Eyetracker Analysis of Fixation Points using an IR HUD in an Automobile

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Abstract:

This paper describes the experimental apparatus and analysis techniques now in place at the US Army Tank-automotive and Armaments Command (TACOM) Visual Perception Lab in Warren, Michigan, and the results of some preliminary trials using these methods. The tools will be used to develop and analyze experiments to better understand how drivers use various displays and viewing systems intended to aid drivers in poor visibility conditions, particularly at night. Visible and infrared (IR) road scene imagery obtained from the field were displayed simultaneously and subject eye fixation and point of gaze measured using a magnetic head tracker and near IR eyetracker. Results were analyzed to determine if personal differences between the various subjects caused them to prefer one display to another. The goal was to see if people prefer to use the heads up display (HUD) or the direct view for driving at night.

Introduction

As part of a Cooperative Research and Development Agreement (CRADA) between Ford Motor Co. and the US Army TACOM, the investigators are doing research on potential enhanced vision systems for automobiles. The National Automotive Center at TACOM is evaluating novel display devices for enhanced vision in military vehicles. This research parallels work in many areas on the use of enhanced or sensor fused imagery to aid in visual perception while driving.[1,2,3] . The goal is to develop various metrics for the objective comparison of various displays and viewing systems to aid drivers in situations with poor visibility. Specifically, the research is aimed at determining what kind of system would be useful for assistance while driving at night. One possible vision enhancement system uses an IR sensor to gather scene data and a HUD as a display device.

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14. ABSTRACT
This paper describes the experimental apparatus and analysis techniques now in place at the US Army Tank-automotive and Armaments Command (TACOM) Visual Perception Lab in Warren, Michigan, and the results of some preliminary trials using these methods. The tools will be used to develop and analyze experiments to better understand how drivers use various displays and viewing systems intended to aid drivers in poor visibility conditions, particularly at night. Visible and infrared (IR) road scene imagery obtained from the field were displayed simultaneously and subject eye fixation and point of gaze measured using a magnetic head tracker and near IR eyetracker. Results were analuzed to determine if personal differences between the various subjects caused them to prefer one disply to another. The goal was to see if people prefer to use the heads up display (HUD) or the direct view for driving at night.

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Method

A modified F-150 was used as the test vehicle for this experiment. The F-150 was outfitted with an Applied Science Laboratories (ASL) eyetracker and headtracker and a HUD supplied by Hughes. For stimuli, longwave infrared video and low-light visual imagery were recorded with a HI 8-mm VCR. The high-resolution video was recorded at night in various locations including a highway, a city street, and a country road. The data were recorded using an 8 to 12 micron, uncooled infrared camera and a low-light visual camera. Both cameras were mounted and bore-sighted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). The infrared imagery was displayed through the HUD mounted in the F-150 test vehicle, and visual black and white imagery was presented on a large wrap-around-screen for direct view through the windshield. Subjects were shown the synchronized HUD and direct view imagery simultaneously for a 5-minute stream of video. They were asked to look at the scene they'd prefer to see while driving during the experiment. The ASL eyetracker recorded the subjects' point-of-gaze. Point-of-gaze is computed from knowledge of both the head position and eye fixation direction. The head position and orientation of the subjects were recorded using a magnetic head-tracker. Ordinarily, a magnetic head tracker is difficult to use inside a vehicle cab that contains magnetic materials. However, if the magnetic pulse rate is sufficiently decreased for the eddy effects to decay, the measurement can be done quite repeatably. After some experimentation, it was found that a transmitted pulse frequency of 25 Hz gave accurate results for both head position and orientation. Performance for the magnetic link was significantly improved by minimizing the propagation length. The magnetic transmitter was located close to the receiver by inserting it into the vehicle through the rear window. Figure 1 below shows a picture of the test vehicle. The infrared imagery was projected onto the HUD and the corresponding visual imagery was projected onto the large 180^0, 10 ft. high, wrap-around screen.

