AVOIDANCE OF HAZARDOUS TRAFFIC SITUATIONS CAUSED BY REDUCED VISIBILITY IN INCLEMENT WEATHER CONDITIONS

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Abstract

Every year, numerous accidents happen on European roads due to reduced visibility (fog, darkness, heavy rain). The fact that transport safety is compromised by inclement weather conditions is a concern to the public and to authorities and industry trying to optimise safety by improvements of infrastructure, technologies, and regulations.

A system for enhanced sight effectiveness, SEE[2], aims at demonstrating how technological solutions may improve transport safety. The purpose is to raise human situation awareness in conditions of reduced visibility in the automotive context by the development of an enhanced vision system (EVS). This paper deals with a brief presentation of the system itself, and with the planning and execution of the evaluation of the system. In such a system a sensor operating in a spectral band less obscured by fog and enhancing the visibility at night - as compared with the visible band - produces an image, which is then presented to the driver on a suitable display inside the car.

The introduction of an efficient enhanced vision system in the automotive sector shall bring safety benefits to several applications, e.g. the direct application of EVS would be the augmentation of the visibility range in fog and at night, supporting avoidance of hazards and vulnerable objects (pedestrians and cyclists etc.). Infrared sensors are means that could help drivers to overpass human eyes limitation.

1 Introduction

Using infrared detection, IR, for improving night sight and sight in foggy weather is not a new issue. However, diverging philosophies have been utilised by various carmakers about how the enhanced images should be displayed. Two types of infrared images with different perceptual qualities are typically discussed. The near IR light lies closer to the visible spectrum of light and thus images based on near IR resemble the normal view closely. Images in near IR spectrum have a high level of detail and may appear more familiar to the subject. However, the high detail level may also result in image clutter making the image more difficult to scan, e.g. light from streetlights and oncoming cars is visible in the near IR image. The far IR is characterized by a low level of detail but a very long range and low image clutter. Images based on far IR may be less familiar to the subject which could result in difficulties of interpreting the images. Conversely, the sharp contrast between warm objects

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[2] SEE, Sight Effectiveness Enhancement, was a European project partly funded by EU

and background may enhance object detection, such as pedestrian, wild life, etc; see Knoll (2002) and Rumar (2003). Carmakers have previous chosen between these two alternatives, see Willie D. Jones. The new idea in the SEE system is to combine the advantages of the two systems by having both available and fuse the two presentations into one.

The System

The requirements for the EVS system were the following:

- The sensors shall operate in two selected spectral ranges of SWIR (1.3-2.5 μm) and LWIR (8-13 μm).
- The field of view should cover 36° x 27° (horizontal x vertical), at least 24° x 18°.
- The camera should provide a resolution of 320 x 240 pixels (1/4 VGA) or more.
- Sensor technology: For usage in cars it is necessary to employ un-cooled sensor assemblies.
- The thermal sensitivity of the system should allow resolving temperature differences of $dT \leq 0.1°$.
- The camera should operate correctly across a range of environmental temperatures of –20°C to +60°C.
- The intensity information per pixel should contain 8 bits, if possible 12 bits.
- Video Standard: PAL
- It is considered essential to house the camera in a pod in order to protect the system against moisture, humidity, snow etc.
- The usage of the IR-camera on a car requires a special protection of the optical system from hits by stones and other objects that can mechanically damage the system.

The position of the IR cameras on the car is indicated in figure 1

Statistics

Statistics of accidents in various countries – especially connected with bad visibility due to fog or darkness - have been studied, and various scenarios have been developed in order to identify realistic situations on which we expect the enhanced vision may carry significant safety improvements.

The statistical data have been taken from a couple of European and a US database. Even though the number of accidents in general may differ from one country to another, comparison among databases shows that accidents due to these specific situations of fog or darkness are of nearly the same sequence as compared to the total number of accidents for various countries. Table 1 compares statistical data from three different European countries, Denmark Statistics, German Statistics, and Swedish Statistics, and from USA, the FARS database, related to accidents due to fog or darkness, respectively, as compared with the total number of accidents

Based on this indication, we claim the validity in using detailed results of any of these databases depending on the available access for the specific kind of request.

Examples of various types of accidents related to reduced visibility are given below based on data from Danish traffic accidents in 1999, see Denmark Statistics. The accidents due to dark environments are distributed according to various situations like single accidents, accidents involving two cars, and accidents involving a car and pedestrians.

The relative numbers of accidents are the following:

For single accidents the most frequent are the three situations shown in figure 2.

