DISCRIMINATION OF SURFACE STATUS OF PAVEMENTS BY EXTRACTING IMAGE DATA

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ABSTRACT

The objective of this work is to study the possibility of knowing the surface status « wet » and to determine a level value of this status using a camera and a light spot usually employed on road sides. The investigation focused on the situations where accidents particularly occur, i.e. at night and with rain. Only black and white pictures were analyzed, with a statistical treatment that has indicated that the most representative gray level is closed to 170 pixels for the dry situation, and around 120 pixels with a wet situation. The use of an infrared device has allowed to determine the wetness of the surface for a percentage ranging from 0 % and 65 %.

KEY-WORDS

IMAGES PROCESSING / SURFACE STATUS / RADIOMETRY

1. INTRODUCTION – BACKGROUND

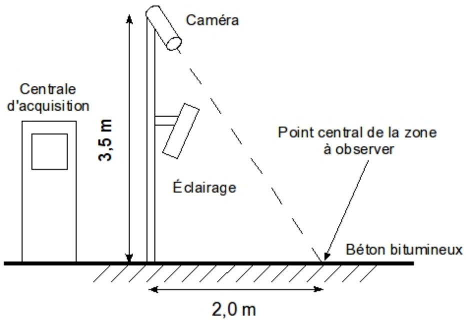
Despite a reduction of deathtoll, the number and the severity in adverse weather conditions are still high. Among the 80300 accidents in France in 2006, 9450 occurred in the presence of rain, 400 due to ice or snow, 684 with fog. The first remark is that a pavement remains either humid or wet long after the rain has stopped, by a factor 1.5 to 9 [1], even if 40 % of precipitations with rain in France do not exceed 0.4 mm. On the other hand, 20 % of the accidents occur during the night (8 pm – 6 am), but are the cause of 30 % of deathtoll in 2006 [2], though the traffic is extremely reduced. The monitoring of surface status could provide to road users and road managers relevant information on the safety of the network. Surface conditions are defined in French (NF P 99-320) and European standards (CEN TC 337 / WG1), but there is a lack of tools to get access to these parameters.
There are many instruments in operation of the deteriorated road conditions. Often inserted in the pavement, they are expensive, and set problems of representativeness, and maintenance. A new generation of non-contact sensors emerged about two years ago but remains expensive. Many techniques developed over the years are based on the infrared spectrum, the radar waves, radio waves, with or without polarization. Data collected by these techniques [4 – 10] are often qualitative. The thick fluid or solid to the road surface is often an inaccessible information. However, the information indicates a level of security appropriate to the road.

The objective of the work presented is to study the possibility of determining the surface status "wet" and the degree of wetting of a surface with a camera and a lighting device. These tools are commonly deployed on the routes. The investigation focused on two conditions that are particularly dangerous in rain and night.

2. EXPERIMENTAL SETUP

2.1 Description

The experimental site (Figure 1a) consists of a bituminous concrete surface, located outdoors, not circulated and subject to weather hazard. On it there is a cabinet containing the different devices. It also has a mast height of 3.5 m to set different instruments. This mast has a remote temperature measuring instrument (infrared radiometer). The radiometer will thereafter establish a link between the radiative temperature and image analysis. The camera is fixed and its lighting too. The field of vision coverage is therefore broad. It includes a CCD sensor of 352 pixels by 288 pixels, similar to a digital camera. The scope of the camera depends on its purpose and its position (Figure 1b). The surface of analysis is chosen by the operator to integrate the relevant points to monitor and process. On the other hand, one can restrict the analysis to one or more areas, including the shape and position are free (eg tracks and between them). All of the acquisitions is performed using an interface developed in C and uses the OpenCV library [11].



(a) Operative device

(b) Field of view camera with the elliptical analysis zone

Figure 1 – Representation of the experimental site

3. IMAGE ANALYSIS OF THE PAVEMENT

3.1 Night lighting conditions

A digital image in the black and white format is an image where each pixel is represented by a grayscale. To allow visualization of shooting stage, night lighting is in place. This provides a stable and uniform brightness on the area(s) of interest. This facilitates stable brightness images processing and interpretation.