PICTURE 1: Experimental F-150 test vehicle with a subject wearing eyetracker

Data Analysis

Figures 1 - 4 are samples of the fixation plots obtained from the subjects. There is an eye fixation plot for each of the subjects in the test. Distributions of fixation points for the windshield and HUD are shown together to represent the actual experimental geometry. There are two areas of interest (AOI) defined in the eyetracker data window. Area 1 is the small red rectangle and represents the HUD inside the car. Area 2 is the larger red rectangle and represents the area of the windshield as seen by a subject sitting in the driver's seat of the test vehicle. The small circles represent fixation periods that are greater than 1 second, and the lines connecting the circles represent the movement of the eye. The ASL eyetracker recorded the subjects' eye point-of-gaze and the transition sequence between points.

The subjects remarked that the image of the infrared scene on the HUD was very clear and sharp and easy to look at while in the test vehicle. In these initial trials the HUD was mounted near the preferred FOV. In subsequent experiments we plan on moving the HUD display to a different location and recording subject eyetracker data. We shall also turn the IR imagery source to the HUD off, and record eye fixation data using just the visual imagery.

The following figures and tables summarize the data from four initial subjects. While the experiments were not yet designed to make definitive conclusions, the analysis demonstrates the capability of the experimental apparatus and test procedures. In the figures the red spot in upper left is the origin in reference coordinate system and there are three areas of interest (AOI):

- Area 0: area outside the windshield
- Area 1: area inside windshield, but outside the HUD
- Area 2: HUD area

In the tables below the following terms are used:

- Dwell Time total time spent in an AOI
- Fix # number of times tracked in this area
- Mean sec average amount of time in this area per point-of-gaze

Tables 1 through 4 are statistical analysis summaries of the probability of the eye moving from the HUD (Area 1) to the windshield (Area 2) or to the area outside of windshield (Area 0). The tables summarize the dwell time in an area as well as the transitions between AOI's. A transition is defined as a fixation or series of consecutive fixations that occurs in Area i and the following fixation or series of fixations occurring in Area j.

There are two types of probability tables below, conditional and joint probability tables. Conditional probability is the likelihood that given a fixation on one specific AOI, the following fixation will be on another specific AOI,

$$P_c(i/j) = \frac{No.of\ fixations\ from\ A_i\ to\ A_j}{No.of\ fixations\ on\ A_i}. \quad (1)$$

Joint probability is the relative likelihood of a transition between two specific AOI's as compared to transitions between other pairs of AOI's,

$$P_j(i/j) = \frac{No.of\ fixations\ from\ A_i\ to\ A_j}{Total\ number\ of\ transition\ pairs}. \quad (2)$$

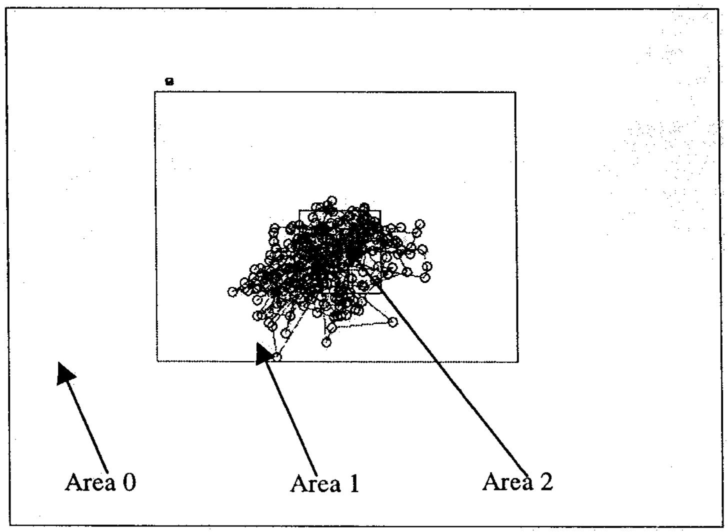

FIGURE 1: Eyetracker Fixation Plot LCD Projector, HUD Subject 1 IR & Visible

Subject #	**1**		
AOI	**Dwell Time**	**Fix #**	**Mean Sec**
0	0	0	0
1	67	206	0.19
2	106	336	0.28

