Development of ACNS in Korea

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ABSTRACT

The e-POST, an automatic crash notification system for the emergent rescue at auto accident has been launched as a national research program of Korea in 2010. The main research objectives of the e-POST are: 1. Development of algorithm that quantifies crash severity and the prediction of occupant injury risk based on the recorded data in EDR (Event Data Recorder). Utilization of video images of inside and/or outside of the vehicle during (or right after) the event are under consideration. We hope this supplemental visual data can provide additional information for an in-depth analysis of the accident situation. For the injury risk prediction of occupants, virtual simulation using digital human body models will be employed. 2. Selection of communication protocol for the data transmits. Secure data transmit to the rescue center is an important part of the system and it becomes even more challenging issue because the additional video data could be a large size.

INTRODUCTION

The overall process of injury risk assessment for the field triage at the accident site is shown as the flow chart in Figure 1. Representing a general vehicle involved in a crash accident, a sled model based on finite element was built with digital human body model and vehicle occupant compartment including a restraints system. Numerous kinds of digital human body models are employed to represent various occupants in anthropometries, age, and genders. Crashworthiness characteristics of numerical sled model will be validated by comparing with the crash tests results of the KNCAP. Three crash modes in the KNCAP tests, i.e., full overlap frontal, offset frontal and side impacts will be quantitatively utilized to validate the vehicle compliance and occupant kinematics of the sled model. In order to quantify the effect of parameters of crash accident (PDOF, ΔV, ..), vehicle structure including restraining condition (vehicle type, belt, airbag, ..) and the occupant (position, size, gender, age, ..) on injury risk, various scenarios of sled simulations are going to be made to build up a simulated injury risk database. It is expected that this simulated injury risk data base can effectively provide most of necessary information to predict and quantify the injury risk from the collected data at EDR device. Using the real accident data including the detailed information of vehicle damage and occupant injury outcomes, the effectiveness of the simulate injury risk database to determine the crash injury severity will be verified.

Unfortunately, there have been very few efforts on in-depth study of real car crash accident in Korea. The advanced in-depth studies of real car crash accident such as NASS/CDS[1] and CIREN[2] in US, ITARDA[3] of Japan, and GIDAS[4] of Germany have been used for the investigation of injury mechanisms to identify potential improvements in vehicle design. As a part of e-POST research program, we started to collect our own domestic real crash accident data. It is expected to collect about 150 cases of real crash accident cases with serious injuries during 8-month period (2011 January-August). This investigation is being operated mainly by a medical team without having any other administrative support such as police. Thus the collecting data is lack of some critical elements i.e., detailed accident information and speed change (ΔV). Four university hospital emergency rooms located respectively in medium size cities in Korea are actively participating to collect the data. The inclusion criterion is crash accident case with serious injured occupant victims (ISS 15+). They take a record of vital signs and AIS codes of the victims. The SAE J224 Collision Deformation Classification (CDC) code for the corresponding accident vehicle is also included. However, we have limited accident information to take an accident reconstruction and therefore the speed change is not included in the database. As an alternative practicable approach to estimate the speed change of the accident vehicle, the computer generated Delta V of the case in the NASS/CDS database which involves same vehicle model (Korean brands exported in US) and similar CDC code is going to be identified and adopted. The analysis of real accident data can provide useful data to verify our injury risk prediction algorithm and also going to be used to evaluate the significance of the relationship between vehicle damage and injury outcomes.

