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INCREASED VISUAL PERCEPTION IN NIGHT-TIME DRIVING CONDITIONS AND/OR REDUCED OPTICAL VISIBILITY

ABSTRACT

The paper presents the significance of visual perception for the safety of traffic participants. The essential guideline of visual perception is visibility, which is severely reduced in night-time driving conditions and/or conditions of reduced optical visibility. In order to increase the visibility in such conditions a thermovision system has been developed, i.e. IR (infrared) system. The operating principle as well as the significance of the new opto-electronic systems which increase the visibility at night and/or conditions of reduced optical visibility have been summarised in this paper. Based on the knowledge of the operating principles it is possible to evaluate correctly the feasibility of such IR systems.

KEY WORDS

visual perception, night-time driving, IR system

1. INTRODUCTION

Visual perception is of vital significance for the road safety: error in visual perception causes the majority of reported road accidents. It is well known that visual perception in traffic requires a kind of dynamic predicting. Visibility can be significant for road safety, mainly when it refers to a moving person who perceives certain objects in movement in a three-dimensional field (driver), and even more if this dynamic visual perception is studied in non-optimal conditions of the visual field and the observers. The importance of visual perception for road safety increases from static towards dynamic observers as well as towards objects, and from normal to worse conditions in the visual field, and also from the optimal observers to those with multiple vision restrictions.

In traffic sciences, studies of visual perception are carried out and they will be the more relevant the more they are directed to the moving observers and the things moving in three-dimensional space. Moreover, possible safety relevance is increased if the study takes into consideration the impact of deteriorated

conditions of the visual field and disturbances in visual perception. Humans have compensation strategies for individual handicaps, but multiple disturbances or multiply deteriorated conditions may seriously affect human reaction.

Advanced electronics in automobiles and on the road may also support or alleviate the visual task of the road user by means of other methods of perception. This paper presents the use of thermovision system in automobiles with the aim of significantly improving driver's visual perception in night-time driving conditions as well as in conditions of reduced visibility.

2. VISUAL PERCEPTION AND ROAD SAFETY

No doubt, visual perception is of vital importance for road safety. Visual perception in traffic is not only determined by visibility, but it also depends on perception. Perception is closely related to the level of attention, selection and activation of memory elements, and also with the central information processing leading to judgements and motoric actions. Perception in driving usually occurs in dynamic conditions. Visual perception in traffic is active cognitive perception and may be better described as predicting. What an experienced road user sees is what causes selection of the learned optical-motoric sequence of actions which refer to the road user dynamics. The driver must predict the oncoming conditions using routine prediction process of the situation on the road and behaviour of other road users in order to adapt their individual behaviour. Error in vision or prediction in traffic may have fatal results. Studies of accidents which included an overall and detailed analysis and interviews with road users who participated in accidents, revealed that the errors in visual perception play a dominant role in causing the accidents. An example is the Nagayama study (Japan), based on 38,625 analysed accidents. The summarised results are given in Table 1.

Table 1 - Main causes of accidents according to the type of error

Main cause	percentage
errors in visual perception	53.7
errors in judgement	37.2
errors independent of human factor and unknown factors	9.1

Equivalent data have been obtained while studying traffic accidents in Australia (Cairney & Catchpole) and in Germany (Otte et al.).

Although traffic infrastructure may be regarded as fairly safe in optimal conditions for visual perception free of any disturbances for the road user perception, its safety changes significantly if the conditions of visual perception deteriorate and especially in the presence of some disturbance of visual perception. This may be considered through the following illustrative example.

Let us assume for this example that:

- a) visual perception in wet road conditions is reduced so much that the visual perception of the risk of accident is reduced by 20%;
- b) some defect in visual acuity and poor night-time visibility reduce additionally the perception of danger from accident by 10%.

Under such non-optimal circumstances and disturbances in visual perception, the probability that two drivers will be involved in an accident among each other is almost double. This follows from the simple law of averages. Denoting the probability of causing accident in optimal conditions for the road user devoid of any disturbances as p , the chance of avoiding accident between two drivers free of any disturbances in optimal conditions for each one independently is $(1 - p)^2$, which means that the probability of avoiding accident for both of them is $(1 - p)^4$. For the individual driver the probability of avoiding accident in the mentioned non-optimal visual conditions and disturbances becomes $0.80 \times 0.90 \times (1-p)^2$, and for both of them independent of one another it amounts to $[0.72 \times (1-p)^2]^2 = 0.5184 \times (1-p)^4$. This means that the probability of avoiding accidents is reduced for the non-optimal driving conditions by almost 50%.

