carried out an extensive research on the causes of crashes which provided the entire statistics and demography of the accidents [10].

The statistics provide data regarding: 1. The number of vehicles involved (one, two, three or more) 2. Vehicle Body Type (Passenger, SUVs, Light Trucks) 3. Atmospheric Condition (Clear, Cloudy, Rainy, Snowy) 4.Natural Lighting Condition (Daylight, Dark, Dusk, Dawn) 5.Role of Occupant (Driver, Passenger) 6. Configuration (Trafficway, Direction, Intersection) 7. Critical Attributes of Driver (Kinds of Error) 8. Critical Mechanical Failure of Vehicle (Engine Failure, Brake Failure)

The statistics reveal that 57.2% of the crashes are due to two vehicles, 30.8% due to a single vehicle, and the remaining 12% due to three or more vehicles. With regard to body configuration of the vehicles involved in crashes, 56.7% are passenger cars, 18.8% are SUVs, 13.3% are light trucks, 7.3% are vans and the rest of the 3.9% are other body types.

Crashes that occurred under various atmospheric conditions reveal that 74% are under clear condition, 17.8% under cloudy, 9.3% under rainy, 2.7% under snow/sleet and the rest 1.5% under other weather conditions. When critically viewed, under the natural lighting conditions prevailing in those crashes, it was found that 71% occur in daylight, 12.8% in dark, 10.2% in dark but lighted condition, 3.4% at dawn and 2.6% at dusk. Even role of
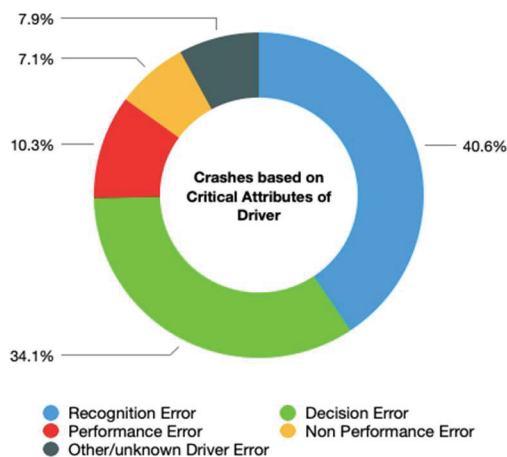
Figure 1   Crashes based on types of human errors.

occupant states that 66.5% crashes occur due to driver and rest 33.5% are caused due to passengers.

Vehicle's mechanical failure leading to crashes showed that 43.3% are due to tire failure or degradation, 25% due to brake failure, 10.5% steering/suspension/transmission/engine related issues, 20.8% other deficiencies and 0.5% which could not be identified.

Figure 1 depicts the classification of human errors, which are the leading causes of crashes, into various categories with the percentage of occurrence of each type. The segments are: 1. Recognition Error – 40.6%, 2. Decision Error – 34.1%, 3. Performance Error – 10.3%, 4. Non-Performance Error – 7.1%, and 5. Unknown Error – 7.9%.

Recognition error is classified into various categories that are self-explanatory with their percentage in crashes. They are inadequate surveillance – 20.3%, internal distraction – 10.7%, external distraction – 3.8%, inattention (such as daydreaming) – 3.2% and other/unknown recognition errors - 2.5%. Decision error is classified into sub-conditions – too fast for conditions – 8.4%, too fast for curve – 4.9%, false assumptions of other's actions – 4.5%, illegal maneuver – 3.8%, misjudgment of gap or other's speed – 3.2%, following too closely – 1.5%, aggressive driving behavior – 1.5% and other/unknown decision errors – 6.2%.

Performance error is classified into overcompensation – 4.9%, poor directional control – 4.7%, panic/freezing – 0.4% and other/unknown performance error – 0.3%. Non-performance error is classified into heart attack/other

physical impairment – 3.2%, sleep – 2.4% and other/critical non-performance error – 1.6%. Around 7.9% of the cases could not be classified into the above categories but are caused due to the human error.

This study was essential in order to show the evidence and find out the causes of accidents which can averted by the use of state-of-the-art detection and prevention systems. Medical conditions actually cause 7.1% of the crashes. Eventually, the road accidents need to be eliminated whose root cause is the human error.