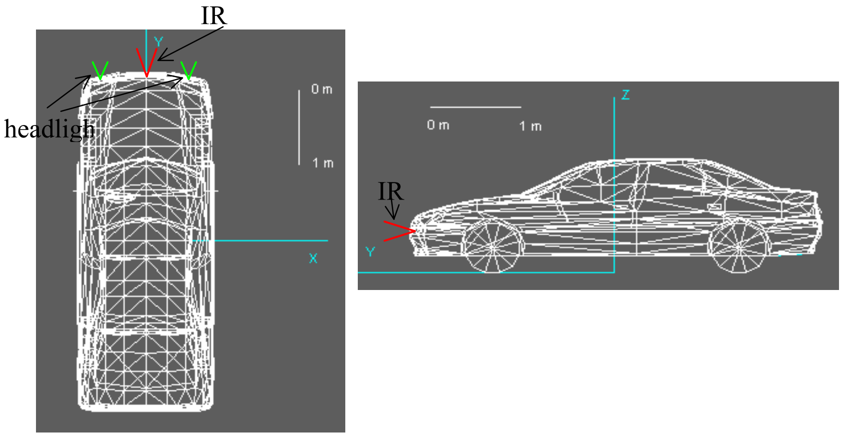
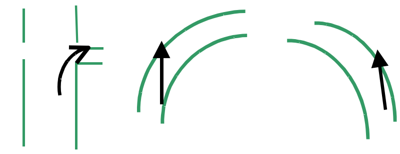


Figure 1, Positions of the SWIR and LWIR cameras

	Accidents due to fog related to total number of accidents	Accidents due to darkness related to total number of accidents
Danish statistical data	1,43%	28,30%
German statistical data	1,34%	23,10%
Swedish statistical data	No information	25,48%
US statistical data	1,45%	28,96%

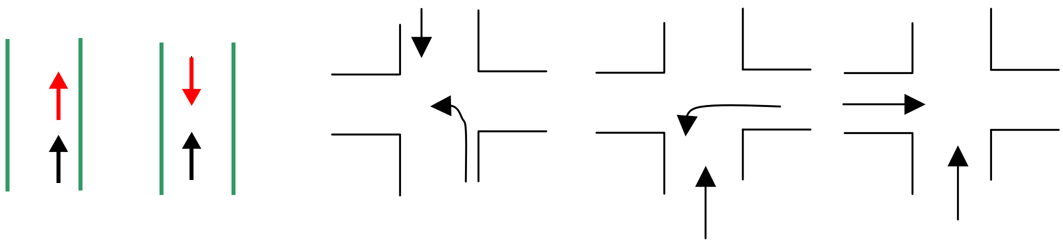
Table 1: Frequency of accidents related to fog or darkness as compared to total number of accidents in a sample of countries



45% (46%)　16% (46%)　21% (45%)

Figure 2: Most frequent single accidents in dark as compared with the total number of single accidents in dark. In brackets the same number of accidents in dark as related to the total number of the same kind of accidents in all kinds of visibility.

For accidents involving two cars a large number of situations are specified, in fact 17



categories, but the most frequent situations are shown in Figure 3.

10% (24%)　13% (27%)　12% (20%)　11% (23%)　14% (19%)

Figure 3: Most frequent accident in dark involving two cars as related to the total number of two cars accidents in dark. In brackets the number of the same accident in dark as related to the total number of the same type of accident for all kinds of visibility.

For accidents involving a car and pedestrians the most frequent are the ones sketched below in Figure 4 with the relative distribution as follows:

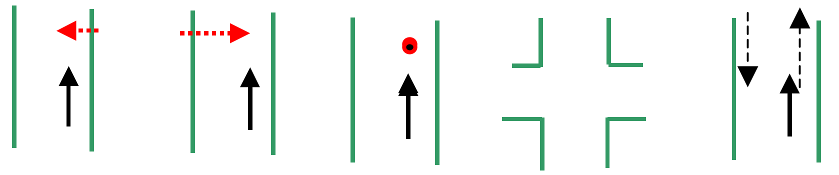


Figure 4: Most frequent accident in dark involving a car and pedestrians as related to the total number of car and pedestrians' accidents in the dark. In brackets the number of the same accident in dark as related to the total number of the same kind of accident for all kinds of visibility.

Similar results are found related to reduced visibility due to fog; see Andersen, V., et al. 2003.

Scenarios & sessions

Based on the statistical survey a number of scenarios were designed for testing the EVS system.

The subjects experienced the scenarios in different kinds of weather conditions and in conditions with or without the SEE enhanced image. The subjects were not all expected to react to all the scenarios, but the expectation was that an adequate number of them would react to the same scenarios allowing analyzing their time of reaction.