In Northwest Europe more than 15% of time it is either raining or snowing, and during more than 25% of daylight time the perception conditions are non-optimal, and clearly, more than 50% of time is night-time or twilight. Apart from that, some kind of moderate disturbances of visual perception refer to the majority of road users. Thus, even when the safety is more or less guaranteed in optimal visual and perceptual conditions, it is quite understandable that errors in visual

perception are not the main cause of road traffic accidents in daily traffic.

Obviously, road system should be relatively safe even in different non-optimal conditions of visual perception and in cases of moderate disturbances of visual perception. Human evolution of visual perception capability was not led by the selection of principles based on self-movement at high speed. Obviously, visual perception at high speeds, however, is not significantly more difficult for the observers without disturbances in optimal conditions. However, reports on road accidents show that visual perception of static objects and those that move at high speeds of self-movement and visual perception of objects which move fast for the observer who moves slowly are significantly disturbed by deteriorated conditions of the visual field and disturbances of visual perception. Therefore, it is necessary to know more on visual perception of static contours by the observer without disturbances and in ideal circumstances in order to be able to design a safe system of roads, vehicles, traffic equipment and regulations.

Emphasis is set on the importance of knowing dynamic visual perception in deteriorated conditions and/or in conditions of moderate visibility disturbances. There are three types of knowledge necessary for the improvement in solving the problems of reduced, i.e. deteriorated visual perception.

- Knowledge of type A is the knowledge of dynamic visual perception based on the studies in ideal circumstances.

Knowledge of type A is necessary, but not sufficient for the safety-relevant knowledge.

- Knowledge of type B deals with questions of how the dynamic visual perception is affected by:
 - 1) deteriorated visual field conditions,
 - 2) moderate disturbances of visibility,
 - 3) interactive effects between 1) and 2).

Knowledge of type B is necessary since ideal circumstances can exist only at laboratories, but are very rarely present in real life.

- Knowledge of type C deals with questions of how dynamic visual perception may be increased in non-optimal conditions of visual field and visibility disturbances. Knowledge of type C is applied in road safety.

Protection and safety in using vehicles depends on the undistorted optical information regarding the driver's environment. This information is transmitted by the passage of light through windshields, windows and mirrors. In this way the information may be significantly distorted if the light is dispersed. Light dispersion leads to degradation of images and/or creation of deceptive images. In both cases wide-angle dispersion needs special consideration. The mentioned problem is especially pronounced during night-time driving

and conditions of reduced visibility since the amount of light from the objects is reduced and disturbances are caused by the lights of other traffic vehicles.

3. INFRARED SYSTEM FOR NIGHT VISION

Night-time driving is much more dangerous than daylight driving. At night the visibility is reduced, the contrast among objects on the road is reduced, and there is the continuously present problem of the dazzle from the oncoming vehicle lights. According to statistical data on traffic accidents about 55% of accidents occur at night, and out of those with fatalities even 62% occur at night. It needs to be considered here that out of the total driving only 25% is done at night. Therefore, in order to reduce the number of accidents it is essential to attempt to eliminate the causes of accidents that occur during night-time driving. Experts have found a solution by using a night-time driving system, which works on the princi-

ple of registering electromagnetic radiation reflected from objects in the infrared region of the spectrum.

Each body emits the so-called thermal radiation and the radiation energy depends primarily on the temperature of the respective body. The body radiates most of the energy at the wavelength determined by the body temperature (Vien's law). Thus a man with 37°C has maximum radiation at wavelength of about 9 μm . Atmosphere is a medium which behaves for infrared radiation as narrowband filter absorbing radiation only slightly in the region ranging from 3 to 5 μm and from 8 to 12 μm , so that this radiation can propagate through atmosphere.