3 Prevalence of Human Error

The statistics of crashes reveal the presence of human error but these errors need to studied extensively in order to find the cause and design protective systems accordingly. This fact is extremely dominant because driving is a complex psychomotor skill. Experienced drivers or individuals driving on a daily basis would not be able to determine the complexity because it is part of their life as a form of habit. Any skill becomes perfect upon regularly practising. Driving has been explained extensively in the following section so as to make researchers and public appreciate the complexity involved which would provide a very essential fundamental for the design of algorithms associated with autonomous driving. Eventually, autonomous driving will completely replace the driver by an array of sensors whose input would be processed by artificial intelligence or machine learning algorithms to carry out decisions similar to which an actual driver would do.

4 Complexity of Driving

Driving, as defined earlier, is a complex psychomotor skill. Psychomotor learning is the development of coordinated routines of muscular behaviours driven by environmental signals. Benjamin Bloom developed the domains of learning which could be categorised into three – 1. Cognitive Domain (Knowledge) 2. Psychomotor Domain (Skills) 3. Affective Domain (Attitudes) [11]. This classification, very commonly known as Bloom's Taxonomy, is scientific in nature and have a very well explained meaning whose discussion is out of the scope of this research. The learning (in general) can be gauged using the measurement of parameters as speed, strength, endurance, coordination, precision, flexibility, agility, dexterity, manipulation, grace and technique [12]. Whereas driving has few specific skills required, which

Table 1   Parameters of psychomotor domain

Parameter	Description
Perception	The capacity to adapt as per sensory input to motor movements
Set	Readiness to act
Guided Response	The capacity to imitate a action demonstrated or to use trial and error
Mechanism	The ability to translate learned responses with competence and confidence into habitual actions
Complex Overt Response	Capacity to implement dynamic sequences of behavior skillfully
Adaptation	The ability to alter the skills learnt to meet special events
Origination	Establish new patterns of activity for a specific circumstance

Table 2   Parameters of visual factor

Parameter	Description
Accommodation	Changing the shape of the eye's lens to focus images
Adaptation	Shift in exposure to varying light conditions
Static Visual Acuity	Capacity to easily perceive the little details
Angular Movement	See objects pass through the field of vision
Movement in Depth	Detecting differences in visible picture dimension
Color Perception	Discrimination between various colors
Contrast Sensitivity	Seeing objects close in luminosity to their context
Depth Perception	Judging the gap between items
Dynamic Visual Acuity	Ability to track passing objects compared to an observer
Eye Movements	Changing the direction of gaze
Glare Sensitivity	Capability to tolerate and recover from glare results
Peripheral Vision	Object recognition at the edge of the field of view

determine the quality as well as safety of the task. Psychomotor domain is very uniquely categorised [13] shown in Table 1.

Focusing on to the aspects related to driving, the three major abilities required are – 1. vision 2. cognition, and 3. motor function, in order to drive safely [14]. Around, 83% of the driving requires visual input [15]. The specific visual factors which are essential for driving is shown in Table 2.

The above tasks become a part of our reflex but upon detailed explanation shows the complexity of the task. Replacing this setup with a video

Table 3   Parameters of cognitive domain

Parameter	Description
Divided Attention or Switching Attention	Monitoring multiple sources of information that are all task-critical
Selective Attention	Directing and focusing attention on the most relevant sources of information, filtering noise and distractions
Visual Attention or Speed of Processing	Extracting information from a portion of the visual field for more in-depth processing, such that stimuli detected are subsequently recognized and may be responded to
Visual Search	Directing gaze fixations to locations where situationally important information can be acquired and processed
Visuospatial Abilities	Organizing visual information into identifiable forms, especially recognizing a whole object when information is missing
Working Memory	The cognitive resource needed to process new inputs while retaining and manipulating information for current use
Permanent or Long Term Memory	Previously learned information that can be retrieved when needed
Executive function (reasoning; decision-making)	Identifying rules and making inferences; choosing (rapidly and correctly) among a range of alternative actions
Geographic Orientation	Knowledge of familiar locations and/or being able to use strategies for route following and to find new destinations
Vigilance	The ability to maintain or sustain attention over a long period

processing setup is a daunting task which leads to the boom of image processing techniques.

The next essential contributions that come from the cognitive domain is described in Table 3.

The final major factor is the motor function which includes the strength, range of motion of extremities, trunk-neck mobility and proprioception (awareness of position and movement of body). These abilities tend to decrease as age increases.

The overall driving has been very elaborately described which confirms the complex decision taking steps occurring in the human brain while driving. The simple task is a dauntingly complex one, which, from an engineering point of view, requires extensive research in order to incorporate it into fully developed autonomous vehicles. Essentially, there is a race going to replace

the human brain for driving. Humans not only drive but carry out their entire life learning new things and carrying out other tasks which goes unnoticed everyday but would make the researchers appreciate the design of brain.