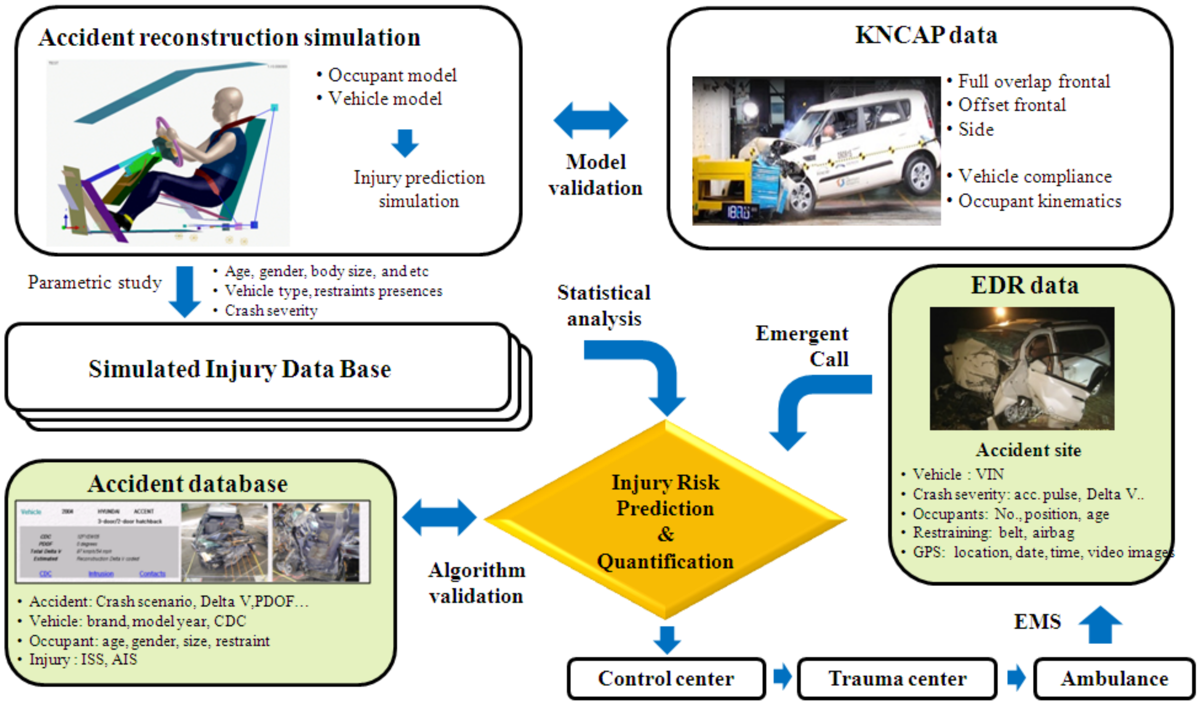

Figure 1. Flow chart of injury risk prediction in ACNS

The video image of occupants inside the vehicle is analyzed to help the estimation of crash severity in e-POST, with the bio-inspired robust visual recognition. The research of visual signal processing aims to identify the position and posture of occupants with environmental status of air-bag activation, at the instant of accident. The current development stage is the recognition of occupants either in the front seat or in the rear seat, while the vehicle is in motion. The detection of seated occupant's fall is also monitored based on the video image of simulated action of occupant.

The analysis methodology is developed by mimicking the principle of visual cortex of brain with similar robust characteristics, while there is practical feasibility of VLSI implementation for low cost device. The successful detection of occupants demonstrates the feasibility of adopting the video-based estimation of severity of injury, with video taken from standard commercial car black box as database in the experiment. The challenge of abrupt illumination change is managed by mixed processing of neuromorphic and frame difference. The video sequence, with resolution of 640x480 and 15 frames per second, of two seconds is successfully evaluated for detecting the positions of occupants and the location of its head. During the sequence, the car drives both open space and between buildings on a bright sunny day. The video analysis of occupants targets to develop the reference model for visual recognition and summary of accident status with precise data and low communication overhead, helping to dispatch the rescue action efficiently and timely.

Primary mobile communication protocols available now and in future (e.g. in-car internet) will be evaluated with the test beds if necessary. The smart mobile devices which are becoming rapidly popular these days, are equipped with some basic technical functions (i.e., communication, G-sensor, camera(s), CPU, etc.) of many existing EDR gadget. One of the plans of this study is to implement the outcome of our development (e.g., occupant injury risk prediction algorithm based on the video image analysis) into a smart mobile ACN application which might easily propagate into the fleet

ACCINDET AND INJURY DATABASE

Korean car involved cases in NASS/CDS data

In the NASS/CDS 2004-2009 data. 1,491 accident cases (4.9% of total number of light vehicle accidents) involved two major Korean brand cars. Just for a reference, their US market share average for those six years (2004-2009) was similarly 5.0% (±1.1) as shown in Figure 2. Since the average of domestic market share of these two manufactures for last 10 years is over 70% (±3.8) in passenger cars, it would not be such an unreasonable approximation of the overall trend of automotive crashworthiness performance in the Korean fleet by the investigation of the accident cases involving their cars.

