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Emotionally Adaptive Driver Voice Alert System for Advanced Driver Assistance System (ADAS) Applications

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***Abstract*—Human cognitive analysis catalyzes the innovations in Human Machine Interface (HMI) for a variety of applications. In an Automotive Advanced Driver Assistance System (ADAS), the continuous cognitive interaction of the driver with the assistance system plays a crucial role in enhancing the active safety system. Multiple ADAS functionalities uses a variety of driver alerts through visual, audio and vibrational means to provide a numerous safety alerts to the driver. The effectiveness of any alert system is measured through its success rate in mitigating the actions which are against the alert commands. The actions taken by the driver for the alerts depends heavily on the driver's moods, which are responsible for driver's perception in understanding the alerts. Even though the voice alerts are considered as the most effective form of human alerts, the static nature of the voice alerts makes them less effective in making the driver to understand the criticality of the alerts when his moods are abnormal or having a reduced driving concentration levels. An adaptive voice alert system with a cognitive driver synchronization makes the alert penetration successful when the driver's moods are abnormal or having a reduced driving concentration levels. Here in this paper the adaptive voice alert system is designed using the driver's emotional cognitive features. The emotionally adaptive voice alert system changes the voice alerts as according to the moods of the driver, which are measured by Deep Learning based Emotion Recognition System. The adaptive voice alert system makes the voice enabled HMI effective which improves the vehicle safety.**

Keywords—Advanced Driver Assistance System (ADAS), Convolutional Neural Network (CNN), Emotion Recognition System (ERS), Human Machine Interface (HMI)

I. INTRODUCTION

Human Machine Interface systems are becoming popular among the diverse applications. In an exponentially growing automotive industry, where all the major OEM's and Tier-1 companies are aiming for an autonomous car by the mid of 2030, the HMI plays a crucial role in achieving the Level-V autonomy. The present day automotive trends are increasing, which are making a smooth way to achieve the full autonomy soon. The footsteps in achieving the full autonomy are the level-III and Level-IV autonomy level features. The below levels of full Level-V autonomy is having multiple number of user interactions with the driver assistance system. The user intractable HMI helps in achieving the system functionalities without the loss of vehicle safety which are measured by both active and passive safety techniques. The interaction of the human with the system ranges from a physical interaction to a cognitive interaction. In an automotive system the interaction of the driver with the automotive system components plays a crucial role in achieving in the performance of the automotive driver assistance systems.

With the physical interaction of the driver with the automotive system components is getting vanishing with the introduction of driverless cars, the interaction of the driver's cognitive features are becoming essential in understanding the driver better to conclude the automotive decisions. The cognitive study is a vast field with a combination of psychology, neuroscience and artificial intelligence. The human emotions are one of the significant cognitive features which describes the internal feelings of a person in a showcasing way. The study of emotions started with the theory of mind past in 1980's. In automotive applications the driver's emotions and the conclusions based on emotional analytics plays a crucial role in achieving a cognitive HMI. The alerts generated during the driving plays a crucial role in taking some critical driving decisions by the driver. In an ADAS system the alerts are generated mainly for alerting the driver regarding some scenarios which are difficult to interpret by the driver alone and also during the decaying driving concentration levels to boost his alertness. The cognitive HMI alert system helps in conveying the alert to the driver effectively.

The paper is organized as follows section II describes the Advanced Driver Assistance System. Section III mentions the different Voice Alerts in Advanced Driver Assistance System. Section IV talks about the Human Facial Emotion Recognition System. Section V describes the Proposed Emotionally Adaptive Voice Alert System, finally section VI shows the Experimental Results with a discussion and ends with a conclusion in section VII.

II. ADVANCED DRIVER ASSISTANCE SYSTEM

Advanced Driver Assistance System is a HMI system designed to assist the driver while driving a vehicle to enhance the road safety. The ADAS functionalities helps in mitigating the human error by providing an automated adaptive assistance to the driver. The advanced ADAS functionalities are designed to reduce the road accidents by continuously monitoring the inside and outside activities through multiple sensor arrangements. The ADAS functionalities minimizes the risks by reducing the driver error, predicting the trajectories, continuously alerting the drivers and taking a vehicle control during driver's incapable situations. The essence of the road safety is taken by few countries across the world, particularly in a European Union countries. The European New Car Assessment Programme (EuroNCAP) [1] is providing the new guidelines in road safety for all the vehicles in European territory and new legal framework is adopted in Europe on 7th July 2010 to deploy the new innovative automotive safety technologies. Similarly National Highway Traffic Safety Administration (NHTSA) [2] is providing the safety guidelines in USA followed by Bharat New Vehicle Safety Assessment Program (BNVSAP) in India. The safety organizations provides the safety reports of the new vehicles based on the performance of the vehicle in testing the impact of collision and also they provide a numerous standard ADAS guidelines to enhance the road safety.

