International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:6, No:5, 2012

Eye-Gesture Analysis for Driver Hazard Awareness

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***Abstract*—**Because road traffic accidents are a major source of death worldwide, attempts have been made to create Advanced Driver Assistance Systems (ADAS) able to detect vehicle, driver and environmental conditions that are cues for possible potential accidents. This paper presents continued work on a novel Non-intrusive Intelligent Driver Assistance and Safety System (Ni-DASS) for assessing driver attention and hazard awareness. It uses two on-board CCD cameras – one observing the road and the other observing the driver's face. The windscreen is divided into cells and analysis of the driver's eye-gaze patterns allows Ni-DASS to determine the windscreen cell the driver is focusing on using eye-gesture templates. Intersecting the driver's field of view through the observed windscreen cell with subsections of the camera's field of view containing a potential hazard allows Ni-DASS to estimate the probability that the driver has actually observed the hazard. Results have shown that the proposed technique is an accurate enough measure of driver observation to be useful in ADAS systems.

***Keywords*—**Advanced Driver Assistance Systems (ADAS), Driver Hazard Awareness, Driver Vigilance, Eye Tracking

I. Introduction

ROAD traffic accidents represent a major cause of fatalities worldwide. According to the World Health Organisation [1], road accidents account for one million deaths each year with another fifty million seriously injured. Within the Organization for Economic Co-operation and Development (OECD) countries, road accidents represent the main cause of death for males under the age of 25 [2].

In the United Kingdom, the Department for Transport report entitled 'Reported Road Casualties Great Britain: 2008' cited speed as a major contributory factor in road traffic accidents. The survey found that 14% of accidents were linked to drivers either exceeding the speed limit or driving too fast for the road conditions. When considering only fatal accidents, the rate rose to 24%. The figures vary depending upon age and gender with young male drivers being particularly at risk due to excess speed with 41% of male fatalities aged between 16-25 linked to excess speed (Department for Transport, 2008).

In the USA, the Department of Transportation published a report entitled 'National Motor Vehicle Crash Causation Survey' (NHTSA, 2008) which represented a nationwide investigation into the causes of crashes involving light passenger vehicles that took place between 2005 to 2007 with the aim of identifying pre-crash events that contributed to an accident.

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The survey found that, of the 6,950 crashes surveyed, about 22% of the vehicles ran off the edge of the road and 11% percent of the vehicles failed to maintain proper lane keeping. However, recent research into the causation of road accidents has found that momentary lack of attention featured in as much as 78% of road accidents [4]. Some researchers claim that lack of attention is the main cause of accidents as factors such as fatigue, alcohol or drug use, distraction and speeding all impair the driver's capacity to pay attention to the vehicle and road conditions [5].

These factors have motivated research efforts that aim to improve driver performance and thus help to reduce accidents. This research has led to the development of Advanced Driver Assistance Systems (ADAS). ADAS systems are on-board computer systems that attempt to reduce the risk of accidents by monitoring the driver, vehicle and environmental conditions and taking some action when a risk is identified. However, there is comparatively little published work that tackles the problem of driver attention with much of the work focusing upon detecting and responding to vehicle and environmental state. Some recent work has attempted to create ADAS systems able to determine the driver's level of attention [5].

This paper hopes to make a contribution in this area by considering the problem as a condition monitoring problem such as will be used in the maintenance or machinery. In order to have reliable and accurate assessment of the driver's condition and her fitness to drive, a number of factors need to be considered such as vehicle behaviour (speed, lane changes, manoeuvres etc), driver's eye gaze (to determine the driver's focus of attention), other road users and road conditions. The driver condition monitoring system proposed in this paper aims to monitor the driver's eye gaze and determine whether the driver has observed a potential hazard. In order to achieve this, we follow [5] and employ two on-board CCD cameras: one observing the driver's face and the other observing the road. In the proposed Non-intrusive Intelligent Driver Assistance and Safety System (Ni-DASS), video images of the road are captured in order to detect potential hazards (such as someone stepping onto the road). The video of the driver's eyes is processed to determine the driver's point of regard on the windscreen. The overall aim of this process is to determine whether the driver has seen the hazard. Because of the 'look but not see phenomenon', it is very difficult to determine if the driver has actually observed a hazard. However, it is often possible to determine if the driver has failed to observe the hazard simply because he has been looking at something else. The main contribution of this paper is an extension our earlier work on eye-gesture recognition for mirror observations [6] to point of regard determination on the windscreen. In this paper, eye-gesture templates are matched with the driver's eye to determine the driver's point of regard on the windscreen.