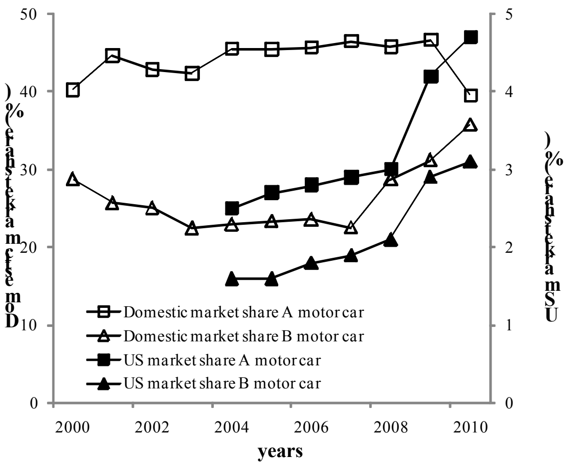

Figure 2. Domestic and US market share trend of major Korean brand cars [5]

The number of accident accompanied the serious injury (ISS 15+) were 102 cases out of 1,491 accidents that involved Korean brand cars in NASS/CDS 2004-2009 data. Excluding those cases with old vehicle model (<2000) or just with incomplete CDC/AIS information, it further reduced to 76 cases. The distributions of accident, vehicle damage, and occupant variables are shown in Figures 3-7.

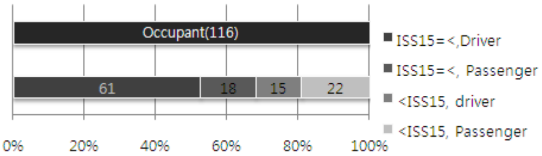

Figure 3. Occupant roles and injury severity of Korean brand cars in NASS/CDS 2004-2009 data

There were 116 occupants in the 76 accident cases and the driver showed relatively higher injury risk than the passenger. The detailed distributions such as age, gender, restraint condition, MAIS, and ISS for 79 occupants who had serious injury levels are shown in Figure 4.

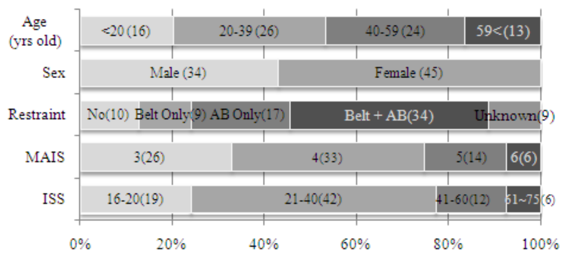

Figure 4. Distribution of seriously injured (ISS 15+) occupant variables

The AIS code distribution is shown in Figure 5. The most fatal injury (AIS6) occurs at head (6 cases) followed by spine (2 cases) and thorax (1 case).

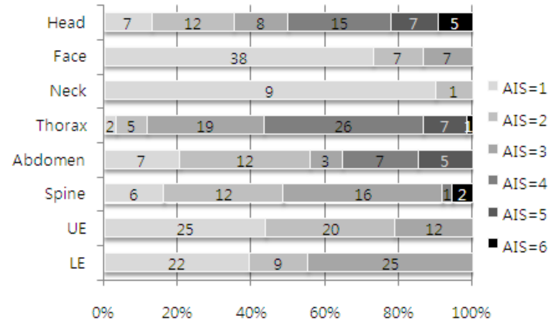

Figure 5. Distribution of AIS codes for seriously injured occupants

The distributions of accident vehicle variables of 76 cases are shown in the Figure 6.