ADAS provides wide range of active safety functionalities such as Adaptive cruise control, Emergency brake assist, Blind spot monitoring, Driver monitoring system, Automatic parking, Forward collision avoidance, Night vision system, Adaptive front lighting system, Intelligent speed adapter, Pedestrian protection, Surround view system, vehicular communication etc. Most of the sophisticated ADAS functionalities uses Camera, RADAR, LiDAR, 3D Cameras, GPS, Accelerometer, Gyroscopes etc. sensors. The sensor information is processed through advanced computer vision and signal processing algorithms with Artificial Intelligence to understand the real time driving conditions effectively. The sensor information is fused to derive a common information about the surroundings. Some of the in-vehicle ADAS functionalities uses microphone, blood pressure sensor, temperature sensor etc. internally to monitor the conditions of the driver inside the vehicle.

III. RELATED WORK ON VOICE ALERTS IN ADVANCED DRIVER ASSISTANCE SYSTEM

Voice alerts are the important system components of internal ADAS functionalities such as Driver health monitoring system, Drowsiness monitoring system as well external ADAS functionalities. Voice alerts warns the driver whenever his driving concentration levels goes low or when some of the human non recognizable events need to be informed to the driver. The alerts inside a vehicle ranges from a visual display on the dashboard to a vibrational alerts in the driver's seat. The alerts generated to alert the driver contains a significant information about the present events and also the predicted event from an ADAS system. In an Adaptive cruise control the alert informs the driver about the speed limit to maintain in all the scenarios, similarly in an Emergency brake assist [3] the alerts informs the driver about the braking when it encounters a pedestrian or an incoming vehicle. In a Blind spot monitoring the system alerts the driver about the presence of objects in a blind spot, in a Lane departure system the system alerts the driver about the change of lane and the movement of nearby vehicles in other lanes. Some of the alerts present in an ADAS system are shown in Figure 1.

Among all the driver alerts in an ADAS system, voice alerts are considered as the significant and the most effective form of alerts in conveying the information to the driver while driving. The voice commands alerts the driver when his concentration levels goes down or when he is distracted or when conveying a message from an ADAS HMI system [4]. Kalaivani et.al [5] provides a system for voice alerts generation to prevent the accident when an obstacle is encountered.

Fig.1. Driver Alerts for different ADAS Applications

Sinha, N et.al [6] provides the survey of all possible driver alerts in an ADAS system which gets triggered after extracting the noticeable information from continuous sensor monitoring. Here the driver inattention and drowsiness monitoring is done through vehicle based, behavioral based and psychological based features. The alert systems in ADAS functionalities of Ford and Toyota are studied briefly through their cruise control, collision control and driver monitoring systems respectively. J. Källhammer et.al [7] proposes a relative driver alert system for the pedestrians. The contextual analysis is studied in prioritizing the alerts and also the pedestrian factors which influences the driver are studied. C. G. Babu et.al [8] proposes an EEG signal based driver inattention detection and alert system for the driver. X. Ma [9] proposes a CNN night time fatigue detection system and alert system for the driver using the video depth sequences. Z. Chaczko et.al [10] introduces an IoT (Internet of Things) based driver alert system for alerting the movement of the cyclists around a range of 20m using the surrounding infrastructure as a network.

The recent studies [5-10] suggests that the voice based driver alert system is incorporated in most of the driver alert systems for both internal and external ADAS functionalities, but there is no significant work is observed in the literature in improving the driver's perception in understanding the voice alerts effectively. Hence there is a need of an exclusive system to make the voice alerts effective and successful in all the mental conditions of the driver. If the moods of the driver are abnormal, which results in a negligence of alerts by the driver. The alert negligence causes a catastrophic failure in an automotive system which results in a loss of a life of both the driver and also the pedestrian with a severe infrastructure losses. Hence there is a need of cognitive analysis system which can monitor the moods of the driver and changes the vice alerts accordingly. The physical interaction of the driver with the voice alert is minimal, hence the cognitive interaction of the driver with the voice generation system makes the system flexible and reliable.