Area Transition

Area	0	1	2
0	0	0	0
1	0	144	205
2	0	205	335

Joint Probability

Area	0	1	2
0	0	0	0
1	0	0.43	0.61
2	0	0.61	1

Conditional Probability

Area	0	1	2
0	0	0	0
1	0	0.7	0.61
2	0	0.61	1

TABLE 1: Statistical Analysis of subject 1

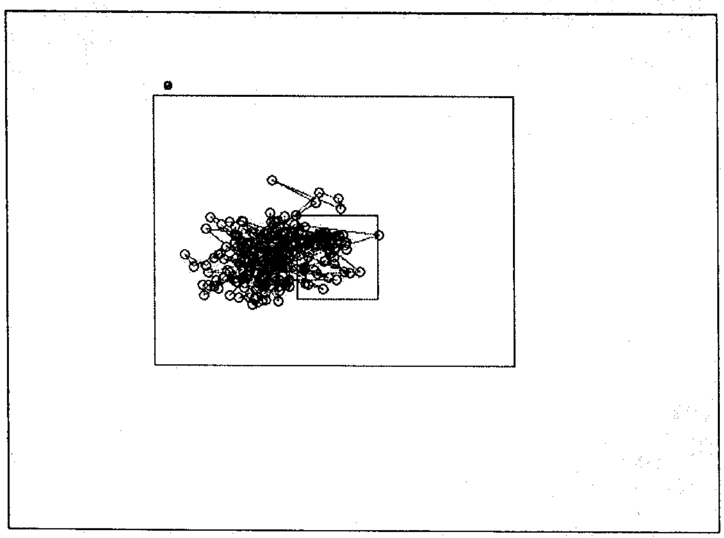

FIGURE 2: Eyetracker Fixation Plot LCD Projector, HUD Subject 2 IR & Visible

Subject #	**2**		
AOI	**Dwell Time**	**Fix #**	**Mean Sec**
0	0	0	0
1	43	75	0.05
2	139	312	0.07

Area Transition

Area	0	1	2
0	0	0	0
1	0	55	75
2	0	74	311

Joint Probability

Area	0	1	2
0	0.00	0.00	0.00
1	0.00	0.18	0.24
2	0.00	0.24	1.00

Conditional Probability

Area	0	1	2

0	0.00	0.00	0.00
1	0.00	0.73	1.00
2	0.00	0.24	1.00

TABLE 2: Statistical Analysis of subject 2

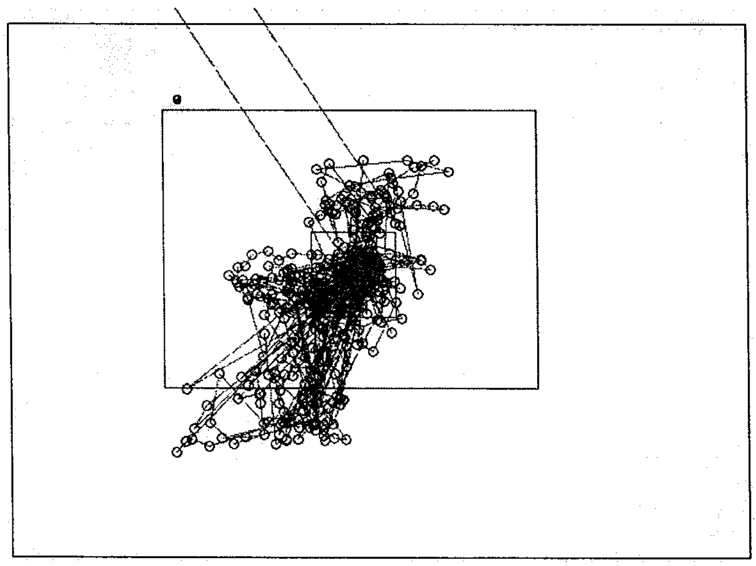

FIGURE 3: Eyetracker Fixation Plot LCD Projector, HUD Subject 3 IR & Visible

Subject #	**3**		
AOI	**Dwell Time**	**Fix #**	**Mean Sec**
0	18.00	75.00	0.13
1	116.00	302.00	0.07
2	164.00	499.00	0.08