Results have shown that it is possible to use gesture recognition techniques to determine point of regard with sufficient accuracy to be used for hazard awareness.

II. Previous Work

ADAS systems have been developed to increase road traffic safety and to reduce the risk of accidents. Researchers have used other names for ADAS including 'Driver Assistance System' and 'Intelligent Driver Assistance System' [7]. However, these terms refer to the same concept: an on-board computer system linked to various sensors to detect environmental, vehicle and driver conditions and to respond to them in such a way as to reduce the risk of accidents. They are numerous approaches which are often combined within ADAS systems. These typically involve incorporating cues on driver behaviour based on visual information of the driver. For instance, [8] make use of driver eye gaze movement and have presented a comparative study of the use of changes in eye gaze and head movements in predicting driver intent to perform lane changes. To monitor eye gaze, they position a monocular camera trained at the drivers face in the middle of the dashboard. Due to the difficulty of accurately assessing eye gaze, video images are manually processed to obtain data relating to changes in gaze direction. They track lane change using the VioLET lane tracker proposed by [9].

Reference [10] has utilised driver's vigilance to estimate the driver's inattention. They have implemented a facial features and eyelid movement classifier to assess driver vigilance. They use a statistically anthropometric face model to find the important features on face. A combination of image processing techniques has been employed to make it robust. A Kalman filter has been used to robustly detect the facial features points over a sequence of human face images taken with different head pose.

Some researchers have used head pose [7] and facial features to determine the driver attention [11]. Reference [8] makes a comparison experiment to distinguish the two cues of eye gaze and head motion when predicting lane changes. They conclude that head movement is an important cue for predicting lane change.

Reference [12] has used an on-board CCD camera to detect visual cues for driver drowsiness to monitor driver attention. The cues are yawn frequency, eye-blinking frequency, eye gaze movement, head movement and facial expression. They employ a machine learning algorithm called VJ Object Detection to detect the driver's face. This algorithm is a combination of three algorithms: integral image, Adaboost technique and cascade classifier.

A few researchers developed ADAS systems based on collision avoidance systems by measuring the distance between cars ([13], [14], [15]). Parameters like lane departure and lane change have also been employed to avoid imminent collision ([9],[14]).

Reference [6] employed eye-gesture analysis to determine whether the driver is making the particular mirror observation with the aim of assessing the sequence of mirror observations performed before and during a manoeuvre. The system, called the Non-Intrusive Driver Assistance System (Ni-DASS), is a context aware non-invasive approach that monitors a vehicle driver's eye gaze (using an on-board CCD camera) and determines if the driver is failing to make a required mirror observation. They show that, due to the constrained nature of the driving situation, it is possible to treat eye-gaze patterns corresponding to mirror observations as characteristic eye-gestures. They form a corresponding set of eye-gesture templates and match these with the driver's eyes within video from an on-board CCD camera observing the driver's face. Recognizing these eye-gestures allows the Ni-DASS system to check whether the driver is making a mirror observation.

III. Proposed Ni-DASS System

The driver condition monitoring system proposed in this paper aims to monitor the driver's eye gaze to determine the driver's point of regard on the windscreen. The rationale for doing this is that, if it is possible to determine the field of view through a particular windscreen cell and to then detect an exterior object (such as a person, or road sign or obstacle etc.) within an on-board CCD camera facing the road then it will be possible to estimate the probability that the driver is observing the exterior object.

A similar approach was followed by [5] who used a forward facing camera to observe road signs and the Seeing Machines' FaceLab eye-tracking system to determine the driver's eye-gaze trajectory. However, using a complex and expensive eye-tracking system such as FaceLab may not be necessary. In many cases, what is actually required is to determine if the driver has positively failed to observe an object. In this case, all that is required is to determine eye-gaze patterns that clearly do not intersect with the object. In this paper, we demonstrate that the use of eye-gesture templates provides sufficient accuracy to determine these negative cases.

