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Research paper

Design of ANFIS based driver fatigue detection system using thermopile and ambient temperature sensors

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Abstract

Safety systems play a vital role in automotive industry. Among the safety systems, fatigue detection system is main part in monitoring the level of fatigue of the driver. Vehicle line departure warning system, drivers eye/face monitoring system, steering pattern-monitoring system etc. are a few of the fatigue detection systems deployed in the vehicle by the OEMs (Original Equipment Manufacturers). Lack of proper sleep, sleep apnea, spikes in blood sugar level, anemia etc., are considered as some of reasons for drivers' fatigue. In this paper, we have designed and prototyped a system to monitor the lev-el of fatigue of the driver in real-time. The proposed system uses temperature sensors (thermopile array and ambient temperature sensor) to capture the heat map information of drivers' face and the frequency of yawns. The neuro-fuzzy system in the background processes the data from the sensors for making a logical conclusion – fatigue/ no fatigue. The accuracy of detection can be improved by training the system across multiple subjects. The proposed system was evaluated across various membership functions, for selecting the right membership function.

Keywords: *ANFIS : Arduino UNO : Fatigue Detection: MLX Sensor: MATLAB:*

1. Introduction

The increased number of accidents due to driver's attention level has become a serious issue in the society. In China, driver weakness acknowledged 3056 deaths in vehicular mishaps in 2004, and caused 925 deaths in highway mischances which implied around 14.8 % of all deaths according to the National Highway Traffic Safety Administration (NHTSA) [1]. Based on the signs and causes of fatigue detection in the recent decade, numerous researchers have been take the advancement of the driver monitoring systems, which utilizes distinctive strategies. Some of the causes of the drivers fatigue are Driving at times, when the driver normally have sleeps, Long working hours, Combination of inexperience and night driving, drug abuse, alcohol and hypnotic medicines etc. Some of the signs of fatigue detection includes, frequent lane changes, alterations in the heart rate of the driver, increased number of yawns in minimal time, daydreaming, Trouble in keeping the head up etc. [2]. The pre-existing systems are based on advanced camera, which detects changes in the facial structure, events of yawns, sporadic driving examples that are seeing by sensors in the vehicle, and so forth.

The OEMs were succeeded in developing the fatigue detection system and some of those systems are of them are: Steering Wheel Movement (SWM) technology[3-4], the sensor which measures the angle of steering while driving, which is more often used in the current generation of the cars for the detection of the level of the fatigue. Graham et.al. observed that restless drivers influenced less guiding to wheel inversions than ordinary drivers.

The camera based fatigue detection systems, analyses the drivers face using image-processing techniques for fatigue detection. The sleepiness of the driver is recognized by utilizing a unique kind of calculation called PERCLOS (Percentage of Closure)[4], which is truncated, as Percentage Closure is a measure of driver readiness. This calculation measures the individual's moderate eyelid conclusion instead of squints. The PERCLOS technique in [4] is widely accepted for the design of fatigue detection system, as in low ambient light conditions, the camera based systems find more difficulties in decision making. Research has demonstrated that there is a connection between body temperature and fatigue levels of a person [5]. This temperature change is significantly more obvious in the facial areas are to be more correct than the intracranial locales, the region around the cheeks and close to the eyes have much change than any other locals. The thought is to utilize an infrared thermopile sensor to identify temperature changes and discover levels of heat exhaustion. This extraordinarily diminishes the general cost of the framework, since infrared thermopile sensors are moderately less expensive than computerized cameras. Due to the change in ambient temperature conditions, an ambient sensor is included in the design to bring more accuracy. The system uses fuzzy based machine intelligence technique to predict whether the driver is fatigue or not.

2. System Design

An The proposed system uses a thermopile sensor (MLX90621), works based on IR [6] and an digital ambient temperature sensor [7] (DS18B20) as indicated in Fig 1a. And Fig. 1b. The thermopile sensor is configured to provide three 4 x 16 data samples per second. The pixel position of the MLX sensor is provided in Fig 2. In this experiment, the object (headrest of the driver's seat is positioned between column 6 and 11) for capturing the temperature data. It has an operational range of -40°C to 85°C and a measur-

ing range of -40°C to 300°C it has target precision of 1° across the full measurement scale.