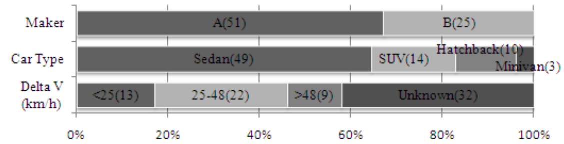

Figure 6. Distribution of accident vehicle variables

All 76 cases had multiple crashes, i.e., 44 cases had event number 2 and 17 cases with event number 3. Front crash resulted in the most rank 1 vehicle damage followed by side impact as shown in Figure 7.

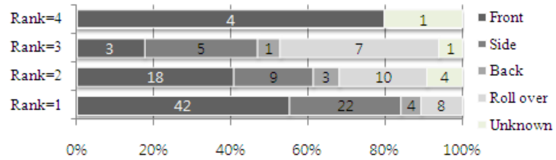

Figure 7. Distribution of crash type and severity

Collection of domestic crash accident case

Four university hospital emergency rooms as in Figure 8 are participating in e-POST project to collect domestic real crash accident cases. During the first eight months (2011 January-August), which is a preliminary trial period, it is expected to collect about 150 cases of crash accident with serious occupant injury. Our occupant data includes vital signs, position, demographics, anthropometry, and a description of injuries and their sources. The damage of vehicle exterior is quantified by a CDC code. We also take photos of the occupant compartment to identify the contact information. However, we do not take a precise measurement of vehicle exterior and interior deformations. There is no estimation of speed change due to the lack of accident event data. The distribution of occupant and vehicle variables of 10 accident cases collected from 2011 January to February at Konkuk University hospital is shown in the Figure 9.

	University hospital	city	Size*
A	Soonchunhyang	Bucheon	1000
B	Yunsei	Wonju	836
C	Dankook	Cheonan	802
D	Konkuk	Chungju	501

*Size of hospital is based on number of beds

Figure 8. Four university hospitals collecting the domestic real crash accident data

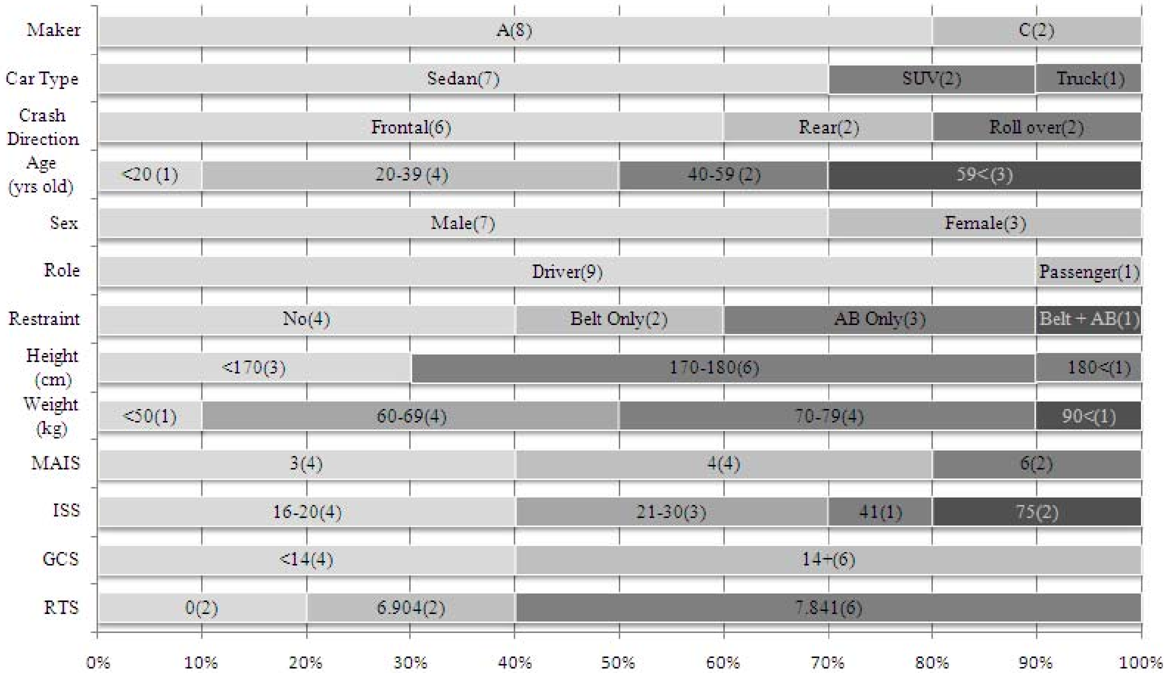

Figure 9. Distribution of occupant and vehicle variables collected at Konkuk University hospital