IV. Driver focus of attention

Within the proposed system, there are two CCD cameras: one facing the road and the other positioned to capture the driver's face. The aim is to process the video output from the camera facing the road to identify focal points that the driver should observe. To determine driver observations, the proposed system makes use of the on-board CCD camera positioned to capture the driver's face. The system uses a template matching algorithm for eye-gesture recognition. To create the eye-gesture templates, the windscreen is divided into a grid of evenly spaced cells. The number of cells used could vary but it has been found empirically that using four rows of six cells per row is a suitable cell resolution for the eye-gesture templates (Figure 1 below). The eye gesture templates are created for a driver looking at the centre of each windscreen cell while sitting in a neutral forward facing calibration position. While capturing the eye-gesture templates, the driver keeps her head fixed in the neutral position and only moves her eyes. With a windscreen grid of 24 cells, 24 corresponding eye-gesture templates are created with the driver facing forward. The aim of creating these templates is to use a template matching algorithm to determine which of the templates represents the best match with the driver's eyes in order to estimate which windscreen cell the driver is looking at during normal driving situations. Once we have determined which windscreen cell the driver is looking at, it is necessary to determine if the driver has seen hazards within the video image of the road.

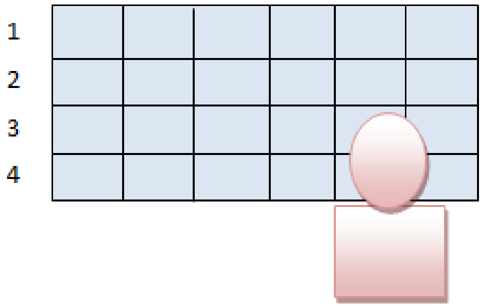


Fig. 1 Windscreen divided into 24 cells consisting of 4 rows of 6 columns. The pink shape being a representation of the driver

V. Assessing Driver Observation

The CCD camera facing the road will capture a portion of the scene in front of the car depending upon its location within the vehicle and focal length of the camera. Suppose the camera is positioned at the centre of the dashboard with the lens located near the windscreen then the camera will capture an image of the scene in front of the car within the camera's field of view. This means that the camera will capture an image of all visible objects within a viewing frustum defined by the camera's position, focal length and the dimensions of the camera's image sensor (near plane). In theory, this viewing frustum will extend outward to infinity but in practice is limited by the camera's capabilities.

Using the eye-gesture analysis approach described above, it is possible to determine which windscreen cell the driver is currently looking at. We can then determine the driver's viewing frustum defined by the driver's eye position, the position and dimensions of the rectangular windscreen cell the driver is currently looking at (near plane). The intersection of the driver and camera frusta will contain all visible objects within the camera's field of view that is also within the driver's viewing frustum. We could then say that the driver has observed the scene elements within the intersection.

However, to determine if a hazard is actually within the this intersection of frusta, it is necessary to estimate the depth of the object within the camera's viewing frustum from the video image. In order to estimate depth, we need further information about the object such as its size or position on the road. Because determining object depth is difficult without further information, we proceed by determining the probability of an object being within the intersection of viewing frusta. To determine this probability we first divide the camera's viewing frustum into eight uniform sub-frusta as shown in Figure 2 below.

We then impose a threshold distance from the windscreen, the hazard observation boundary, which is the distance in front of the car in which a hazard should be observed.

We note that, given rectangular windscreen cells, the driver's line of sight through a windscreen cell forms a rectangular pyramid. We determine which sub-frusta contain the hazard by dividing the camera's video image into eight corresponding uniform cells (representing the projection of the frusta onto the camera's imaging sensor) and locating the hazard within these cells. We then calculate the intersection of the camera sub-frusta containing the hazard with the driver viewing frustum that lies above a planar approximation of the road within the limits of the hazard observation boundary.