Area Transition

Area	0	1	2
0	48	14	27
1	15	235	287
2	27	287	471

Joint Probability

Area	0	1	2
0	0.08	0.02	0.05
1	0.03	0.41	0.52
2	0.05	0.50	0.82

Conditional Probability

Area	0	1	2
0	0.65	0.19	0.37

1	0.05	0.78	0.95
2	0.05	0.58	0.95

TABLE 3: Statistical Analysis of subject 3

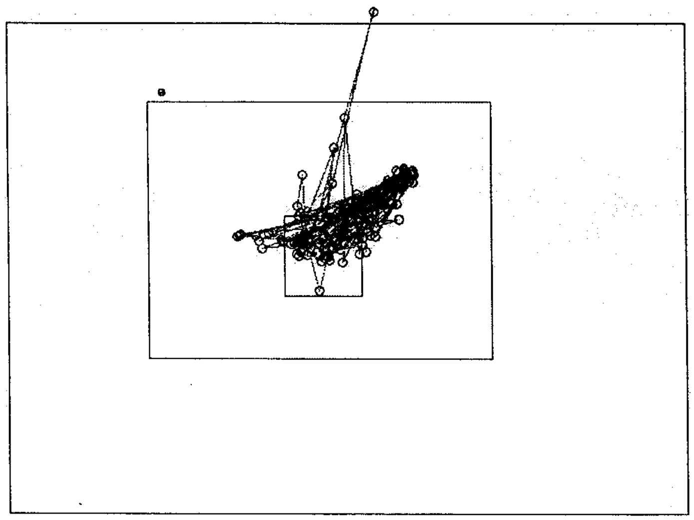

FIGURE 4: Eyetracker Fixation Plot LCD Projector, HUD Subject 4 IR & Visible

Subject #	**4**		
AOI	**Dwell Time**	**Fix #**	**Mean Sec**
0	0.65	4	2.77
1	9.44	57	2.06
2	33.1	199	1.67

Area Transition

Area	0	1	2
0	3	1	1
1	1	20	55
2	1	56	197

Joint Probability

Area	0	1	2
0	0.02	0.01	0.01
1	0.01	0.10	0.27
2	0.01	0.28	0.98

Conditional Probability

Area	0	1	2
0	1.00	0.33	0.33
1	0.02	0.36	0.98

2	0.01	0.28	1.00

TABLE 4: Statistical Analysis of subject 4

The data from all the subjects show they spent over half their time looking at the HUD. Although we have over 300 data points for each subject we had only 4 subjects for this initial trial. The t-test and F-test analyses for mean fixation time shown below indicate that there is no strong difference in the amount of time subjects looked at the HUD. This is consistent with our instructions to the subjects who received no training and were asked only that they look at whichever display they preferred, rather than perform a driving task using the IR imagery.

AOI #1		AOI #2	
Mean	0.5925	Mean	0.525
Standard Error	0.490142	Standard Error	0.384719
Median	0.13	Median	0.18
Mode	#N/A	Mode	#N/A
Standard Deviation	0.980285	Standard Deviation	0.769437
Sample Variance	0.960958	Sample Variance	0.592033
Kurtosis	3.917462	Kurtosis	3.660675
Skewness	1.976498	Skewness	1.908536
Range	2.01	Range	1.6
Minimum	0.05	Minimum	0.07
Maximum	2.06	Maximum	1.67
Sum	2.37	Sum	2.1

