MOBILIZED AND MOBILIZABLE VISIBILITY DISTANCES FOR ROAD VISIBILITY IN FOG

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ABSTRACT

Fog is a challenging problem for road safety. To estimate the fog density and estimate the meteorological visibility distance, some attempts using an in-vehicle cameras are being developed. To complete the notion of meteorological visibility, we propose to estimate the distance to the most distant visible object belonging to the road surface. We call this distance the mobilized visibility distance, which may be compared with the mobilizable visibility distance which is defined as being the greatest distance at which a potential object on the road surface would be visible. In this paper, the relationships between these distances and the meteorological visibility distance are established. To illustrate our proposal, our methods to estimate the meteorological visibility distance and the mobilized visibility distance are presented and samples of results are given.

Keywords: meteorological visibility distance, fog, camera, driving assistance

1. INTRODUCTION

Fog is a challenging problem for road safety. Indeed, although fog is involved in a small number of accidents (around 2% of road fatalities in France), the accidents which occur during foggy weather are generally more serious and involve a greater number of vehicles, in particular on motorways [6]. To prevent such pile-ups, some information systems using variable message signs have been deployed to inform people of an incoming fog area. To automate these systems, solutions based on static optical instruments have been developed to estimate the fog density. More recently, some attempts using surveillance or in-vehicle cameras are being developed. The methods we present in this paper belong to the last category. Such methods could be used to warn the driver in case of inappropriate speed according to local visibility conditions, to communicate the presence of fog to other vehicles, or to automate tasks such as turning on (and off) the fog lamps.

By day, we have shown that daytime fog can be detected and that the meteorological visibility distance can be estimated using a single camera mounted behind the windshield of an automotive vehicle [1]. However, this distance is not necessarily sufficient for a driver, because it only expresses the value of a physical parameter of the atmosphere. Consequently, it does not take into account the nature of the road scene and the objects that are really present on its surface, e.g. the road markings.

To complete the notion of meteorological visibility, we have thus proposed to estimate directly the distance to the most distant visible object belonging to the road surface. This proposal fits quite well with the CIE definition of the optical visual range [3]. We call this distance the mobilized visibility distance. This distance may be compared with the mobilizable visibility distance, which is defined as being the greatest distance at which a potential object on the road surface would be visible. However, contrary to the mobilizable visibility distance, the mobilized visibility distance can be directly estimated using in-vehicle cameras. We developed such a method [2].

Our paper is organized as follows. In a first part, we make a short state of the art on fog modelling and detection. We introduce the notion of meteorological visibility. Then, we define and explain the notion of mobilized and mobilizable visibility distances. In particular, the relationships between these distances and the meteorological visibility distance are established. To illustrate our proposal, our methods to estimate the meteorological visibility and the mobilized visibility are presented. Finally, some examples of visibility measurements using actual video sequences are given.

2. DAYTIME FOG MODELLING AND METEOROLOGICAL VISIBILITY DISTANCE

In the atmosphere, visible light is mainly attenuated by the scattering phenomenon characterized by an extinction coefficient k. The phenomenon is particularly strong in fog and causes a luminous veil which impairs visibility in daytime [4]. In 1924, Koschmieder [5] established a simple relationship between the apparent luminance L of an object at a distance d, and its intrinsic luminance L_0:

$$L = L_0 e^{-kd} + L_f (1 - e^{-kd}) \tag{1}$$

where L_f denotes the luminance of background sky. Based on these results, Duntley [5] derived a law for the atmospheric attenuation of contrasts:

$$C = \frac{|L - L_f|}{L_f} = C_0 e^{-kd} \tag{2}$$

where C designates the apparent contrast at distance d and C_0 the intrinsic contrast of the object against the sky. The Commission Internationale de l'Eclairage [3] adopted a contrast threshold of 5% to define V_{met}, the meteorological visibility distance, as the greatest distance at which a black object (C_0 = 1) of suitable dimensions can be recognized by day against the horizon sky:

$$V_{met} = -\frac{1}{k}\log(0.05) \approx \frac{3}{k} \tag{3}$$

3. NEW VISIBILITY DISTANCES DEFINITIONS

3.1. Mobilized Visibility Distance

The meteorological visibility distance is the greatest distance at which a black object of a suitable dimension can be seen in the sky on the horizon. We have decided to build a method which is close to this definition. In this aim, we propose to study the distance to the most distant object belonging to the road surface having enough contrast with respect to its background. On Fig.1, we represent a simplified road with dash road marking. On Fig.1a, we suppose that the most distant visible object is the extremity of the last road marking (it could have been the border of the road too). On Fig.1b, the vehicle has moved and a new road marking is now visible. We call this distance to the most distant visible object, which depends on the road scene, the mobilized visibility distance V_{mob}. This distance has to be compared to the mobilizable visibility distance V_{max}. This is the greatest distance at which a picture element on the road surface would be visible. This vocabulary is directly inspired from the terms which are usually used to describe the tire-road friction of an automotive vehicle.

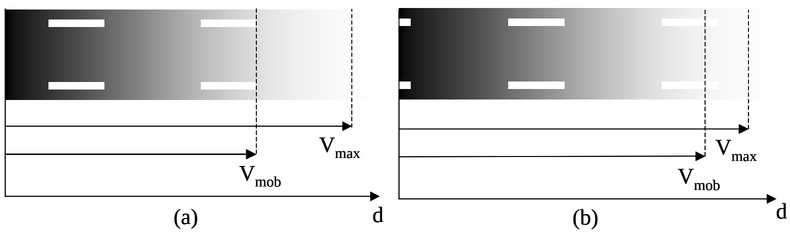

Figure 1: Examples of mobilized and mobilizable visibility distances.