5 Medical Conditions Affecting Driving

The fact that chronic illness has influence on driving generally goes unnoticed but it plays a very significant role. Statistics presented earlier, which categorized the human error into multiple, showed that medical condition does play a significant role in it. This discussion shows the exact chronic illnesses which have minute or significant influence on the driving ability [16]. The conditions that have shown influence are in Table 4.

These vast number of chronic illnesses which affect driving is a matter of concern. Discussing each and every illness elaborately is out of the scope

Table 4 Disorders influence on driving

	Disorder Class (Specific Disorder)
	Alcohol Abuse & Alcohol Dependence
	Cardiovascular Disease
	Cerebrovascular Accident (Stroke)
Cognitive Impairment	Dementia, Traumatic Brain Injury
	Diabetes Mellitus
	Epilepsy & Seizure Disorders
	Musculoskeletal Disorders
Neurological Conditions	Parkinson's disease, Multiple Sclerosis, Cerebral palsy, Spina bifida,
Psychiatric Illness	Schizophrenia, Depression, Anxiety Disorders, Personality Disorders, Attention Deficit Hyperactivity Disorder (ADHD)
	Respiratory Disorders
Sleep Apnea related Disorders	Sleep Apnea, Narcolepsy
	Vestibular (Balance) Disorders
Vision Disorders	Cataract, Glaucoma, Age-Related Macular Degeneration (ARMD), Diabetic Retinopathy, Refractive Errors, Retinitis Pigmentosa, Hemianopia, Color Vision Disorders, Monocular Vision, Corneal Pathology, Nystagmus, Visual Acuity, Visual Field Loss, Contrast Sensitivity

of this research. They can be diagnosed using specific machines and under clinical setting. However, the upcoming new research suggests that the definition of objective biomarkers allows the clinicians and engineers to detect the disorders. Biomarkers are, by nature, measurable and quantifiable features of biological processes [17]. They tend to provide clinically relevant information which would, upon detection, provide an ample amount of medical condition of any person. Throughout the area of biomedical, engineering and scientific analysis, objectivity is pursued in order to standardize the criteria.

6 Objective Biomarkers

Clinically, eyes reveal a lot about person's well-being. Ocular movements are clinically found to be associated with the neurological disorders. Saccade is the rapid movement in the eyes. There exists behavioral correlation of saccade abnormalities with the neurological conditions [18]. Gaze movement has been categorized into following –

1. Slow – The slow movement correspond to pursuit and keep track of moving stimuli keeping it centered on fovea. Generally, it ranges from 30–45 degree/sec.
2. Fast – Such movement correspond to saccade. It is characterized by ballistic eye movement or abrupt change of line of sight. Typically, 2 to 6 times/sec, a saccade is performed.

New age high precision cameras are very well equipped to detect the gaze of the eyes in alliance with powerful state of the art algorithms. Disorders such as Parkinson's disease (early & advanced), Spinocerebellar degeneration, Progressive Supranuclear Palsy and Focal Lesion are some of the disorders which could be detected using saccade patterns.

Research has found eye movements in patients with neurodegenerative disorders that states properly the criteria for ocular movements in order to statistically and clinically predict Parkinson's disease, Parkinson's disease Dementia, Dementia with Lewy Bodies, Huntington Disease and Alzheimer's Disease [19].

Ocular events were finally categorized with their own metrics which would depict multiple biomarkers [20]. These events are in Table 5.

These metrics mentioned in Table V help predict the age, balance, hearing capability, quality of sleep, stress & anxiety, cognition & cognitive ergonomics, pain and mental disorders, which are discussed below.

Table 5 List of oculometrics

Event	Metrics
Saccade	Amplitude, duration, velocity, peak velocity–amplitude relationship (mean sequence), rate (frequency), acceleration, deceleration, latency
Fixation	Duration, rate (frequency)
Blink	Duration, rate (frequency)
Vergence	Velocity, amplitude, duration, latency
Pursuit	Root-mean-square error of gaze and target position, and latency
Vestibulo-ocular	The ratio of eye velocity to head velocity
Optokinetic Response	Amplitude, duration and velocity of compensatory slow phases and saccadic quick phases of eye movements
Pupillary responses	Statistical features (e.g., mean, range) of pupil diameter, latency and peak of task-evoked pupil dilations, (pupillary) index of cognitive activity

Eye movements can provide the ability to assess mental disorders [21, 22] and very distinctively differentiate between schizophrenia from obsessive compulsive disorder [22]. Tracking of eyes does benefit in diagnosing anti-social personality disorder, dyslexia, autism, the acquired immunodeficiency syndrome dementia complex [23].