TABLE 5: The summary statistical table for mean fixation time

F-test Two-Sample for Variances

	AOI #1	AOI #2
Mean	0.5925	0.525
Variance	0.960958	0.5920333
Observations	4	4
df	3	3
F	1.623149	
P(F<=f) one-tail	0.350201	
F Critical one-tail	9.276619	

t-test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	0.5925	0.525
Variance	0.960958	0.592033
Observations	4	4
Hypothesized Mean Difference	0.5	
df	6	
t Stat	-0.69412	
P(T<=t) one-tail	0.256787	
t Critical one-tail	1.943181	
P(T<=t) two-tail	0.513573	
t Critical two-tail	2.446914	

TABLE 6: f-test and t-test for mean time

AOI #1		AOI #2	
Mean	160	Mean	336.5
Standard Error	57.8172408	Standard Error	61.85534
Median	140.5	Median	324
Mode	#N/A	Mode	#N/A
Standard Deviation	115.6344816	Standard Deviation	123.7107
Sample Variance	13371.33333	Sample Variance	15304.33
Kurtosis	-2.764730894	Kurtosis	1.515581
Skewness	0.540586548	Skewness	0.590395
Range	245	Range	300
Minimum	57	Minimum	199
Maximum	302	Maximum	499
Sum	640	Sum	1346
Count	4	Count	4

TABLE 7: Summary table for number of fixations

t-Test: Paired Two Sample for Means

	AOI #1	AOI #2
Mean	160	336.5
Variance	13371.33	15304.33
Observations	4	4
Pearson Correlation		0.91568
Hypothesized Mean Difference		0
df		3
t Stat		-7.09175
P(T<=t) one-tail		0.002884
t Critical one-tail		2.353363
P(T<=t) two-tail		0.005767
t Critical two-tail		3.182449

TABLE 8: t-test for number of fixations

It's interesting to observe that there is no significant difference between the HUD and windshield for mean fixation times, however there is a significant difference between HUD and windshield for the number of fixations. At this point we are not sure this is because of the novelty of the tool or if people really prefer to use the HUD.

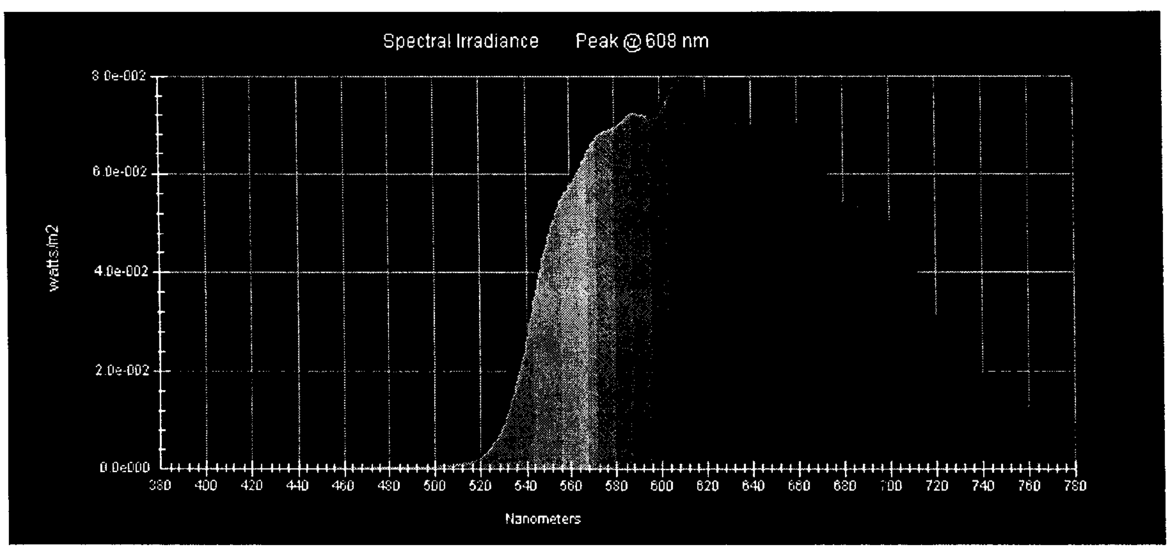

FIGURE 5: HUD Spectrum

Figure 5 above shows a picture of the spectrum of light emitted by the Hughes HUD. The light spectrum peaks at 608 nm. Figure 6 below shows the spectrum of light reflected from the wide screen in the visual perception lab. The peak is around 540 nm. The image spectrums were not used much in this paper, although we intend to analyze the light spectrums of the displayed images in a future paper and use the spectrums a s a discrimination factor in the evaluation of enhanced vision displays.