IV. EMOTION RECOGNITION SYSTEM

Human emotions are the prominent cognitive features which describes the internal feelings of a person trough a set of emotional outcomes such as happy, angry, sad, fear, disgust, surprise and neutral emotions. Emotions measure the conscious experiences which are responsible for the moods of the individual. Driver's cognitive analysis inside a vehicle environment helps in understanding the mental state of the driver while driving. The mental state of the driver is strongly influenced by both the internal thought processes and also on the happenings in the surrounding environment. The emotional analysis of the driver serve as an important tool in understanding the driver cognitively. The process of identification of human emotions is done through multiple means via emotion recognition from face, emotion recognition from voice, emotion recognition from body temperature, emotion recognition from EEG, emotion recognition from blood pressure etc. Among them the emotion recognition using face is more feasible considering the sensor arrangements and also the continuous availability of the facial data through a fixed front camera inside the vehicle.

Facial emotion recognition system is implemented through a Deep Learning system by training the Convolution Neural Networks (CNN) using the facial emotion data. Compared to traditional pattern recognition systems, the deep learning based systems provides a significant advantage in accuracy and also in performance. The incoming input image from the camera is processed and the face is detected using Haar-Cascades Classifiers (Viola-Jones Algorithm). The detected face image is fed into the CNN input later for both feature extraction and learning. The cascade of convolutional layer followed by a pooling layer is used for feature extraction inside the CNN. The convolutional layer consists of multiple filter banks of different orientations to extract the features present in an image though a 2D convolution operation, where all the directional features are extracted. The feature image is fed into the pooling layer for down sampling, where the dimension of the feature map is reduced. The down sampled image is applied a non-linear ReLU activation function to introduce the non-linearity into the system. The cascaded layers of convolutional and pooling layers are used to reduce the dimension of the image significantly. Finally the extracted non-linearly activated feature map is fed into the output layer which has a softmax activation function to predict the output classes using the posterior probability. The output layer consists of seven neurons to output seven classes of the emotions. The entire flow of the facial emotion recognition system is shown in Figure 2.

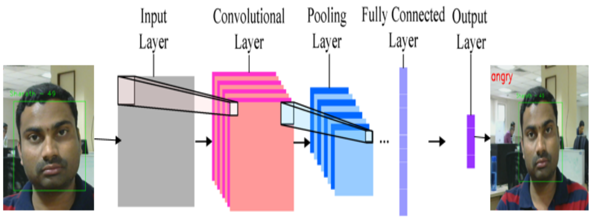

Fig. 2. Human Facial Emotion Recognition System using CNN

The CNN based ERS gets trained using a large emotion dataset. The hyper parameters of the neural network are tuned to train the CNN model efficiently to classify the incoming emotions with a good classification accuracy.

V. PROPOSED EMOTIONALLY ADAPTIVE VOICE ALERT SYSTEM

The proposed emotionally adaptive voice alert system is shown in Figure 3. The CNN is trained for a large dataset of human facial emotional images. The incoming driver's facial image which is captured using the front camera as shown in Figure 3, which is fed into the ERS after face detection. Prior to ERS, the incoming sensor image from the front camera is processed and the driver's face is detected. The detected face is fed into the trained CNN, where deep learning model classifies the incoming emotions into one of the predefined emotion classes such as happy, sad, angry, surprise, disgust, neutral and fear.

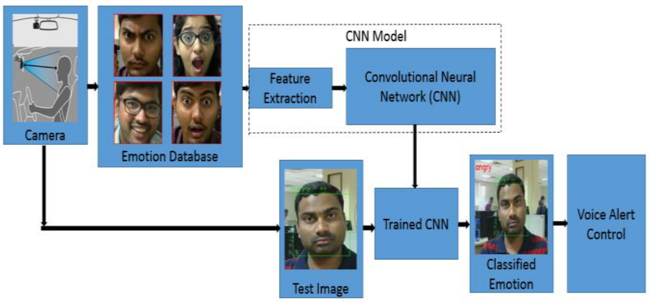

Fig. 3. Flow Diagram of Proposed System

The proposed system analyzes the emotions of the driver continuously and analytics is performed on the emotion data over a fixed duration of time. Based on the result of the emotion recognition system the Voice Alert Control system generates the voice alerts accordingly. When the driver is in a happy emotion, which means usually he follows the voice alert commands. Hence the voice alerts are generated moderately when the happy emotion is observed over a fixed emotion analytics duration. When the emotion of the driver is observed as angry in an emotion analytics duration, then the voice alerts are changed and made elaborative to make the driver to understand the criticality of the driving situation and also alerts the driver to control his emotions which impacts the driving significantly. The alert control system generates the voice alerts intensely during the state of negative emotions like sad, angry, disgust and fear and it generates the voice alerts moderately during the state of positive emotions like happy, neutral and surprise. The proposed voice alert control system adapts to the changes in the driver's emotions and because of this nature it can able to convey the alert information effectively to the driver irrespective of the driver's moods.