For some dozen years the systems for night "vision" and conditions of poor visibility have been used for military purposes and they represent a component of the sophisticated armament called IR (infra-red) systems. The operating principle of one general IR system is presented in Figure 1. It consists of five subsystems, as follows: a) optics, b) detector with related electronics, c) digitisation, d) image processing and e) image reconstruction.

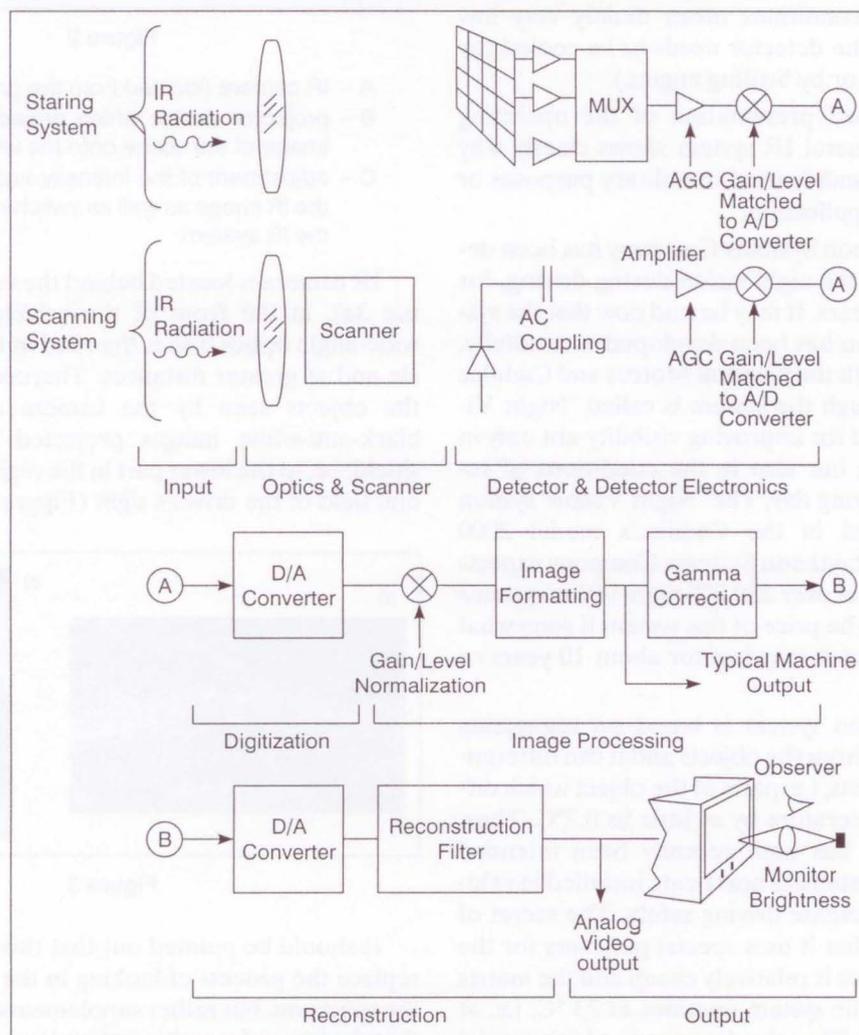


Figure 1 - Flowchart of general IR system

Figure 1 shows that IR systems include two basic principles of "looking", and that is observing the whole scene when there is a detector field, i.e. matrix detector, and by scanning the scene when there is an array of detectors or only a single detector.

Thermal radiation reaches the optics of the IR system, and it focuses the radiation to a detector. It should be mentioned that this optics is of material which lets through the electromagnetic waves mainly from the spectrum regions of the IR system (3 - 5 μm or 8 - 12 μm). Since this is optical material of specific properties, it is much more expensive than the optics used in the visible range of the spectrum. When thermal radiation reaches the detector it generates a signal proportional to the radiation. The signal is weak and needs to be amplified and processed so that IR system could produce an image which corresponds to the temperature distribution of the object, i.e. the scene which IR system "sees". Special problem lies in realising the conditions of detector operation in which it can provide a sufficiently strong signal when it is hit by the thermal radiation from the object of observance. These operating conditions mean mainly very low temperature, i.e. the detector needs to be cooled (by liquefied nitrogen or by Striling engine).