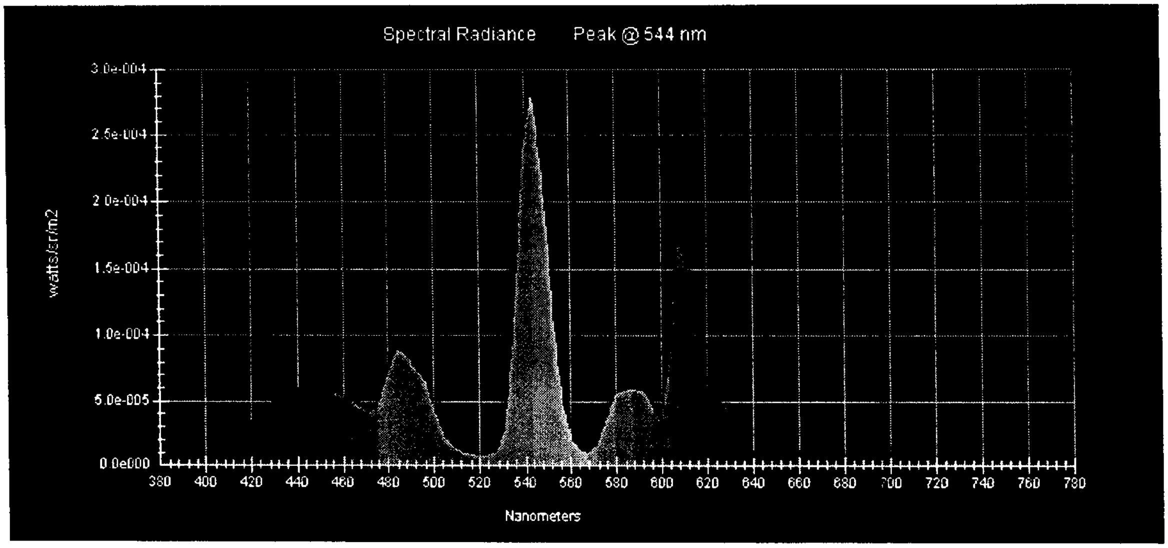

FIGURE 6: Screen Spectrum

Conclusions and Observations

These experiments were designed to test the experimental tools and not to provide answers to a particular hypothesis. However, from the plots in Figure1 through Figure 4 it is clear people use the HUD that displays IR imagery. This is no doubt due in part to the novel nature of the HUD. However, many people who participated in this test have mentioned that they prefer to look at the HUD because it provides a clear image and keeps their attention.

Future tests will address the question of subject's reactions to scenes requiring driver actions. Using eyetracker data we will be able to trace the drivers visual response to cues displayed on a visual aid display and in the "real world" of the 180^0 wrap-around screen.

References

1.CIE Technical Report on Fundamentals of the Visual Task of Night Driving, 1st edition 1992.

2. McCarley, J.S., Krebs, W.K. (in review). "Visibility of road hazards in thermal, visible, and sensor-fused nighttime imagery." Applied Ergonomics.

3. Sinai, M.J., and Krebs, W.K. (in review). "An assessment of sensor-fused imagery: a comparison using target detection, target recognition, situational awareness, and scene recognition tasks." Journal of Applied Experimental Psychology:

4. Applied Science Labs Eyetracker manual, 1996, Applied Science Labs, Norwood, MA, pp.4-7- to 4-8.