VIDEO IMAGE RECORDING AND ANALYSIS

Bio-inspired occupant detection

The state of the occupant needs to be estimated to determine the crash severity for e-POST. But before attempting to determine the state of the occupant, it is necessary to determine the position and posture of the occupant. To determine the position and location of the occupant bio-inspired robust visual recognition is implemented in this paper with the final goal of creating a system that can monitor all passengers whilst the vehicle is in motion. Much of computer vision algorithms are effective in their specific usage, however they lack the robustness of human vision and for most times will underperform in varied conditions. [6]

Although there is not a definite model of visual cortex, Hubel and Wiesel's research on cat's striate cortex confirmed the idea on the functioning of simple cell [7]. It is from this discovery which motivated various theories of object recognition from characters to complex natural images [8]. These researches on neurophysiology introduced the principles of biologically plausible electronic implementation. One of the electronic implementation is the Hodgkin and Huxley's model of neuron which is utilized in this paper to show feasibility of implementation of proposed bio-inspired visual processing electronically. The motivation for it was found from the result of the well-known experimentation of simple cell by Hubel and Wiesel as shown in Figure 10. By mimicking the simple cell, similar robustness of visual cortex can be achieved.

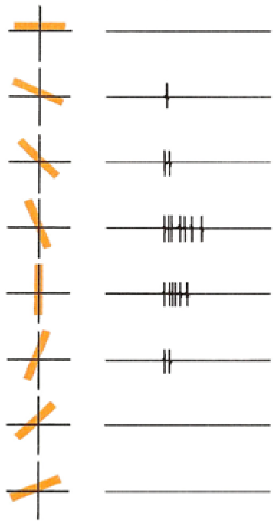

Figure 10. Response of the cat's cortex when a rectangular slit of light of different orientations is shown. [1]

Neuromorphic circuit mimicking the primary function of visual cortex The Hodgkin-Huxley (H-H) is a widely adopted idea of neuron's biophysical characterization as shown in Figure 11. H-H formalism is not used as much in neural networks as it does not give any major advantages however the asynchronous spikes are considered as principle element of high level or large scale neural computing system.

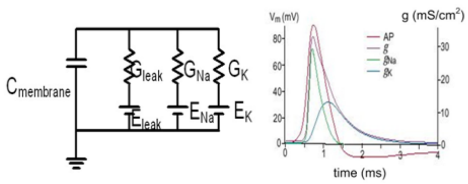

Figure 11. An electrical equivalent circuit of neuron, H-H formalism where the asynchronous spike of a neuron as shown on the right can be reproduced. [9]

The empirical mathematical formulae of conductance element in the formalism is expressed as (1) where b is the sigmoid function of membrane potential. And V_m is a membrane potential and the overall dynamic modeled by an Action potential and related ionic conduction.

$$G_{ion} = G_{ionmax} . x$$

$$dx/dt = \alpha(b - x)$$

$$i_{ion} = G_{ion}(V_m - E_{ion}) \qquad (1)$$

From these relationships dynamic behavior of biological neuron can be implemented electronically by the ion-based conductance controlled by membrane potential as shown in Figure 12.

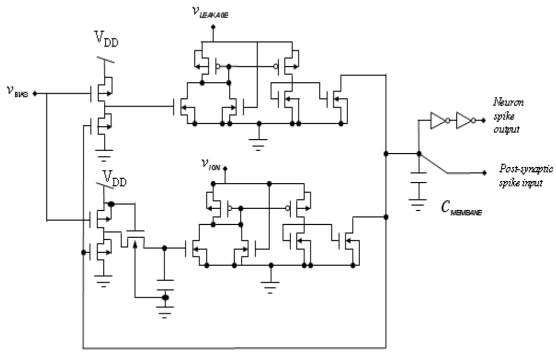

Figure 12. Voltage-controlled linear conductance by a pair of MOSFETs in the triode region, b. the tunable linear transconductance circuit, c. the chip photograph of CMOS transconductor.