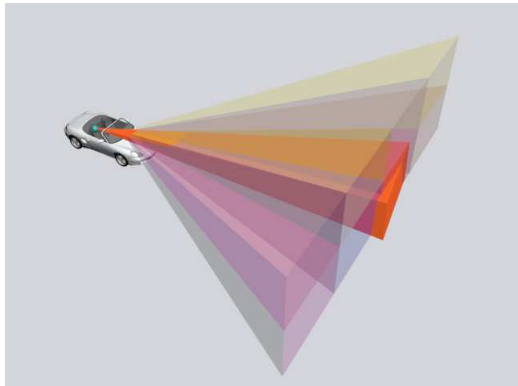


Fig. 2 Eight semi-transparent camera sub-frusta composing the camera's field of view (viewing frustum) and the driver's viewing frustum (solid) through a particular windscreen cell

The probability that a hazard within the camera sub-frustum lies within the observation boundary and is within the driver's viewing frustum is determined by dividing the volume of the intersection of frusta that lies above the planar approximation of the road by the volume of the camera's sub-frusta containing the object above the road. This gives the probability that an object within a camera sub-frusta, that is also within the hazard observation boundary, is within the driver's viewing frustum through a given windscreen cell.

Figure 3 illustrates this process. The camera's viewing frustum contains a sub-frustum (green arrows) containing three hazards (stars). The driver's line of sight through a particular windscreen cell forms a viewing pyramid (viewing frustum). In order to determine the probability that the driver has actually observed the hazards, we determine the intersection of the camera's sub-frustum with the driver's viewing frustum (shaded) within the hazard observation boundary. We then divide the intersection volume by the sub-frusta volume within the hazard observation boundary. However, the probability is used only as an estimate of a hazard observation as it is difficult to determine whether a hazard is actually within the intersection - only one of the hazards (blue star) within the camera's sub-frusta is actually contained within the intersection of frusta.

For a given hazard observation boundary distance, the probabilities form the intersection of viewing frusta are constant for a given driver position. Taking an average driver position as the calibration position for which the probabilities are calculated allows us to determine an approximate probability for an observation having been made and these probabilities can be used within a real-time estimation of hazard observation.

International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:6, No:5, 2012

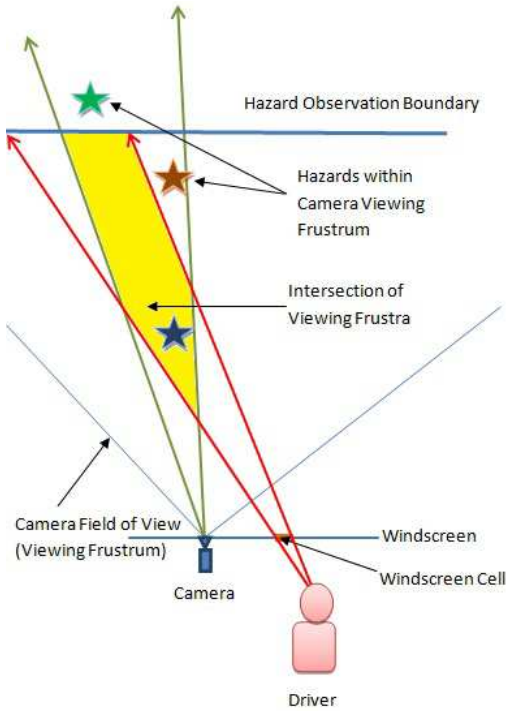


Fig. 3 Intersection of viewing frusta (shaded) allows for an estimation of the probability that the driver has observed a hazard (stars).

VI. Experiment One: Eye gesture templates

The windscreen of a Ford Focus car was divided up into 24 cells consisting of 4 rows of 6 columns with each cell approximately 20.3cm wide and 17.8cm high. Figure 4 shows an image of the car with the windscreen cells marked out with masking tape. A CCD camera was placed on the centre of the dashboard and aligned to capture the driver's face. The camera was positioned so as to be able to capture the head region when a driver is in the full range of driving positions. To create the eye-gesture templates, the calibration driver was asked to sit in a normal driving position with her head in a neutral, forward facing position.

Figure 5a shows the calibration driver seated in the driver's position. Images of the calibration driver's left eye were captured as she looked at the centre of each windscreen cell while keeping her head in the neutral forward facing position. These eye-gesture templates were then cropped to approximately the same size and show the calibration driver's left eye with a small portion of skin surrounding the eye.