Fig 1a: MLX90621

Fig 1b: DS18b2

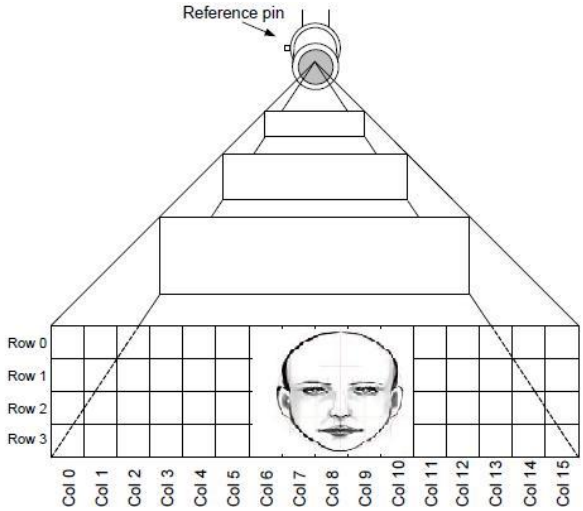

Fig 2: Pixel position in the whole Field of view

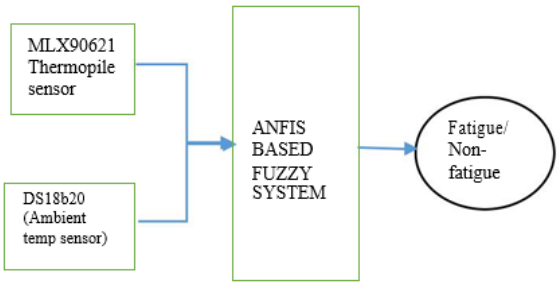

Fig 3: Block Diagram

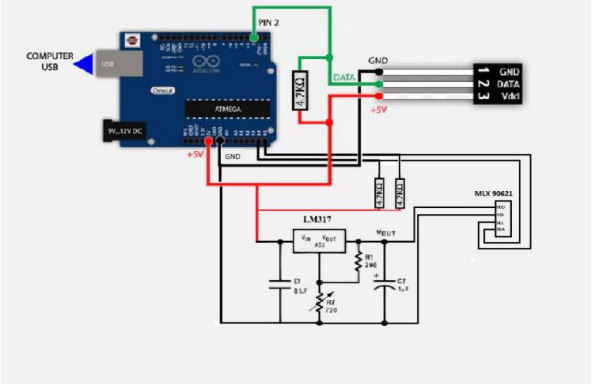

Fig 4: Circuit Diagram

The wiring diagram in Fig 4., indicates the connction of Arduino controller with the sensors. For the thermopile sensor, it is required to restrict the voltge by using lm317t circuit to the voltage of 2.6v and conncet the SDA and SCL to A4 and A5 (serial pins of arduino) and connect Ground and voltage pins respectively.

3. Fusion Algorithm

In this experiment, we have designed an ANFIS (Adaptive Neuro Fuzzy Inference system) based data fusion with Thermopile sensor and ambient temperature sensor. The block diagram of the system is given in Fig. 3. The ANFIS uses a FIS based on T-S model and a neural network to understand the three essential procedures including fuzzification of fuzzy control, fuzzy inference and defuzzification. The system uses the mechanism of artificial neural network to extract rules from the input sample data [8] and uses the rules to predict the output of the system. ANFIS is widely used for addressing various research problems [9-12]. In this work, we collected twelve thousand data samples; we need to process these samples as the input to this system. The Fig. 5 and Fig 6 represent the experiment setup made for capturing the real-time data.