3.2 Distribution of grey levels for black and white images

For each shot in black and white we get the distribution of levels of gray pixels. These gray levels are coded from 0 (black) to 255 (white). For each image, we recover the *most representative* gray level in the image, and the number of pixels corresponding to this gray level. We track its evolution according to the time in Figure 2, the gray level is represented as constant during the night, facilitating the analysis, but becomes unstable and grows at sunrise. Over this period the standard deviation is 1 gray level which shows the reliability of the operation of shooting these phases at night. The level of gray is also represented in each camera and its merits.

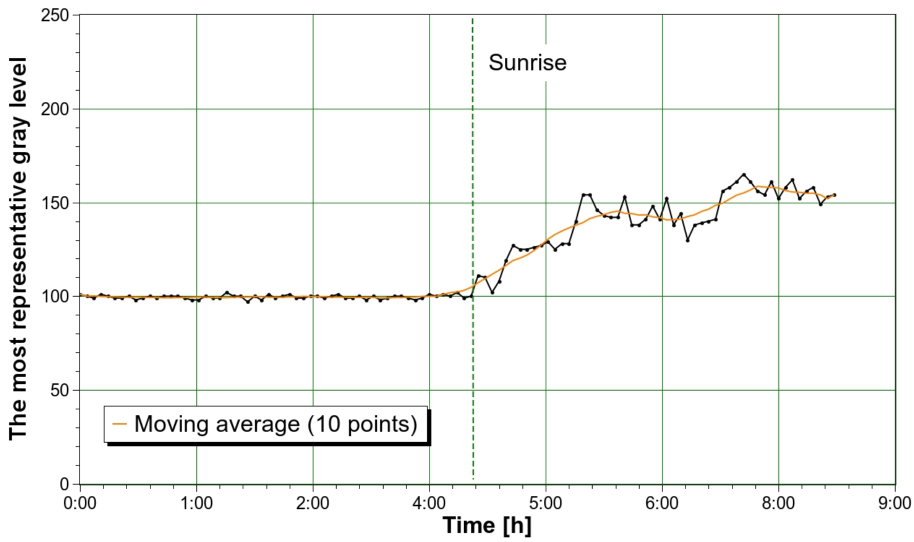


Figure 2 – Changes in the level of gray according to the time during the night

In Figure 3, we find that during the day the gray level is represented as fairly stable, but it varies depending on the brightness and still quite noisy. The surface was wet to 21H30. There is then a diminution of the gray level, although at this time of year (mid-June), the brightness is still very important. As long as the surface remains wet, the gray level remains constant. When the surface becomes dry, there is a gradual increase in the number of pixels whose gray level is closer to the high values. This graph shows that the analysis of shots from the camera allows to distinguished a dry surface status from a wet in fixed lighting conditions and therefore constant brightness. During the phase when the roadway is wet, i.e. before drying, the standard deviation is 3 gray levels which demonstrates the sensitivity of this method. The analysis of the shooting is reliable and the distinction between a dry surface and wet surface status is established in phase at night. These graphs also show that this analysis of shots from the camera is easier at night than during the day. As before the period from 11h to 19h (sunset), the average of gray levels is 145 and standard deviation is 12 gray levels. This shows that changes in image brightness noise the image but the distinction of a dry and a wet state remains possible on a diurnal phase.