Fig. 4 Marking out windscreen cells

A test driver (Figure 5b) was then asked to sit in the driver's seat in a neutral, forward facing position. Images of the test driver were taken with the CCD camera as she looked at the centre of each windscreen cell without moving her head giving a total of 24 images of the test driver. Each of the 24 images of the test driver was then matched with each of the 24 eye-gesture templates giving a total of 576 combinations with the top match recorded for each combination using the cvMatch Template template matching function within OpenCV 2.1 with a normalised correlation coefficient matching algorithm. During matching, the search area within the images was restricted to a rectangular region of interest enclosing the lower forehead and upper nose.

VII. Experiment One Results

Table I bellow shows the results of matching the test driver image for cell (1,1) with all 24 eye-gesture templates. For the first row of templates, the highest matching template is for cell (1,1) with a match percentage of 88%. The match percentage decreases gradually along row one and reaches a minimum at cell (1,5) with a value of 39%. The percentage match then increases to 58% for eye-gesture template for cell (1,6). The gradual decline in match between cell (1,1) and cell(1,5) reflects the movement of the pupil from left side of the eye to the right side of the eye reducing the match between the templates and the test driver's eyes. The unexpected increase in percentage match for cell(1,6) is due to the matching of the pupil with the test driver's eye-liner make-up at the right-hand interior of the left eye. A similar pattern is seen for the second row with the highest match being for the eye-gesture template for cell (2,1) with a value of 87% and a gradually decrease in matching value until a minimum value of 43% is reached for cell(2,5). Once again, there is an anomalous result for cell (2,6) with a value of 56% due to the matching of the pupil within the template with eye-liner make-up. Similar trends are seen with template rows three and four, with the highest matching result being lower than in the preceding row and a gradual decrease in match value until the last two templates in each row which see an increase due to the matching of pupil with eye make-up.

VIII. Experiment Two Hazard Awareness

The windscreen of the Ford Focus car was divided into 24 cells as in Experiment One. A second CCD camera was positioned in the centre of the dashboard adjacent to the windscreen cell (4,3) and oriented to face the road. The camera used was a Sentient 540TVL IR CCTV Camera. This is a dual visible spectrum and infrared camera with a variable focal length and a sensor size of 1/3 inch. A focal length of 4mm was used during the experiment. A test driver was asked to sit in the driver's seat in a natural driving position. If the camera lens is considered to be at the origin of a Cartesian coordinate axis with the positive x-axis pointing to the right, the positive y-axis pointing up and the positive z-axis pointing out the windscreen then the test driver's left eye was measured to be at coordinate (40.64cm, 17.78cm, -91.44cm).

The coordinates of the centres of the windscreen cells were recorded (Table 2) together with the dimensions of each cell (Table 3). The camera viewing frustum was calculated then divided into 8 sub-frusta as described above. The driver viewing frustum was calculated for each windscreen cell based upon the calibration position of the driver's left eye and the coordinates of the corners of each windscreen cell. The intersection of each camera sub-frusta with each driver windscreen cell frusta was calculated for the frusta region above the road (a planar approximation of the road was used where the plane was positioned 41CM below the camera lens) and within the hazard observation boundary (set at 25 meters from the camera lens). The volume of each intersection was then divided by the remaining volume of the corresponding camera frustum above the road and within the hazard observation boundary to give an estimate of the probability of the driver seeing a hazard within the camera sub-frusta. Table 4 to 11 shows the calculated probabilities.

Three traffic cones were then placed on the road within camera frustum (2, 2) and (2, 3) as shown within Figure 6 with the aim of determining the probability of the calibration driver observing the cones.

IX. Experiment Two Results

Table IV to XI shows the probabilities that a driver has seen a hazard within a camera sub-frustum within the camera's field of view for each windscreen cell (4 rows of 6 columns) where windscreen cell (1, 1) represents the top left cell and cell(4, 6) represents the bottom right windscreen cell. Looking at the results, we see that when the driver is looking through any of the top six cells of the windscreen, he/she is classed as not having seen a hazard within any camera sub-frustum. This is because the driver's viewing frustum for each of these cells rises above the camera's viewing frustum and does not intersect.