This summarised presentation of the operating principles of a general IR system shows clearly why such systems are mainly used in military purposes or for some special application.

The US Raytheon Systems Company has been developing a system for night vision during driving, for already about 15 years. It may be said now that the system for night vision has been developed successfully, in co-operation with the General Motors and Cadillac companies. Although the system is called "Night Vision", it is intended for improving visibility not only in night-time driving but also in the conditions of reduced visibility during day. The "Night Vision" system has been installed in the Cadillac's model 2000 DeVille, and the Raytheon Systems Company expects that they will market over 650,000 night vision systems by the year 2005. The price of this system is somewhat less than 2000\$ and it may last for about 10 years or about 200,000 km.

The night vision system is based on registering thermal radiation from the objects and it can differentiate between objects, i.e. parts of the object which differ regarding temperature by as little as 0.2°C. Thus, technology which has until recently been intended only for military systems is now being installed in vehicles in order to increase driving safety. The secret of this IR system is that it uses special polymers for the optics, so that optics is relatively cheap and the matrix detector used by the system operates at 23 °C, i.e. at room temperature. Thus the detector needs no special and therefore expensive cooling. The detector was de-

veloped by Texas Instruments Company and it is called UFPA (Uncooled Focal Planar Array) and was made of barium strontium titanite. Since this detector successfully detects thermal radiation at an operating temperature of 23°C, and registering differences in temperatures of only 0.2°C, thermo-electric radiator is used to maintain this temperature.

Illustration of the IR system "Night Vision" is given in Figure 2.

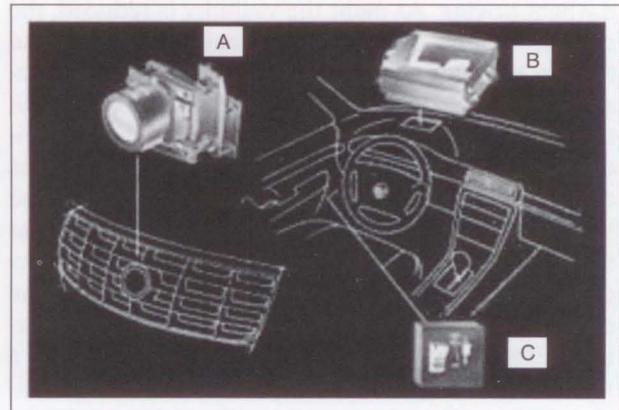


Figure 2

- A – IR camera (located from the grille),
- B – projector device which projects the infrared image of the scene onto the windshield,
- C – adjustment of the intensity and brightness of the IR image as well as switching on and off of the IR system

IR camera is located behind the vehicle grille (Figure 3a), at the front of the vehicle, and owing to wide-angle optics it sees the road in front of the vehicle and at greater distances. Thermal radiation from the objects seen by the camera are turned into black-and-white images projected onto the windshield, i.e. to the lower part in the region of the peripheral field of the driver's sight (Figure 3b).

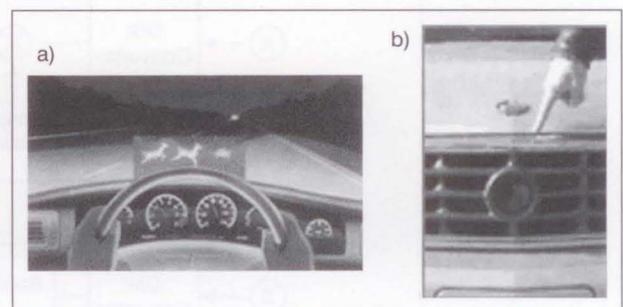


Figure 3

It should be pointed out that this system does not replace the process of looking in the visible region of the spectrum, but rather supplements it. It is therefore that the image from this system is projected in the periphery of the driver's field of sight so that the driver

might occasionally "glance" at this road image as well. Figure 4 clearly shows the difference in the object visibility on the road.