The scenarios were implemented in a movie simulating a recorded tour in real environments. The road layout and the surroundings in the simulated movie were realistic and included buildings, trees, open areas and other vehicles. In this way a realistic level of visual workload was achieved. The weather situations simulated were the ones shown in table 2.

Scenario Matrix – Automotive				
SEE Function	**No Fog Day**	**Dense Fog Day**	**No Fog Night**	**Dense Fog Night**
With SEE				
No SEE				

Table 2: Visibility conditions in the automotive evaluation.

However, for daylight in clear weather it was not expected that the SEE enhanced vision would be used, as there was no need for it, and this situation was simulated only without the using the SEE system just for reference.

During the session the subjects were inspecting the movies of different weather conditions in various orders for reducing learning effects. All potential dangerous situations, especially concerning 'soft road-users' such as pedestrians and cyclist ought to be indicated, and all indications were logged with the related time tag in the 'Observer'[3] system.

The velocity of the car in the video was about 60 km/h. During darkness and dense fog it was possible to see and navigate by the road-side and the white-lining on the road. With a reduced visibility of, e.g., 20 meters due to dense fog, the speed allowed the person only 1.2 seconds for responding to unexpected objects ahead.

Technical set-up

As indicated, no real car or real environments were used for evaluating the system. Simulations of various weather situations were provided for avoiding the constraints due to needed but missing real weather conditions. In the experiment the 'Observer' was used for collecting data. Data were extracted from the 'Observer' system and analyzed with the statistical functionality of Microsoft Excel. A 'Concept Board' was used as input device as an alternative to a normal keyboard. When the subject touched anywhere inside a large area of the board a code was sent to the 'Observer' registering the time of the push (minutes, seconds and milliseconds). Figure 5 shows the setup in the experiment room.

The size of the window at which the subject looked was approximately 8 inches in order to correspond to the size of the display expected to be developed for use in a car.

The experimenter controlled the sessions by means of a keyboard. She was in the room during all sessions, seated out of sight of the subject.

Instruction

The instruction included a cover story in order to counterbalance the limited realism and ecological validity of the experiment caused by the lack of a real driving environment, such as a car or a real car simulator. Subjects were introduced to the system as a passenger sitting besides the driver helping to navigate during the bad visibility. The rationale behind the story was that it would be more plausible than instructing the subjects to be the drivers since they had not control over the events in the movie.

Figure 5: Picture of the setup in the test room.

Debriefing

Immediately following the test session the subjects were put through a brief interview concerning their subjective impression of the various versions of the movie. A questionnaire was filled out concerning the general impression of the infrared images per se, and in comparison with the vision without the SEE system. Likewise, the questions were related to

[3] The Observer is a piece of software developed to collect and analyze any kind of behavioural data. About The Observer and other related products go to Noldus Information Technology at: http://www.noldus.com/

perception of objects and obstacles, and perception of terrain features. For comments not covered by the questionnaire there was room for 'Other comment about the infra-red presentations, positive or negative'. The overall satisfaction is shown in figure 6. For the detailed response concerning object identification and manoeuvring, see Andersen, V., et al. 2006.

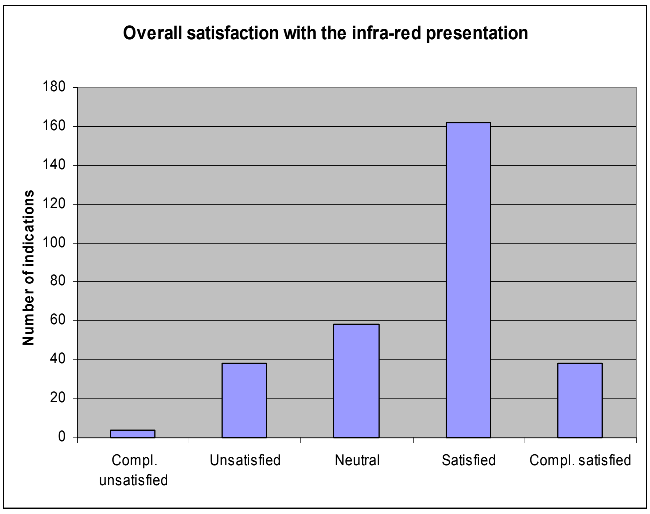


Figure 6: The overall satisfaction with the options offered by the SEE system.

Experimental Design

Based on the loggings, scenarios responded to by nearly all of the subjects were selected.