The same is true for the bottom six windscreen cells where either the driver's viewing frustum does not intersect the camera sub-frusta or the intersection is negligible.A similar result is obtained for the first two windscreen columns where the driver's viewing frustum extends to the left of the camera's sub-frusta.

However, for other cells there is a degree of intersection that can be used to estimate the likelihood that a driver has seen a hazard within a given camera sub-frusta.

Figure 6 shows a frame from the road-facing camera with two traffic cones placed in camera sub-frustum (2, 2) and one cone in sub-frustum (2, 3). From the Table 7, it can be seen that the driver will only observed the cones within sub-frustum(2, 2) when he/she is looking through the driver frustum for windscreen cell (3, 4) with a probability of having actually observed the cones of 0.646 and windscreen cell(4,4) with a probability of actually observing the cones of 0.351. The probability of observing the cones is zero for all other driver viewing frusta. For the cone within camera sub-frustum(2, 3), a driver looking through viewing frustum for windscreen cell(3,5) will observe the cone with a probability of 0.580 and when looking through windscreen cell (3, 6) will observe the cone with a probability of 0.475.

X. Conclusion And Future Work

The work presented in this paper aims to propose a new approach to determining driver observations within vehicles. By treating the eye-gaze estimation problem as a gesture recognition problem rather than a conventional eye-tracking problem allows us to estimate the driver's point of regard on the windscreen within a course 24 cell resolution. However, as hazard awareness systems are more concerned with determining situations when the driver has not seen a hazard rather that the precise eye-trajectory calculations needed to determine if the driver has actually observed a hazard, using an approximate approach is attractive as it greatly reduces the computational cost and complexity of the on-board eye-tracking system while allowing for sufficient accuracy to detect situations when the driver has probably not observed the hazard. This will allow the system to alert the driver in situations when the probability of observation is low.

The proposed Ni-DASS system will be extended to include analysis of sequences of windscreen cell observations to allow a better estimate of the probability of observation as the driver moves his/her line of sight on the windscreen and the hazard object moves between different camera sub-frusta.

Fig. 5(a) Calibration driver looking at cell(1,2)

Fig. 5(b) Test driver looking at cell(1,1)

International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:6, No:5, 2012

TABLE I
TEMPLATE MATCHING RESULTS (PERCENTAGE MATCH) BASED ON MATCHING EYE-GESTURE TEMPLATES OF THE CALIBRATION DRIVER (SHOWN) WITH VIDEO FRAME SHOWING TEST DRIVER LOOKING AT CELL (1, 2)

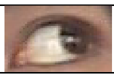
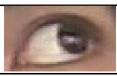
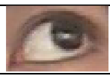
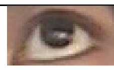
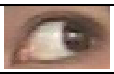
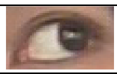
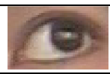
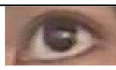
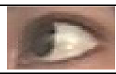
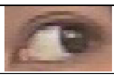
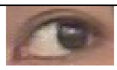
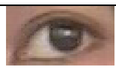
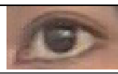
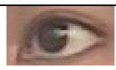
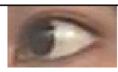
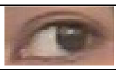
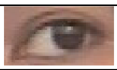
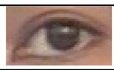
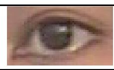
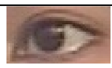
					
Cell(1,1)	Cell(1,2)	Cell(1,3)	Cell(1,4)	Cell(1,5)	Cell(1,6)
88%	82%	77%	37%	39%	58%
					
Cell(2,1)	Cell(2,2)	Cell(2,3)	Cell(2,4)	Cell(2,5)	Cell(2,6)
87%	81%	67%	40%	43%	56%
					
Cell(3,1)	Cell(3,2)	Cell(3,3)	Cell(3,4)	Cell(3,5)	Cell(3,6)
77%	68%	48%	40%	48%	49%
					
Cell(4,1)	Cell(4,2)	Cell(4,3)	Cell(4,4)	Cell(4,5)	Cell(4,6)
63%	56%	39%	48%	49%	51%