VI. RESULTS AND DISCUSSION

The ERS is trained using available emotion classification standard dataset Facial Emotion Recognition (FER) 2013 [11]. The FER-2013 dataset consists of 28,000 labeled images in the training set, 3,500 labeled images in the development set, and 3,500 images in the test set. Each image in FER-2013 is labeled as one of seven emotions: happy, sad, angry, fear, surprise, disgust, and neutral. The image size of the FER-2013 dataset is 48x48. The CNN model is trained using the FER-2013 dataset by tuning the hyper parameters such as number of epochs, learning rate, batch size etc.

The trained CNN based ERS is fed with a test face detected image coming from the front camera sensor. The performance of the proposed system is evaluated by interfacing the speaker with the Raspberry Pi as a hardware system arrangement. The emotion output coming from the ERS is passed into the Raspberry Pi and the voice control is achieved through a speaker which is connected to the Raspberry Pi via a speaker interface module. The incoming camera images are processed using Open-CV and face is detected using the Haar-Cascade classifier and the face detected image is fed into ERS as shown in Figure 3.

The voice alerts generated in an ADAS system directly depends on the ADAS functionality from where the alert is generating. The alerts generated by the Brake assist system is entirely different than the alerts generated by the drowsiness monitoring system, but the overall impact of the alerts on the driver depends on the perception of the driver in understanding the alerts which in turn depends on his moods. Here the voice alerts are generated as according to the moods of the driver by keeping the alert information content unaltered.

The voice control through a speaker for driver's facial emotion 'Angry' is shown in Figure 4. Here the voice alerts depends on the ADAS functionality from where the alert is originating, but the alerts are played as according to the emotions of the driver. The voice alerts for angry emotion will be elaborated and additional alerts are added to inform the driver to have a control over his emotion since the angry emotion causes an aggressive driving.

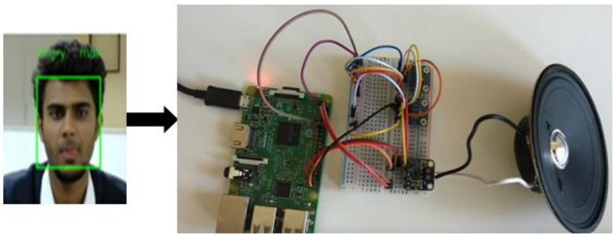

Fig. 4. Voice Control for Facial 'Angry' Emotion

The voice control through a speaker for driver's facial emotion 'surprise' is shown in Figure 5.

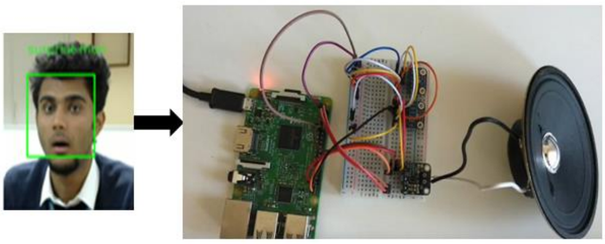

Fig. 5. Voice Control for Facial 'Surprise' Emotion

The voice alerts for surprise emotion will be normal and the alert commands additionally alerts the driver to come out of the surprise emotion state soon, since it causes a shift in the driver's attention from driving towards the surprising incident.

The voice control through a speaker for driver's facial emotion 'neutral' is shown in Figure 6. The voice alerts for neutral emotion will be normal and the alert commands are played as normal as according to the incident.

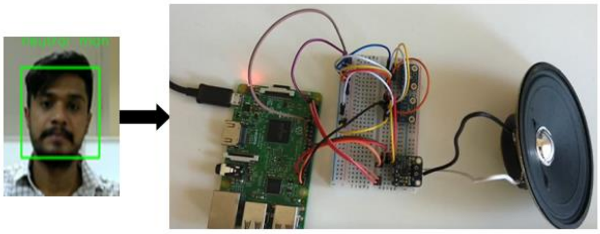

Fig. 6. Voice Control for Facial 'Neutral' Emotion

VII. CONCLUSION

The innovations in the ADAS solutions providing a way for all the automotive companies to achieve an autonomous car with zero accidents. ADAS serve as a building block of the fully autonomous car from driver assistance to driver elimination at the end. The cognitive interaction of the ADAS HMI is an attempt to achieve the futuristic autonomous cars HMI. The adaptive voice alert system makes the HMI more sophisticated and makes the ADAS system more effective in achieving zero accident vision by a continuous smoothening of the driving activity.

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