A NIGHT-TIME ROAD VISIBILITY INDEX FOR THE DIAGNOSIS OF RURAL ROAD NETWORKS

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ABSTRACT

Road visibility is used as a performance index by both road lighting and automobile lighting engineers. We propose a road network visibility index devoted to road operators, in order to assess the quality of their inter-urban networks in terms of night-time visibility. On rural roads at night (without public lighting), an object on the road is only visible to the driver if it is illuminated by the headlights. Its visibility depends on its geometric and photometric properties, on the photometric properties of the headlamps, and on the retro-reflection properties of the road in the background. Our goal is to compute a “visibility level” index along a road itinerary, to serve as a tool of diagnosis for road operators who may want to know where on their network the night-time visibility is poor. This tool may also assess the improvement brought by modifications of the infrastructure. We use an instrumented vehicle (Ecodyn), calibrated it in order to measure the retro-reflection of the road pavement. We get a profile of the retro-reflectivity along the road, then we consider average headlamp photometric data (UMTRI European low-beam), and compute the profile of the visibility level, as indicated in Adrian’s model, for a given target along the road. This methodology was tested on two itineraries of several kilometers. As a conclusion, we propose a night-time road visibility index for roads without street lighting, and show the feasibility of the measurement with an existing photometric system. This methodology is mainly dedicated to road operators, but may also find applications in the conception of advanced front-lighting systems through the in-vehicle use of “visibility level” digital maps of road networks.

Keywords: night driving, road visibility, quality index, road diagnosis, onboard equipment.

1. NIGHT-TIME VISIBILITY ALONG THE ROAD

Road visibility is used as a performance index by both public lighting and automobile lighting engineers. In this paper, we propose a road network visibility index for the road operators, in order to assess the quality of their inter-urban networks in terms of night-time visibility.

On rural roads at night, without public lighting, an object on the road is only visible to the driver if it is illuminated by the car headlights. Its visibility depends on its geometrical and photometrical properties, as well as on the photometric properties of the headlamps, and on the retro-reflection properties of the road in the background. Following (CIE, 1981), the now standard visibility model proposed by Adrian (Adrian, 1989), is widely used for road lighting applications (Brémond, 2007). We suggest here that it may also find a relevant field of application to assess the quality of automotive lighting through the visibility of small targets. This idea leads to measure the “visibility level” (VL) index along a road itinerary, providing a tool for the diagnosis of the road network. This tool may be helpful for road operators who may want to know where on their network the night-time visibility is poor. This tool may also serve to assess the improvement brought by modifications of the road infrastructure.

2. COMPUTATIONNAL MODEL

We use a specific driving scenario in order to compute the VL at any specific point on the road. The scenario is designed in order to be close to the standard situation described in (Adrian, 1987): a car with standard headlamps stands 70 meters from a standard vertical target 18 cm in width (which results in a 9’ angular size), on a straight road without public lighting and without traffic. The retro-reflection of the target is conventionally set to 0.2 $cd.m^{-2}.lux^{-1}$. Observation time is 200 ms. The observer is 25 years old and his gaze is 120 cm high from the road surface.

Photometric data is collected in order to compute the VL of the target in this configuration. We consider average headlamp photometric data (from the UMTRI European low-beam database), while the road retro-reflection is measured with an instrumented vehicle called *Ecodyn* (CERF, 2000) which is usually devoted to the measurement the retro-reflection of road markings. We calibrated it in order to measure the retro-reflection of the road pavement, which allowed to get a profile of the retro-reflectivity along the road.

Figure 1. The Ecodyn mlpc® vehicle.

This data allows to compute the VL profile along the road, using Adrian's model, for a given theoretical target along the road (the background luminance of the road behind the target is supposed to be uniform). Some parameters are needed in order to compute this visibility index: size, distance and reflection coefficient of the target, driver's age, etc. The VL is computed as:

$$VL = \frac{\Delta L}{\Delta L_t} \tag{1}$$

where ΔL is the luminance difference between target and background (that is, here, between a virtual target and the computed luminance of the road behind the location of the target). ΔL_t is the contrast threshold of the human eye (Blackwell, 1946), that is to say the threshold under which the contrast is detected with a probability less than 99.93%. This threshold can be computed from the photometric and geometric parameters. These parameters being conventional, the resulting quality index is relative (one may note that the VL index is non-dimensional). This is not a problem because road operators are interested in locating the places where night-time visibility is poor compared to the rest of the road, rather than assessing an absolute visibility level.

3. EXPERIMENTAL DATA

This methodology was tested in two environments: first on a road near Strasbourg (France) with two types of pavement with different photometric properties, referred to as “road section 1” in the following, then on a rural road south of Paris (France) with dark pavement, referred to as “road section 2”. As an illustration, we indicate the VL=7 threshold, as it is considered relevant for a driving task (Adrian, 1987; AFE, 2002). Fig. 2 shows the VL along road section 1 for the reference conditions. The change in road surface is apparent, and the data may be compared to the reference VL=7 level.

In addition, Adrian's model being parametric, it is possible to explore the impact of several conventional parameters to quantify the importance of target parameters (size, photometric properties), driver's parameters (age) and geometric parameters (target's distance). Fig. 3 shows, for instance, the influence of the driver's age on the VL, for road section 1. It may interest the road authorities to see how the visibility index changes when considering different populations, and how a road may be over the VL=7 threshold for young people, and below this threshold for older drivers on the same section.