TABLE II
COORDINATE OF THE CENTRE OF EACH WINDSCREEN CELL WITH THE CAMERA AT THE ORIGIN WITH COORDINATE IN CM

	1	**2**	**3**	**4**	**5**	**6**
1	(-16.5, 25, -21.5)	(-8.5, 25,-21.5)	(0, 25, -21.5)	(7.5, 25, -21.5)	(14.5, 25, -21.5)	(22, 25, -21.5)
2	(-17.5, 16.5, -15)	(-8.5, 16.5, -15)	(0, 16.5, -15)	(8.5, 16.5, -15)	(15.5, 16.5, -15)	(24, 16.5, -15)
3	(-18, 9.5, -7.5)	(-8.5, 9.5, -7.5)	(0, 9.5, -7.5)	(8.5, 9.5, -7.5)	(15.5, 9.5, -7.5)	(25, 9.5, -7.5)
4	(-18.5, 0, 0)	(-8.5, 0, 0)	(0, 0, 0)	(8.5, 0, 0)	(16.5, 0, 0)	(25.5, 0, 0)

TABLE III
DIMENSION (WIDTH, HEIGHT) OF EACH WINDSCREEN CELL IN CM

	1	**2**	**3**	**4**	**5**	**6**
1	22W, 21H	19W, 20H	21W, 20.5H	18W, 21H	19W, 21H	21W, 18H
2	24W, 20H	20W, 20H	21W, 20H	19W, 19.5H	19W, 20H	23W, 19.5H
3	27W, 20H	21W, 19H	21.5W, 19H	22W, 19.5H	19.5W, 19.5H	26W, 18H
4	29.5W, 19H	21.5W. 23H	22W, 23.5H	23W, 23.5H	19.5W, 22H	28W, 19.5H

TABLE IV
PROBABILITIES OF DRIVER SEEING HAZARD WITHIN CAMERA SUB-FRUSTUM (1, 1) WHERE ROW AND COLUMN UNITS FOR MAGNETIC PROPERTIES

Row/Column	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0.101	0.414	0	0
3	0	0	0.156	0.095	0	0
4	0	0	0	0	0	0

TABLE V
PROBABILITIES OF DRIVER SEEING HAZARD WITHIN CAMERA SUB-FRUSTUM (1,2) WHERE ROW AND COLUMN IDENTIFIES THE WINDSCREEN CELL INTERSECTED WITH THE CAMERA SUB-FRUSTUM

Row/Column	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0.102	0	0	0
3	0	0	0.628	0.356	0	0
4	0	0	0	0	0	0

TABLE VI
PROBABILITIES OF DRIVER SEEING HAZARD WITHIN CAMERA SUB-FRUSTUM (1,3) WHERE ROW AND COLUMN IDENTIFIES THE WINDSCREEN CELL INTERSECTED WITH THE CAMERA SUB-FRUSTUM

Row/Column	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0.167	0.320	0
3	0	0	0	0.173	0.094	0
4	0	0	0	0	0	0

TABLE VII
PROBABILITIES OF DRIVER SEEING HAZARD WITHIN CAMERA SUB-FRUSTUM (1,4) WHERE ROW AND COLUMN IDENTIFIES THE WINDSCREEN CELL INTERSECTED WITH THE CAMERA SUB FRUSTUM

Row/Column	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0.646	0.351	0
4	0	0	0	0	0	0

TABLE VIII
PROBABILITIES OF DRIVER SEEING HAZARD WITHIN CAMERA SUB-FRUSTUM (2,1) WHERE ROW AND COLUMN IDENTIFIES THE WINDSCREEN CELL INTERSECTED WITH THE CAMERA SUB-FRUSTUM

Row/Column	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0.292	0.177
3	0	0	0	0	0.155	0.100
4	0	0	0	0	0	0

TABLE IX
PROBABILITIES OF DRIVER SEEING HAZARD WITHIN CAMERA SUB-FRUSTUM (2,2) WHERE ROW AND COLUMN IDENTIFIES THE WINDSCREEN CELL INTERSECTED WITH THE CAMERA SUB-FRUSTUM

.Row/Column	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0.580	0.475
4	0	0	0	0	0	0