The implemented system was simulated with different orientation inputs as it is believed that the tuning properties of orientation selectivity plays key role for perception in visual cortex as it was shown in Figure 10. For the simulation, a tuned feature map of 5 x 5 synaptic weights, shown in Figure 13, is based on the reference stimulus to match, with the minor adjustment depending on the output was prepared to mimic the orientation selectivity property of the simple cell. The synaptic weights are in the ratio of 1:-0.6:0.1 for black: grey: white respectively. The stimulus were six 50 x 50 pixel sized rectangles at different angles as to give same effect as the inputs give to the cat in Hubel and Wiesel's experiment. The result of stimulation shown in Figure 14 showed consistent outcome as the outcome of Hubel and Wiesel's experiment shown in Figure 10.

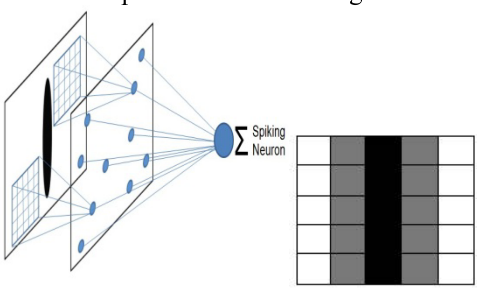

Figure 13. The artificial primary visual cortex model with orientation selective synaptic weights to mimic the simple cell.

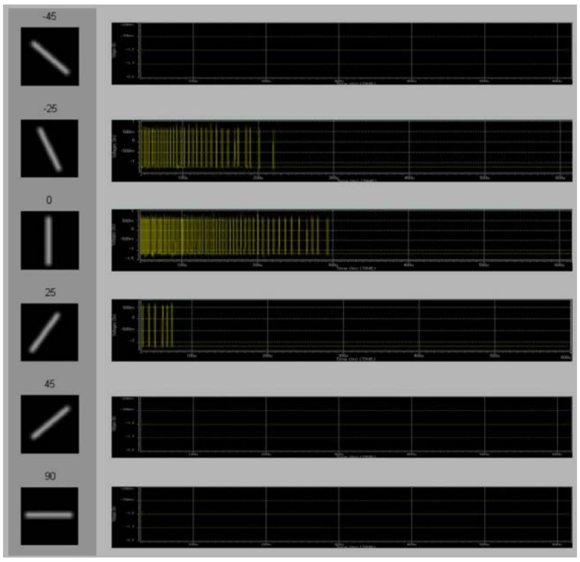

Figure 14. The simulated spike burst of VLSI visual cortex to stimulus in various orientations.

<u>**Passenger detection**</u> The orientation selective characteristic of visual cortex is implemented for the human face detection to detect the position of the passengers. Human face can be seen as complex shape with many different orientations joined together. The basic outline of the idea can be seen in Figure 15.

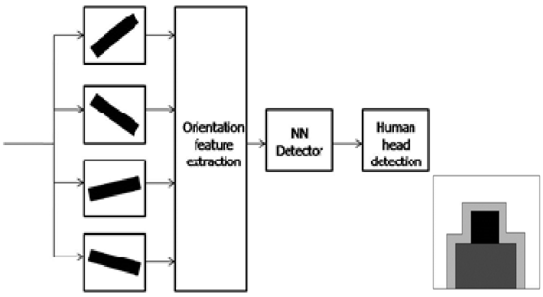

Figure 15. The outline of the proposed system. The head-torso shape shown on the right is used in neural network detector.

This system was initially tested on still images taken inside a car to prove its robustness. Challenging aspect of passenger detection is that the passenger will not be always directly facing the camera, in this case a commercially available car black box with resolution of 640 x 480 and 15 fps. So it is unwise to use the facial feature of human to detect the position of passengers. In addition, the background will be constantly changing since the vehicle will be at most time in motion. The robustness was tested on detection of a same passenger on two occasions: facing the camera directly in Figure 16 and facing away from the camera in Figure 17.