Pain is another biomarker revealed using attentional bias towards pain distraction [24–26] which can be detected very accurately using oculometrics. It proves to be an important biomarker.

Factors of Cognition – memory [27, 28], attention [29] and decision-making [30] is extremely well diagnosed by tracking the eye. Moreover, empirical correlation has been found by the effects of ageing on safe driving [31]. Navigation is hampered upon disoriented spatial memory, which is a cognitive ability [32]. Eyes can even measure the mental load of performing a task [33–35].

Sleeping pattern can be detected using the eye movements – Rapid Eye Movement (REM) & non-REM sleep. It does depict the quality of sleep but under extreme clinical settings which doesn't suffice with the driver's non-invasiveness [36].

Research shows several patterns on facial landmarks which predicted the level of drowsiness in driver from camera which suggested the facial landmarks as one of the biomarkers [37].

Thus, these biomarkers have a direct clinical correlation to specific disorders. Detection of such would aid the prediction of medical condition of the drivers.

7 Influence of Psychological Disorders on Driving

Recent reports from WHO suggests that 450 million people suffer from psychiatric illness [38]. It also is the leading causes of ill-health. Moreover, treatments are available but nearly, two-thirds of them never seek professional help. Lifestyle lead by the individual is an important aspect of the person's mental health. Physical activity, mental activity, alcohol consumption, smoking, life rhythm and body mass index are some of the predictors of the mental health [39].

The psychotic conditions have a correlation to the changes occurred in physical and cognition of humans. Specific impact of each disorder named earlier, has been explained.

Schizophrenia is a chronic illness typically characterized by hallucinations, delusions and deep distortions in the way of thinking. It is categorized [40] into three – 1. Positive or Psychotic Symptoms 2. Disorganized Symptoms 3. Negative Symptoms whose elaborate discussion is out of the scope of this technical paper. But, individuals portray a reduced capability to selectively attend important information from unimportant ones, reduced concentration and reduced ability to perform in complex condition.

Depression is a psychological condition marked by an intense sense of distress, feelings of despair, lack of motivation or satisfaction in nearly all task, feelings of hopelessness and suicidal thoughts or self-blame. Research [41] shows that depressive patients typically demonstrate disturbances in attention, impaired information processing & judgment, psychomotor retardation, reduced concentration, change in reaction time, suicidal ideation and fatigue. In context of drivers, their slow responsivity, poor concentration and suicidal ideation are practical conditions which leads to crashes.

Anxiety Disorders are defined by signs of intense distress, panic and action of avoidance. Decreased working memory, lack of attentional capacity and getting easily distracted are some typical traits of person with such disorder. A potential to experience Panic attack has severe consequences which was shown statistically in the earlier section.

Personality disorder is described as profoundly ingrained and lasting patterns of omnipresent and inflexible personality traits which deviate from

cultural norms and trigger distress or functional disability. They are categorized into three clusters. They are at a high risk of alcohol or drug abuse and violent or self-destructive behaviors. Functional impairments such as aggression, egocentricity, impulsiveness, intolerance of frustration, irresponsibility and resentment of authority have obvious consequences on driving ability.

ADHD is a debilitating chronic personality condition marked by deficient rates of cognitive focus and/or hyperactivity-impulsiveness. They are often characterized by difficulty in planning, organizing, estimating time, shifting focus, filtering distractions, managing frustrations, modulating emotions, recalling and impaired processing speed with inability to carry a task in face of temptation, frustration or interruption.

The reason to point out all the impairments demonstrated by various psychiatric illnesses was to show the impact they have on the cognitive abilities of an individual which has a direct or indirect impact on the driving ability.

8 Commercial Safety Systems in Vehicles

Currently, vehicles contain an array of protective systems in it to prevent drivers from crashing as well as some essential systems which protect the driver during a crash [42]. The active safety systems contain many levels of protection.

Forward Collision Warning System (FCWS) is an advanced safety technology that monitors a vehicle's speed, the speed of the vehicle in front of it, and the distance between the vehicles. Upon critical condition, warning pops up for driver but it does not take full control of the vehicle. Automatic Emergency Braking (AEB) is a system that slows down the vehicle and potentially reduce collision severity in an unavoidable circumstances. It gets activated only when driver's braking is not enough to avoid collision. Antilock Braking System (ABS) is a system that prevents the brake from locking up which ceases the rotation and avoids uncontrolled skidding.