TABLE X
PROBABILITIES OF DRIVER SEEING HAZARD WITHIN CAMERA SUB-FRUSTUM (2,3) WHERE ROW AND COLUMN IDENTIFIES THE WINDSCREEN CELL INTERSECTED WITH THE CAMERA SUB-FRUSTUM

Row/Column	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0	0.472
3	0	0	0	0	0	0.161
4	0	0	0	0	0	0

TABLE XI
PROBABILITIES OF DRIVER SEEING HAZARD WITHIN CAMERA SUB-FRUSTUM (2, 4) WHERE ROW AND COLUMN IDENTIFIES THE WINDSCREEN CELL INTERSECTED WITH THE CAMERA SUB-FRUSTUM

Row/Column	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0.766
4	0	0	0	0	0	0

ACKNOWLEDGMENT

This work has been supported by the Malaysian Government through MARA one of the sponsor agencies in Malaysia that help students to access education. We would like to thank my friend Dr John Cox for his contribution to this paper by proof reading and helping set up the experiment.

REFERENCES

[1] WHO, ''World Health Report, Technical Report'', World Health Organisation, http://www.who.int/whr2001/2001/main/en/index.html, 2001.
[2] OECD/ECMT, ''Ambitious Road Safety Targets and the Safe System Approach'', OECD Publishing, 2006.
[3] National Highway Traffic Safety Administration, 'National Motor Vehicle Survey Crash Causation: Report to Congress, pg 35, www.nhtsa.gov, July, 2008.
[4] Neale, V. L, Dingus, T., A, Klauer, S.G., Sudweeks, J., and Goodman, M.,''Overview of the 100-Car Naturalistic study and findings'', Proceedings of the International Conference on Enhanced Safety of Vehicles, 2005.
[5] Fletcher, L. and Zelinsky, A., '' Driver Inattention Detection based on Eye Gaze–Road Event Correlation,'' International Journal of Robotics, 774–801, 2000.
[6] Mohd Zaid, S.N.H., Mohamed A.M, and Soliman, A.H., ''Towards Eye Gesture Analysis for Driver Assistance System using Template Matching'', Proceeding on 4th Engineering Conference, Malaysia,2011.
[7] Doshi, A., and Trivedi, M., ''A comparative Exploration of Eye Gaze and Head Motion Cues for Lane Change Intent Prediction'', Proc. IEEE Intelligent Vehicles Symposium, Eindhoven Netherland, 49-54, 2008.
[8] Doshi,A., and Trivedi M.M., ''On the Roles of Eye Gaze and Head Dynamics in Predicting Driver's Intent to Change Lanes'', In Proc IEEE Transaction on Intelligent Transportation Systems'', 10 (3), 453 – 462,2009.
[9] McCall, J. C. Wipf, D. P. Trivedi, M. M. Rao, B. D., ''Lane Change Intent Analysis Using Robust Operators and Sparse Bayesian Learning, IEEE Transactions on Intelligent Transportation Systems'', 8(3), 431-440,2005.
[10] Batista, J., '' A Drowsiness and Point of Attention Monitoring System for Driver Vigilance'', Proceedings IEEE Intelligent Transportation Systems Conference, 702 – 708, USA, 2007.
[11] Smith, P., Shah, M.,and Lobo, N., V., '' Determining Driver Visual Attention with One Camera'', IEEE Transaction on Intelligent Transportation Systems, 4 (4), 205 – 218,2003.
[12] Flores, M., J., Armingol, J., M., and Escalera, A.,''Real Time Warning System for Driver Drowsiness Detection Using Visual Information'', Journal of Intelligent and Robotic, 59 (2), 2010.
[13] Hillenbrand, J., Krochel, K., and Schmid, V., ''Situation Assessment algorithm for a collision prevention assistant'', In Proceeding IEEE Intelligent Vehicle Symposium, 459-465, 2005.
[14] Cannolly,C., '' Driver Assistance Systems Aim to Halve Traffic Accidents'', Journal of Drivers, Transportation safety, Road safety, Motorways, Car.,29(1), 13-19, 2009.
[15] McCall, J.C., and Trivedi, M.M.,"Driver Behaviour and Situation Aware Brake Assistant for Intelligent Vehicles", Proceedings of the IEEE, 95(2), 374-387,2007.