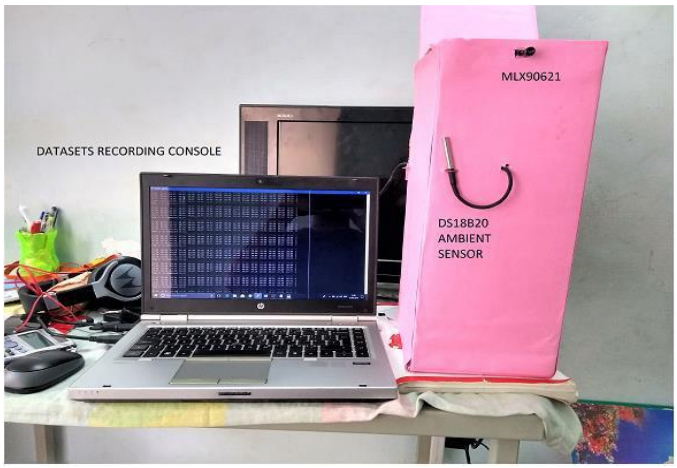

Fig 5: Experimental Setup

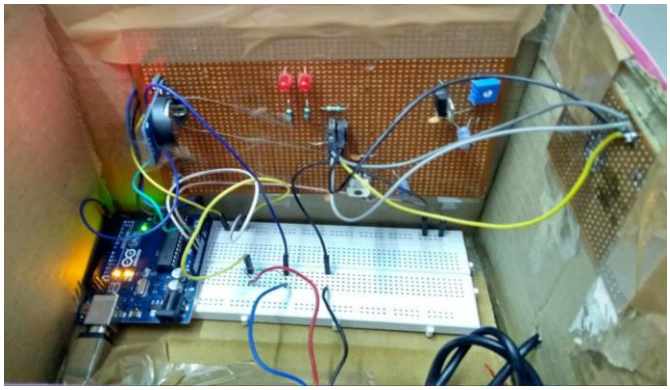

Fig 6: Experimental Setup Lateral View

Algorithm used for Data fusion as follows;

Step 1: Collect the real-time data from thermopile array and ambient temperature sensor and label the same under fatigue/ non-fatigue categories.

Step 2: Generate a fuzzy system with 5 inputs and 1 output. Among the five inputs, 3 inputs represents the average temperature reading. Other two inputs represent the ambient temperature and circuit temperature respectively.

Step 3: Initialize The Neuro-Fuzzy Designer With 9000 Training datasets into training data type and 1000 data sets into testing data type.

Step 4: Select the appropriate membership function (Triangular) in generate the FIS module.

Step 5: Train the system with certain number of epochs. In this experiment, we have selected 500 epochs to train the network.

Step 6: Test and evaluate the FIS generated with 2000 datasets.

The structure of the neural network generated based on the data is provided in Fig. 7. In this experiment, we have evaluated the generated FIS across various membership functions such as Trapezoidal, Gaussian etc. Among the 2000 samples considered for the evaluation of the FIS, the following confusion matrices were made. The generated FIS is now evaluated using the 2000 samples (n=2000). The confusion matrix obtained across various membership functions were indicated in Table 1, 2 and 3.

Table 1: Confusion matrix for triangular membership function

N=2000	Predicted: No	Predicted: Yes	Total
Actual: No	Tn= 1000	Fp= 0	1000
Actual : Yes	Fn=34	Tp= 966	1000
Total	1034	966	

Table 2: Confusion matrix for trapezoidal membership function

N=2000	Predicted: No	Predicted: Yes	Total
Actual: No	Tn= 1000	Fp= 0	1000
Actual : Yes	Fn=72	Tp= 928	1000
Total	1072	928	

Table 3: Confusion matrix for Gaussian membership function

N=2000	Predicted: No	Predicted: Yes	Total
Actual: No	Tn= 1000	Fp= 0	1000
Actual : Yes	Fn=46	Tp= 954	1000
Total	1046	954	

4. Result and Conclusion

The results indicated that, the system could predict the fatigue/ non-fatigue condition with an accuracy of 98.3% for the neuro fuzzy system, based on triangular membership function. In this experiment, we have collected the data from 10 different subjects. It is recommended to collect the temperature information across multiple subjects, so that the reliability of the overall system can be enhanced.

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