Electronic Stability Control (ESC) prevents crashes by reducing the danger of vehicle skidding or driver losing control of vehicle as a result of oversteering. Adaptive Cruise Control (ACC) is an intelligent form of cruise control which speeds up or slows down to maintain a steady distance from vehicles ahead via onboard sensors. Tire Pressure Monitoring System (TPMS) checks the air pressure within the pneumatic tires of various vehicles. Unbalanced pressures lead to uncontrolled steering which can cause crashes.

Lane Departure Warning (LDW) warns drivers who tend to move out of lane on freeways or arterial roads in order to reduce collisions due to distractions, drowsiness or other errors. Blind Spot Detection (BSD) helps in detection of areas not visible to drivers due to window pillars, headrests, backseat passengers & other objects can lead to crashes. This system detects other vehicles located to driver's side and rear. Road Sign Recognition (RSR) is a system that notifies drivers of the enforced restrictions on the roads.

Similarly, there are some standard passive systems onboard which save the drivers during an emergency. Airbag is a flexible bag which gets inflated upon collision few milliseconds before the driver heads collide with any part of the vehicle. Seatbelt secures driver's position from getting changed or impacted due to collision, jerk or sudden braking. Occupant Sensing System detects the presence of an occupant and simultaneously switches on & off the air bag system as it is a sophisticated technology. Pedestrian Safety System detects the pedestrians and automatically reduces the speed of the vehicle to avoid collision or decrease the damage due to such.

9 Suggested Methodology

The current commercial systems does take into account a wide amount of information and process accordingly to safeguard the driver. But, the medical sensors could take into account of the drivers' well-being. A cognitive wellness, ocular health and mental wellbeing, if measured at an appropriate degree of precision, may contribute to a significantly safer system since driving is a dynamic psychomotor ability.

Effects of ageing and many other distinct biomarkers could be very effectively be predicted using the ocular movements as mentioned earlier. Research carried by University of Helsinki [43] shows the correlation of increased heartbeat and blood pressure with psychiatric conditions. Resting heartbeat greater than 82 beats per minute (BPM) during youth are 69% more likely to be diagnosed with Obsessive Compulsive Disorder (OCD) than people having resting heartbeat less than 62 BPM. Moreover, the chance to have schizophrenia increases by 21% and anxiety disorder by 18%.

Harvard Medical School published some medical disorders related to increased and decreased heartbeat to heart attacks, having certain infections, varied levels of potassium anemia, atrial fibrillation and even asthma [44].

Research carried out on heart variability in depressive and anxiety disorders and found out that beat to beat variability is a measure of cardiac

autonomic innervation by the brain, which leads to death [45]. Psychosocial factors affect the development and prognosis of cardiovascular disease. Decreased heart rate variability is a key predictor of cardiac health and adaptability.

Modern sensors are very effective for the monitoring of heartbeats, which is one of the main biomarkers. Compared to its scale, cameras now a day are of exceptionally high performance. Research needs to be conducted extensively to evolve sensors that are capable of detecting the biomarkers identified in a non-invasive manner, which is the goal. These sensors cannot obstruct or threaten drivers in some manner that may possibly induce a crash rather than deterring it from occurring. Image based processing and wearable technology allows the detection with non-invasive being the key essential factor.

After acquiring the data from the array of sensors, processing them is another challenging task in a limited time frame and processing capability. This is exactly where the ultra-high speed 5G communication architecture plays a role. The generated data can be preprocessed on-board to segregate the essentials from the non-essentials. These data can be uploaded in a real time manner to the cloud for processing and extracting the meaningful data, which is the health condition of the driver. The extremely low latency of the communication setup plays a key role in this.

Intelligent Transport Systems (ITS) is the application of sensing, analysis, control and communications technologies to ground transportation in order to improve safety, mobility and efficiency [46]. Safety has always been the top priority for any organization due to the mental losses of family members as well as financial losses to the government. The benefits of having an ITS infrastructure or architecture are safety, traffic flow efficiency, productivity & cost reduction and environmental benefits [47, 48].