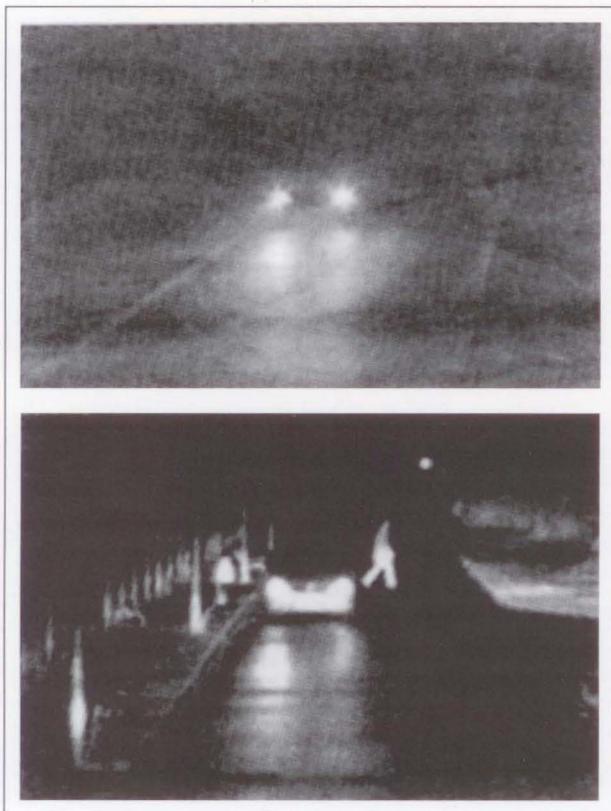


Figure 4

Above on top is the image in the optical and at the bottom in the infrared region of the spectrum. The image clearly shows that the IR system optics does not provide a clear image which is why polymer lenses are not used in military and IR systems intended for special purposes. This not clear image does not represent a barrier for application in vehicles in order to increase driving safety in night-time driving conditions and conditions of reduced visibility.

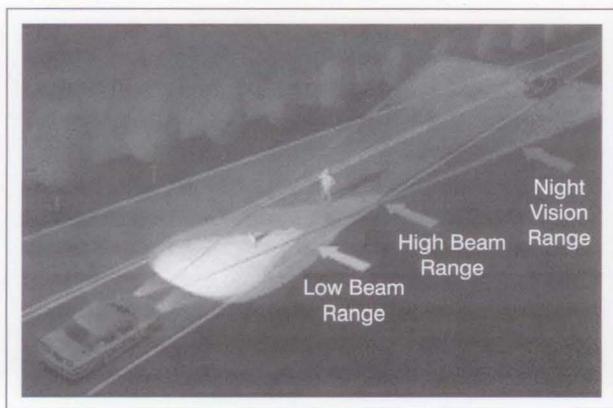


Figure 5

IR system increases road visibility three to five times compared to the visibility in the optical region, and in night-time driving. This means that at vehicle speeds of about 100 km/h the driver's response time increases from some 3.5 seconds to almost 15 seconds, which means drastic increase of driving safety. Illustration of this is given in Figure 5.

4. CONCLUSION

Visual perception is of vital importance for road safety and it is a significant component of visibility. Therefore, any improvement, i.e. increase of visibility means also an increase in driving safety.

Advanced electronics in automobiles and on the road can also support or alleviate the visual efforts of the road user by means of other methods of perception. More recently technical assumptions have been realised for the usage of thermovision system in automobiles with the aim of significant improvement of the driver's visual perception in the conditions of night-time driving as well as in the conditions of reduced visibility. In order to make proper evaluation of the well-being regarding safer driving, by means of IR systems, their basic operating principles need to be studied.

SAŽETAK

POVEĆANJE VIZUALNE PERCEPCIJE U UVJETIMA NOĆNE VOŽNJE I/ILI OTEŽANE OPTIČKE VIDLJIVOSTI

U radu se daje značaj vizualne percepcije za sigurnost sudionika u prometu. Bitna odrednica vizualne percepcije je vidljivost, a koja je značajno smanjena u uvjetima vožnje noću i/ili uvjetima smanjene optičke vidljivosti. S ciljem povećanja vidljivosti u navedenim uvjetima razvijen je termovizijski sustav, odnosno IC (infracrveni) sustav. Princip rada kao i značaj novih optoelektroničkih sustava koji povećavaju vidljivost noću i/ili uvjetima smanjene optičke vidljivosti sažeto su dati u radu. Temeljem poznavanja principa rada moguća je i pravilna ocjena upotrebljivosti takovih IC sustava.

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