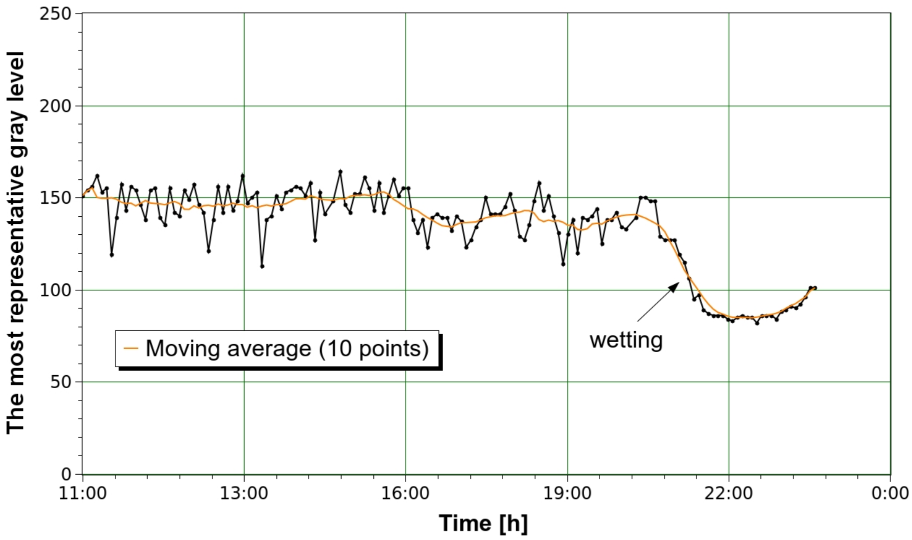


Figure 3 – Changes in the gray level according to the time with wetting

3.4 Distinction between dry status and wet status

The average levels of gray for a dry surface at night were calculated (Figure 4). This average distribution was compared to distributions of gray levels for the same dry surface for each nights of the month of June 2008. We can observe that these distributions correspond with a very good agreement.

The comparison of this average distribution was on a fully wet surface, and then on a partly wet surface. The distribution of gray levels shifts all the more toward the black level as the surface is wet. The distinction between these two surface status (dry and wet) is possible at night with the support of a simple camera and a lighting device.

A threshold was determined from the average distribution of greyscale for a dry surface at night. This value of gray level is used to define at what value the presence of water is likely to be detected. This is particularly critical because the adhesion mobilized on a surface depends on the degree of wetting. Below this threshold, we consider the surface as wet. This threshold was chosen so that, in an surface identified as dry during the night, 90% of the pixels of the average distribution of gray levels are beyond the threshold, outside the digital noise. The threshold value for the experimental site is at 89 gray level. Conversely, the more pixels in an image will be below this value, the more the surface is wet. Thus, in Figure 4, the curve on the left is a wet surface completely, the central curve is obtained for a partially wet surface and the right curve represents the distribution for a dry surface.

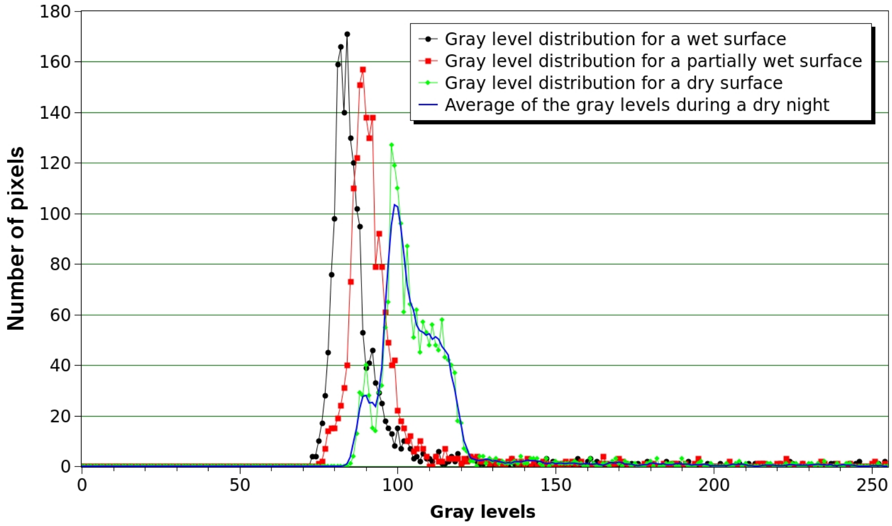


Figure 4 – Distribution of gray levels for different surface conditions

3.5 Adding a multispectral radiometer

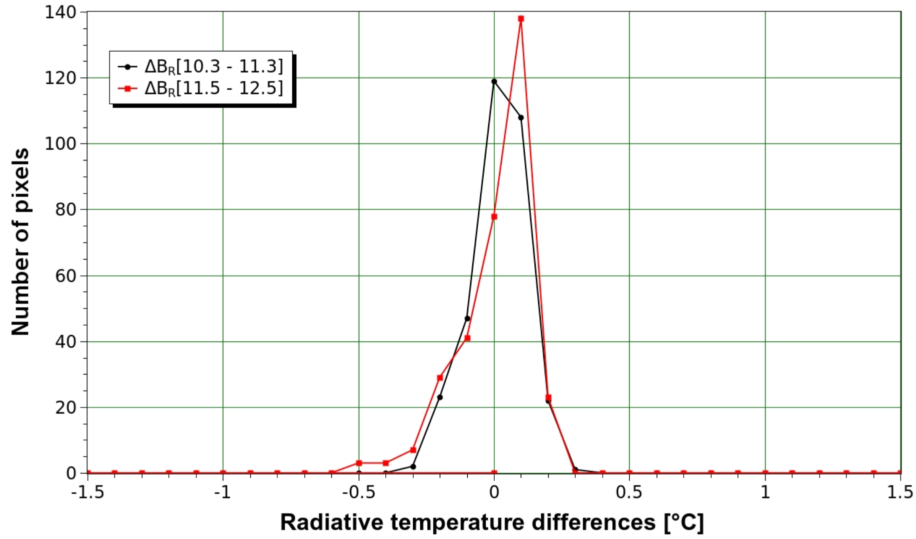
The second point was on the confirmation of these observations with an infrared multispectral radiometer. This instrument uses the capacity of water to absorb infrared radiation in specific ways according to spectral bands. A previous study conducted in CETE de l'Est had shown the ability of this instrument to discriminate against a dry surface from a wet one [12]. It has also a very high sensitivity and good precision (±0.5°C).