Thus, intravehicular communication, an essential part of the ITS, plays a key role. Sharing information between vehicles is what comes next in the sequence to take collaborative actions. Collaborative actions include informing the health condition of the driver and vehicle to others nearby which makes them aware and alerts them to have a precautionary approach on roads. It makes the travel safer on road for everyone. Reliable communication media are being identified and developed to establish secure and stable reliable connection so that information can be shared. Dedicated Short Range Communication (DSRC) is an open source protocol for wireless communication very similar to WiFi [49]. The fundamental difference from WiFi lies in the highly secure, high-speed wireless communication between vehicles

and infrastructure. The key attributes of DSRC comprise of low latency in order of 0.02 seconds, limited interference (because of robustness) and strong performance under adverse weather conditions.

The method of communication from at least one vehicle to other vehicle (vehicle-to-vehicle – V2V) or infrastructure entity (vehicle to anything – V2X) is the fundamental of connected vehicle architecture which in the basis of sharing information of sensors in large volumes [50].

Reliability of communication between vehicles can be increased further by the implementation of mmWave in alliance with DSRC or 4G cellular communications infrastructure to permit large data transmission from sensors [51].

Cooper, i.e. cooperative perception is the new area of technology which aims to improve the wrong decisions taken by the autonomous vehicles due to inaccurate detection and recognition through integration of real world scenes and raw sensors data. This setup is also used to assist the driver to make them perceive about the traffic system beyond the field-of-view [52]. Integrating medical sensors in this domain would make the road travel much safer for the driver as well others nearby.

Implementation of DSRC in real-time and finding the drowsiness patterns in drivers to inform the nearby drivers and proceed with precaution was done to show the real application of this technology [53]. This is only the beginning of some robust technologies because, on the basis of that, driving will take into consideration the health condition of the driver which was absent or was not investigated.

10 Conclusion

The statistics portrayed in this documentation is evidentiary about the role of human error in road accidents. Classification of errors based on various conditions provides a deeper understanding of such unwanted fatal events. The medical condition of a driver does have a profound impact on the ability of driving. It helps the industry to develop safety equipment as well as methodologies to prevent accidents. Reliable technologies are being developed at a staggering rate but implementation of non-invasive array of sensors to monitor the mentioned biomarkers of driver would ascertain their health. Interconnected vehicles sharing real time data with the vehicles nearby could have a cautionary stance if anyone shows indication of illness. If the conditions fall beyond the understanding of the system, these data could be sent to the nearby hospitals. It may be reviewed by the Emergency Response Teams

for clinical validations. Under critical medical circumstances, the driver could be advised to travel to the closest hospital for health examination and to prevent any accident. Alternatively, should conditions warrant, an ambulance could be dispatched and the driver advised to pull off the road. This provides an added layer of safety for the driver and everyone around. Features of connected cars such as the ones described could pave the way for a city to transition to a smart city.

Acknowledgment

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He has co-authored the textbook Source and Channel Coding: An Algorithmic Approach. He has contributed to several books, including Mobile Communications Handbook and The Communications Handbook (both CRC Press). He holds fourteen patents in the area of wireless location management and authentication strategies as well as in the area of enhanced services for wireless. He is the recipient of the SAIC Publication Prize for Information and Communications Technology. He has served or is serving on the Editorial Boards of IEEE Personal Communications, IEEE Surveys, IEEE Communications Magazine, Journal of Mobility and Cyber Security and International Journal on Wireless Personal Communications (Springer) and has chaired sessions in many international conferences and workshops. He has also served as a Guest Editor for several Special issues of IEEE Network, IEEE Communications Magazine, and ACM MONET. He served as a co-guest editor of the Feature Topic "Human Bond Communications," that appeared in the February 2019 issue of IEEE Communications Magazine. He served as a guest editor of 2015 October IEEE Communications Feature Topic titled "Social Networks Meet Next Generation Mobile Multimedia Internet," March 2012 IEEE Communications Feature Topic titled "Convergence of Applications Services in Next Generation Networks" as well as the June 2012 Feature Topic titled "Social Networks Meet Wireless Networks." In April 2011, he was awarded 2010 IEEE Region 5 Outstanding Engineering Educator Award. He received the best paper award for the paper "A Multi-Path Routing Scheme for GMPLS-Controlled WDM Networks," presented at the 4th IEEE Advanced Networks and Telecommunications Systems conference. Dr. Mohan is a co-founder of the startup IntelliNexus, LLC, the objective of which are the development of innovative adhoc vehicular networking to advance the notion of connected cars and the development of IoT and IoV applications to improve traffic safety and reduce accidents and congestion. He holds a Ph.D. degree in electrical and computer engineering from McMaster University, Canada, the Master's degree in electrical engineering from the Indian Institute of Technology, Kanpur, India, and the Bachelor's degree in Electronics and Telecommunications from the University of Madras, India.