Other such parametric studies may be conducted, such as considering the target distance or retro-reflectivity. Target distance may be chosen, for instance, in relation with the stopping distance at the regulatory speed limit; target retro-reflectivity may be explored in order to consider actual photometric properties of clothes (Stark, 2002).

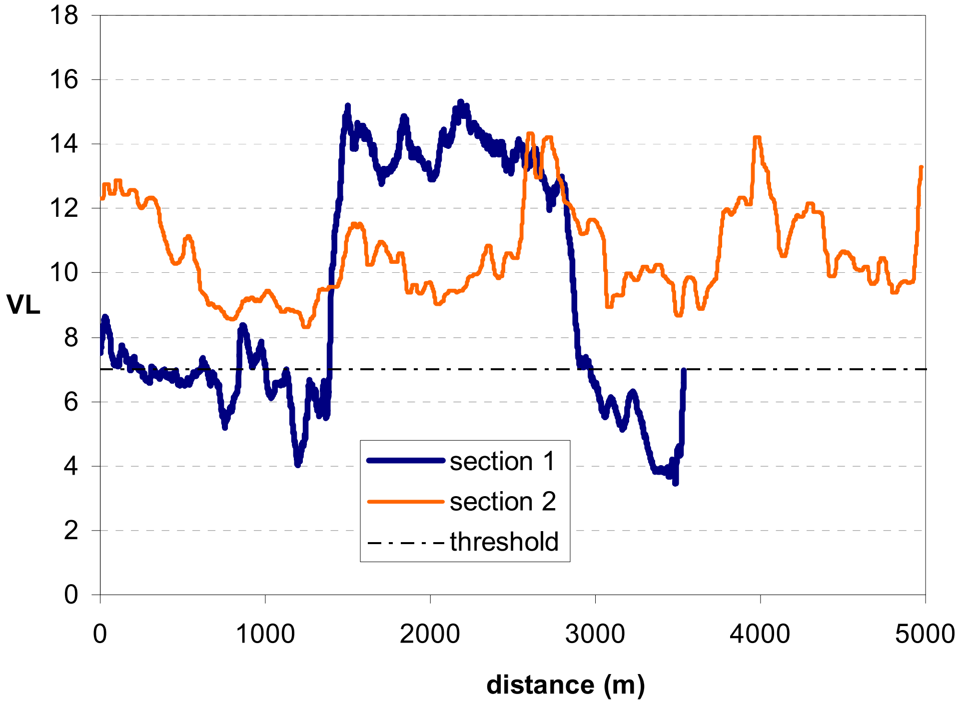

Figure 2. VL computation along road sections 1 and 2, standard configuration. The dashed line shows the VL=7 threshold.

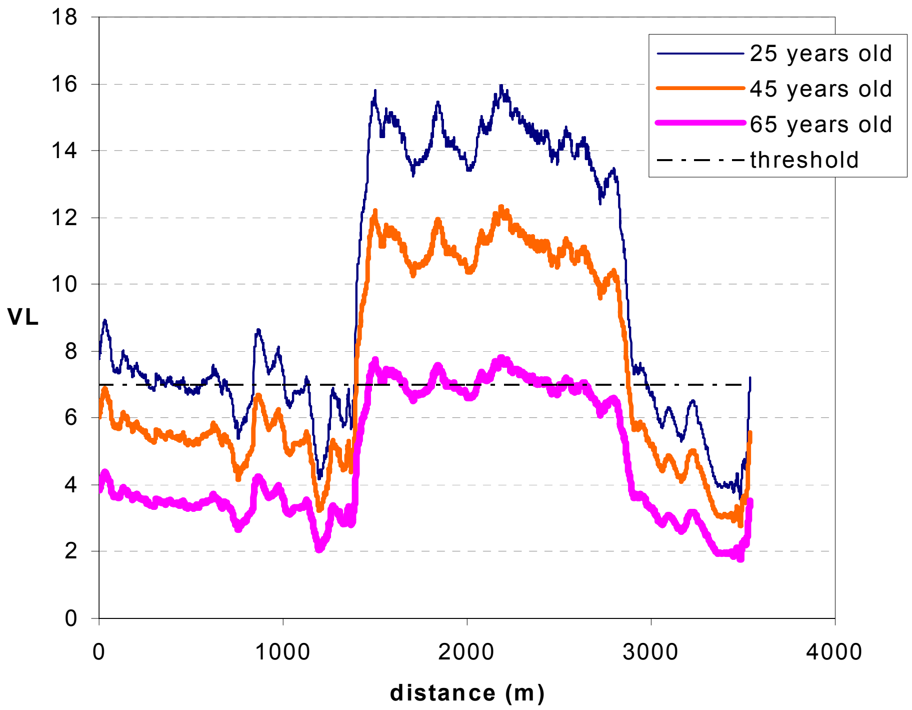

Figure 3. VL along road section 1, depending on the driver's age. The dashed line shows the VL=7 threshold.

4. CONCLUSION AND FUTURE WORK

We have proposed a night-time road visibility index for roads without street-lighting, and demonstrated the feasibility and simplicity of the measurement with an existing photometric system. This methodology is mainly dedicated to road operators, but it may also find applications in the conception of advanced front-lighting systems (AFS) through the in-vehicle use of VL digital maps of road networks.

The geometry of the road leads to visibility masks which may lower the actual visibility (e.g. in a curve, or due to vegetation). Thus, our visibility index should be mixed with a geometric visibility index (Brun, 2006). This second order index is currently being developed in the French SARI project (SARI). The resulting index is intended to provide day and night visibility indexes to the road authorities.

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