Thus, we established a link between the percentage of wetted surface and the radiative temperature determined by the radiometer. It has four separate filters each corresponding to four spectral bands (8 – 13 µm ; 8,2 – 9,2 µm ; 10.3 – 11.3 µm and 11.5 – 12.5 µm). When the analyzed surface becomes wet, the radiative temperatures given by each filter are closer to each other.

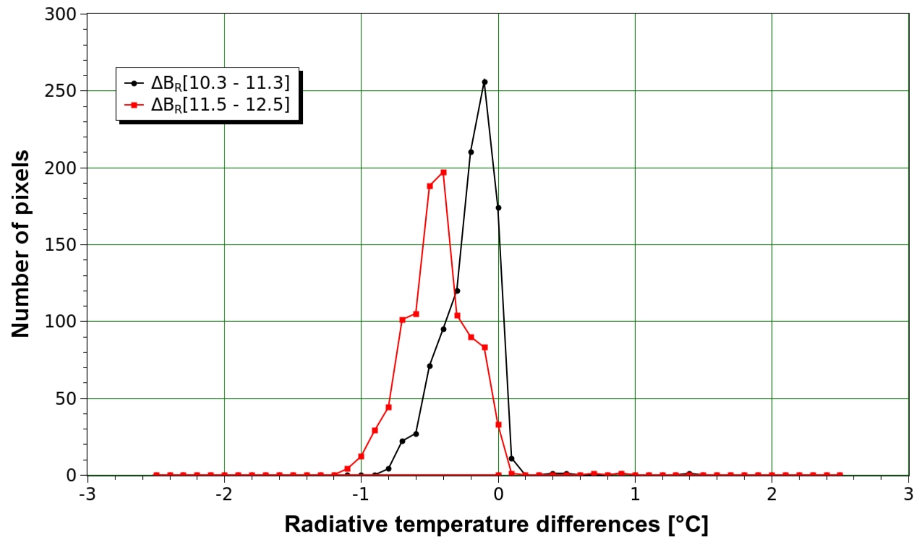
The radiative temperature difference between the filters in pairs has been calculated. Subtracting the value of each filter value given by the strip 8 – 13 µm wide. This reference was chosen because the curve of temperature for large filters remains at the center of the others and it has the spectral bands of other filters. We then call $\Delta B_R[8.2-9.2]$ the temperature difference between the filter 2 (8,2 – 9,2 µm) and the filter 1 (8 – 13 µm), $\Delta B_R[10.3-11.3]$ the difference between the filter 3 (10,3 – 11,3 µm) and filter 1 and $\Delta B_R[11.5-12.5]$ the difference between the filter 4 (11.5-12.5 µm) and the filter 1.

For a wet surface (Figure 5a), the distribution of points is well centered around 0°C. The differences between the filters give curves almost superimposed to each other. In the case of a dry surface (Figure 5b), they are far away and distinct from one another.

The accuracy of the multispectral radiometer (0.1°C) yields a radiative temperature measurement with an excellent degree of confidence. This observation on the different radiation is an additional indication to detect water on the surface of the roadway. Also, it is necessary to determine whether the radiative temperature difference of about 0.4°C remains constant whatever the degree of wetting of the surface, or whether it changes with the road surface.



(a) wet surface



(b) dry surface

Figure 5 – Distribution of radiative temperature differences between filters centered on 12 µm and 11 µm with the 8 – 13 µm wide band

As mentioned previously, $\Delta B_R[11{,}5-12{,}5]$ was used as a reference. This evolution is shown in Figure 6. It relies both on the analysis of images provided by the camera during shooting night thanks to the study of the distribution of gray level pixels, and radiative temperature of the multispectral radiometer at the same time.