3.2. Mobilizable Visibility Distance

In this section, we are going to establish the link between V_{mob} and V_{met}. V_{mob} is the distance to the most distant object W considered as visible. We denote L_{b_0} and L_{W_0}, the intrinsic luminances and L_b and L_w the luminances at the distance d of the road B and the object W. (1) gives us the theoretical variations of these values according to the distance d. Let's express the contrast C_{BW} of W with respect to B like Weber does:

$$C_{BW} = \frac{\Delta L}{L} = \frac{\left(L_{W_0} - L_{b_0}\right)e^{-kd}}{L_{b_0} e^{-kd} + L_f\left(1 - e^{-kd}\right)} \tag{4}$$

We deduce the expression of d according to the photometric parameters, C_{BW} and k:

$$d = -\frac{1}{k}\log\left(\frac{C_{BW}L_f}{L_{w_0} - L_{b_0} + C_{BW}\left(L_f - L_{b_0}\right)}\right) \tag{5}$$

That is to say the distance where an object W is perceived with a contrast of C_{BW}. Thanks to (3), we can express this value according to V_{met}:

$$d = -\frac{V_{met}}{3}\log\left(\frac{C_{BW}L_f}{L_{w_0} - L_{b_0} + C_{BW}\left(L_f - L_{b_0}\right)}\right) \tag{6}$$

Like CIE does, we can choose a threshold $\tilde{C}_{BW}$ below which the object is considered as being not visible. Like for the computation of V_{met}, we assume that the road intrinsic luminance is equal to zero. Then, we define V_{max} valid for every threshold contrast:

$$V_{\max} = \max_{L_{w0}\in]0,M]} -\frac{V_{met}}{3}\log\left(\frac{\tilde{C}_{BW}L_f}{L_{w_0} + \tilde{C}_{BW}L_f}\right) \tag{7}$$

The energy received by the object W is not entirely reflected towards the camera. Consequently, we have the following relationship:

$$L_{W_0} \leq L_f \tag{8}$$

We deduce the value of V_{max}:

$$V_{\max} = -\frac{V_{met}}{3}\log\left(\frac{\tilde{C}_{BW}}{1+\tilde{C}_{BW}}\right) \tag{9}$$

Then, we easily obtain the value $\tilde{C}_{BW}$ so that V_{max}=V_{met}:

$$\tilde{C}_{BW} = \frac{1}{e^3 - 1} \approx 5\%$$

So, by choosing a contrast threshold $\tilde{C}_{BW}$ of 5%, V_{max} is close to V_{met} for a black object. Actually, the road is never black and the sky rarely white. V_{max} represents a maximum of visibility distance rarely reachable, since it is the greatest distance at which the clearest object is visible on a black road. On the other hand, V_{mob} which only takes into account the gray objects encountered in the image is the distance that we are able to estimate directly.

4. METHODS

A first method is able to detect the presence of daytime fog and to estimate V_{met} [1]. In this aim, we find the position of an inflection point on the representative curve of Koschmieder's law with respect to the image line. Knowing the position of the horizon line, the difference between the two positions is directly proportional to the fog density value. A result is given on Fig.2a.

A second method estimates V_{mob} [2]. It computes a reliable disparity (depth) map of the road surface by stereovision. Then, the local contrast of the neighbourhoods where the disparity is known is computed using a sweeping window. Starting from the horizon line, this one goes from top to bottom. Thus, thanks to the structure of the disparity map, as soon as a local contrast above 5% is found, the computation is stopped. V_{mob} is then given by the disparity of the pixel. A result is given on Fig.2b.The experimental validation of both methods is published in [7].

5. APPLICATIONS

According to the used sensor, two different kinds of application can be derived [6]. If it is possible to map the gray levels of the image and the luminance levels and if the dynamic of the sensor is large enough, the estimated visibility distance can be used to inform the driver about the visibility

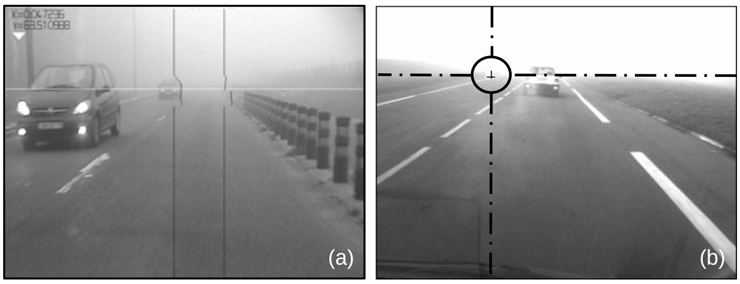

Figure 2: (a) First method: the horizontal white line represents the estimation of V_{met}. The black vertical lines represent the limits of the vertical band analyzed ($V_{met} \approx 60m$). (b) Second method: the most distant window with a contrast above 5% on the road surface is painted white ($V_{mob} \approx 50m$).

distance and to alert him if he is driving too fast according to the visibility conditions. In the contrary case, this information is useful for the sensor itself and can constitute a kind of self-diagnostic system of the vision sensor. It is then possible to adapt the operation of the sensor, to improve the quality of the signal and/or to dynamically adjust some parameters in the associated processing.

6. CONCLUSION

In this paper, we presented two new visibility distances for road visibility in fog. The relationships between these distances and the meteorological visibility distance are established. Two methods for in-vehicle estimation of the visibility distance are then presented. Samples of results are given. Some applications using these methods are briefly described.

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