Figure 16. (from top left in clockwise direction) input image, orientation feature image, neural net detector output image, action level of detection neuron and the detected human head: case of facing forward

Figure 17. (from left) input image, neural net detector output image and the detected human head: case of facing away

The successful detection of the passenger at two different angle showed that the proposed idea is indeed robust. The proposed idea was tested on a detection of multiple passengers from a video stream when the car is in motion. Since using video stream, difference of orientation features from current and its previous frame is used to minimize the background noise. Background has much more high frequency features when the image is taken from a car in motion. Figure 18 shows the result of doing a difference of orientation feature images.

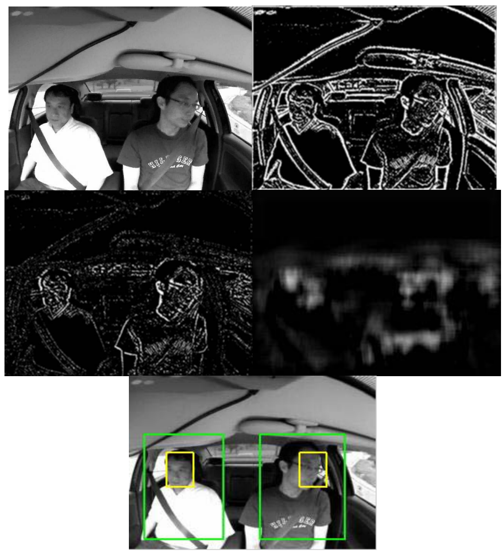

Figure 18. Detection of multiple passengers from a vehicle in motion. (from top left in clockwise) Input image, orientation feature image, difference of orientation feature from current and previous

image, neural net detection image and the resulted detection.:

The detection was not always successful but this was somewhat improved when an idea inspired from animal vision was applied. It is believed that animals do not see all the color rather it only sees specific color component, mostly red. An example of this case can be observed in Figure 19. The neural net detection showed that the head of the passenger that was not detected (left side case in Fig. 19) at first had higher frequency when only red component was used to successfully detect the passenger (right side case in Fig. 19).

Figure 19. Improving accuracy of the system. Left hand side images show the misclassified image and its neural net detection and the right hand side images show the successful detection and its neural net detection.

Passenger posture change detection Posture of passenger is important element to determine when dealing with e-POST cases since in severe crashes the passenger will be most likely in abrupt motion. Video stream was obtained from the same environment using the same camera as before. Typical sequence used can be seen in Figure 20.

Figure 20. Simulated motion from the video stream used for pose detection experimentation.

Same process as passenger detection is used to detect the head of the passengers which is that the orientation feature is extracted which is then used to difference with previous frame's orientation feature followed by neural net detection. Once the head is detected, base line of the torso is initialized after few frames which is made possible by making an fair assumption that the torso is directly below the head i.e. passenger is seating upright. Then the position of head relative to the baseline of the torso can determine the pose the passenger is in. Pose detection for images shown in Figure 20 were successful as shown in Figure 21.

Figure21. Successful pose detection for the images shown in figure 11.

The experiments have shown that the proposed idea performed robustly in different situations but since e-POST should function in evening as well as the day, an image was taken at night using an IR camera of same resolution, 640 x 480. As shown in Figure 22, the proposed idea performed robustly and thus the detection of the passenger was successful.

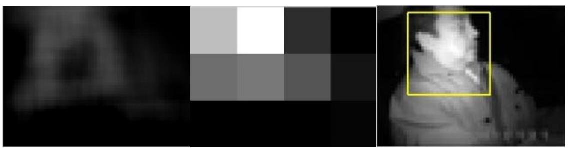

Figure 22. Successful detection of the passenger at night time. (from left) neural net detection, action level of detection neuron and the result.

CONCLUSION

The bio-inspired visual processing showed the robustness and flexibility required in constantly changing condition that is of moving vehicle. The robustness was shown in different application using same fundamental idea and by testing in wide range of conditions. Implementation of the idea electronically is also very much feasible into 7mm x 7mm of chip size in 0.18um CMOS technology.

ACKNOWLEDGEMENTS

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