For each weather-condition a time window was defined. The time window begins at the time at which the situation reacted upon may be spotted and ends when the situation is passed by the test car. The time of reaction for each of the subjects within this time window was recorded, and the time distribution of reactions for each weather situation related to using or not using the SEE system were compared by a 'paired two sample for means t-test' to check the difference in mean-time and the significance of this observation.

Results

For night-time, clear weather condition, the results for all four scenarios showed an advantage in using the SEE system: drivers detected the obstacle earlier with increased opportunity of avoiding dangerous situations. For scenario one and two the subjects' detections using the SEE system was more than 0.5 sec earlier than the detections made without the SEE system. However, even so, the difference was not statistically significant due to the fact that the variance of these observations was rather high as the decision about a safety critical situation was dubious for these scenarios - cyclist along the road - which may be seen as dangerous or just a normal situation. For scenarios 3 and 5, however - a man lying on the road and a cyclist crossing the road - it was obvious to everybody that this was a safety-critical situation. As expected, therefore, all subjects reacted promptly to these situations, and the advantage was significant.

In foggy weather the outcome was very different. In fact, the analysis showed a *disadvantage* in using the SEE system – as summarised in Table 3. However, a detailed analysis of the parameterization of the fog simulation has shown that the lack of sight effectiveness enhancement was due to a non-optimal selection of parameterization issues in the simulations, see below.

Figure 7 shows an example of the same frame: with SEE at the left and without SEE at the right hand side during night.

Scenarios	Day, dense fog	Night, no fog	Night, dense fog
1	disadvantage, significant	advantage not significant	disadvantage significant
2	disadvantage significant	advantage not significant	disadvantage significant
3	advantage not significant	advantage significant	advantage not significant
5	disadvantage significant	advantage significant	advantage significant

Table 3: Detection times with indication of advantage/disadvantage of the SEE system

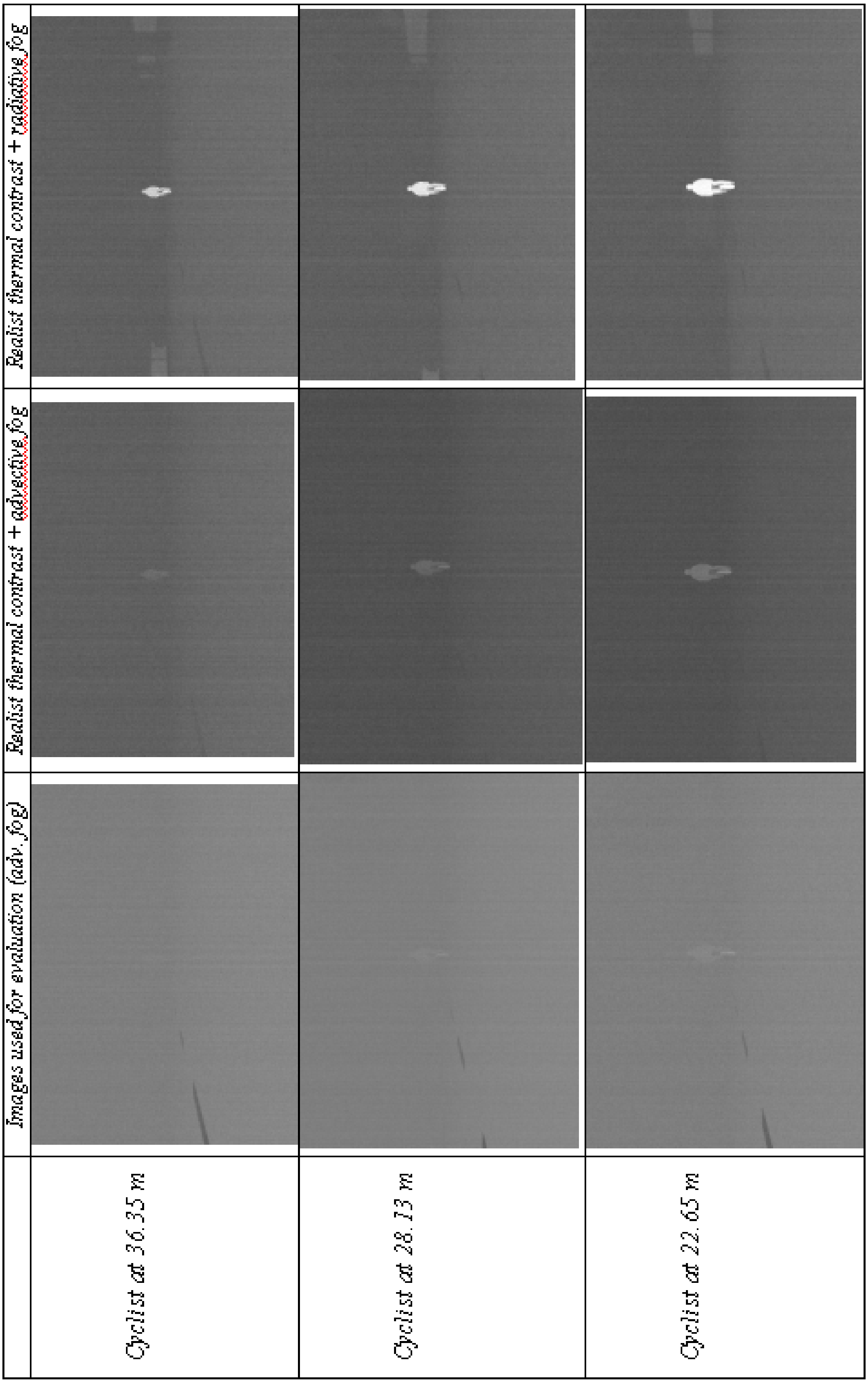
Figure 7: Night, clear weather. Cyclist is completely visible with SEE, but only a back-light is visible without SEE, i.e. missing back light means no sight of the cyclist without the SEE system.