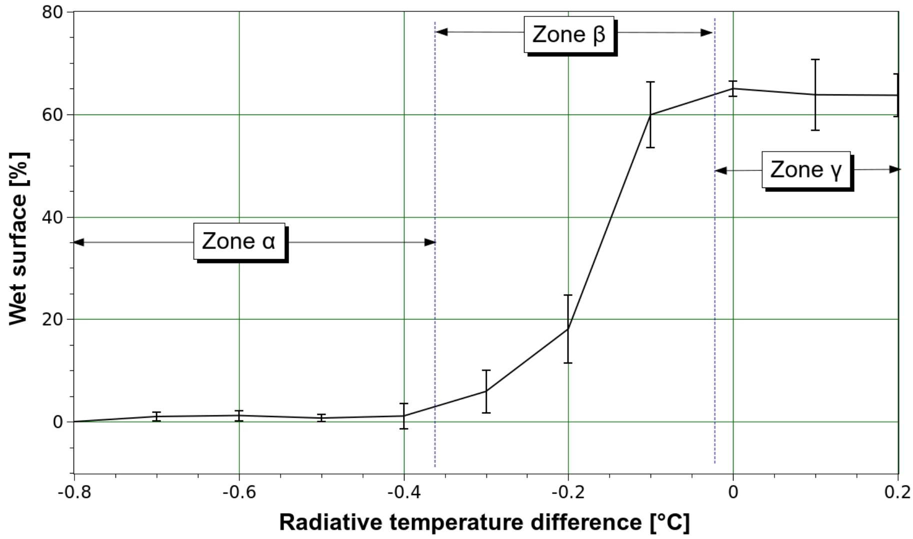


Figure 6 – Percentage of wetted surface according to the radiative temperature difference

We observed in the zone α that the curve is stable and the percentage of wetted area is close to 0%. Below this value, the limits of the radiometer are reached, and the surface is considered dry. The percentage of wetted surface grows on zone β. It can therefore be used to assess the degree of wetting of the pavement. This degree of wetting extends approximately 65%. On the zone γ, the radiometer provides no more relevant information. However, with a wet surface to two-thirds, the degree of associated slipperiness is significant.
Uncertainties associated with the deducted percentages of wetted surface have been established for each radiative temperature. For each point on the curve, the standard deviation was calculated from experimental data. In zone α, the standard deviation is very low, the dry surface is known with near certainty. In zone β, the standard deviations increase. This is mainly due to a lack of measurements data. It is important to note that a surface wet from 10% to 30% can be detected. It corresponds especially to the onset of precipitation, where the slipping pavement begins to manifest itself, and the danger too. In zone γ, the standard deviations remain significant. This corresponds to a situation where at least 65% of the surface is wet. The slipperiness is then detectable by a user.
More generally, two tools are now potentially available to distinguish the surface status of a dry pavement from a wet one. When radiative temperatures are measured, establishing differences between them would already get a first diagnosis.

4. CONCLUSION AND PERSPECTIVES

The objective of this study was to establish the possibility of determining the relationship between the wet surface, and the degree of wetting of a surface with a visible camera and a lighting device. This study was conducted at night on an outdoor test site, in conditions close to those found on circulated pavement. The instrumentation used was a CCD camera and a lighting device. An infrared multispectral radiometer was used to confirm support for the observations.
It appeared that the distribution of gray levels allowed to distinguish a dry status from a

wet status with a stable and homogeneous illumination. The distribution of gray levels is sufficiently discriminating between these two situations. On the other hand, the analysis of this distribution allows to evaluate the degree of wetting of the investigated surface. It is based on a count of pixels whose gray level is below a threshold value which was established on an average night of the situations typically encountered with a dry pavement. This threshold is such that in the picture, 90% of the pixels that constitute a grayscale value are above the threshold value. The use of the radiometer multispecral confirmed the observations. It was also possible to establish the limits of the instrument. This work has highlighted two tools for detection of surface status.
An implementation of this new instrumentation is underway, with analysis of the images in daylight. In addition, the acquisition may be improved, such as obstacle detection to remove images with a vehicle, or the detection of accidents. Finally, it should extend the study of surface taking into account the precipitation (of snow, ice).

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