Parameter Selection

As the results from the simulations did not show the improved performance of the system for foggy weather conditions as expected from a real test of a prototype of the SEE system, renewed efforts were made to identify the sources of the difference in performance between the real SEE prototype system and the simulated one. These efforts have identified the reasons why the simulations have been far from optimal with regard to bringing out differences between using the SEE and not using the SEE system during foggy conditions. It turned out that the parameterization selected for the simulations have not been optimal – but have in fact by chance reproduced a type of fog that puts the SEE system at a distinct disadvantage. Moreover, the temperature difference between the simulated, surrounding fog and the simulated objects (cyclists) was too small as compared with real conditions.

New simulations were produced with a more realistic temperature difference between the simulated objects and the environments resulting in improved performance of the system, and furthermore simulations were repeated with radiative type of fog instead of the advective type of fog as for the initial simulations[1]. The result is shown in figure 8 comparing the initial simulations with the new ones for fog during day. The new simulations show a drastic improvement of system performance and conform better to the informal tests with the SEE prototype system.

Figure 8, comparing the initial simulations with the new ones for fog during day



Conclusion

A sight effectiveness system for automotive enhanced vision for decreasing the risk of road traffic accidents was developed and evaluated from a simulation of the system using test subjects.

For night-time, *clear* weather condition, the results for all selected scenarios show a clear advantage in using the SEE system.

In foggy weather the situations was somewhat different. The analysis showed, in some situations, a disadvantage in using the SEE system. Nevertheless, the advantage of the system for night vision came through even under foggy conditions where the SEE system shows a statistically significant advantage for two of the selected scenarios. However, new and more realistic simulations of foggy conditions resulted in a drastic improvement in the performance of the SEE system.

Results from the questionnaire responses by the test subjects show largely positive reactions. A great improvement by using the SEE system for night driving in clear weather is indicated by 95% of the test persons. However, although the objective test showed no positive effect of the SEE system during foggy weather 55% of the test persons agreed that the system improved their vision, see Andersen, V., et al. 2006.

However, we have tested the system only in simulated conditions, not in a natural context with the system installed in a real car. Drawbacks of the real system may be – like for navigation systems – that it may take too much attention, taking the drivers focus away from the road. Furthermore, people have to be acquainted with the system in order make the right interpretation of the image, and elderly people being the ones with the highest need of visual support in bad weather conditions may be the ones most reluctant to use that kind of new system. Moreover, the system itself has a more limited filed of view as compared to the normal sight out the wind screen.

Finally, a general consideration related to all efforts trying to increase safety on the roads, like technical improvements, better roads, or tighten up traffic regulations is that many people are tempted to increase speed until they have the same subjective feeling of being in control.

The SEE system may find use in a number of other domains. Especially it has been evaluated similarly within the domain of aviation, likewise with positive results; see Andersen, H.B., et al. 2006.

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[1] Radiative fog tends to form late at night or in early morning hours. It may also form following precipitation that clears near or after sunset. Considerable variation is likely, especially over open areas or near water sources where fog will tend to be denser. Dense areas may be isolated but can present a hazard to land, air, and sea travel. The Advective fog can form and advect into a region almost any time of day. It shows some tendency to develop in late afternoon or evening hours over coastal areas. It may range from thin to dense, but dense conditions may cover larger area than radiation fogs, and changes in intensity tend to be more gradual than with radiation events.