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Road surface information system

J. Casselgren [1], S. Rosendahl [1] and J. Eliasson [2]

[1] Luleå University of Technology, Div. Experimental Mechanics, Luleå, Sweden
[2] Luleå University of Technology, Div. EISLAB, Luleå, Sweden

Corresponding author's E-mail: johan.casselgren@ltu.se

ABSTRACT

In order to classify the road condition, dry asphalt and asphalt covered with water, ice and snow a technique using a sensor called Road eye is presented. The Road eye sensor uses three wavelengths and one photo detector to determine the intensities that are reflected from the road surface and is then able to estimate the road condition. By linking the Road eye sensor to a GPS and a Mulle, a miniature wireless Embedded Internet System, the road conditions can be associated with the correct road position, making it possible to use the information in many different applications.

Keywords: Road condition, Information system, Server connection, Map.

1 INTRODUCTION

In the technical report [1] it is shown that there is a significant correlation between traffic accidents and slippery road conditions. Classification of slippery road conditions has been the subject of intense research for some years. Incorporating a device that estimates slippery road conditions on-line in a vehicle would benefit both the driver as well as systems in the vehicle as the anti-lock braking system (ABS), traction control system (TCS) and the electronic stability program (ESP). However, slippery road information would of course interest all road users. Hence, sending the slippery road information to a server would increase the information dissemination to more than just one vehicle. For near infrared wavelengths of light it has been shown that the spectrums of water, ice and snow are distinguishable [2-5]. This in combination with the fact that the four road conditions, dry, wet, icy and snowy asphalt, also have different light scattering properties makes light ideal to use for a sensor that estimates slippery road condition.

Today there are a number of optical prototype sensors for classification of road conditions. What all techniques have in common is that they exploit the difference in light reflection for different road conditions. Two techniques that don't use any additional illumination is a Stereo-camera system combined with image processing [6] and a technique where the ratio of incoming and reflected light (albedo) is measured with two pyrometers [7]. Both techniques are dependent on street lights or oncoming vehicles during nighttime to work properly, which makes the methods complicated. However, the large monitoring area of the stereo camera system is an advantage. A third technique, the one that is used in this investigation, is based on laser diodes of different wavelengths and a photo detector [8-9]. The wavelengths are chosen because the differences in absorption between water, ice and snow are specifically large in their spectral bands and that cheap off-the-shelf laser diodes are available in these frequencies.

The optical sensor Road eye uses the laser diode technique and has been modified during many years, in several Swedish and EC-funded projects [10-16]. The off-the-shelf laser diodes make the sensor competitive in price as well as in performance. The focus of this paper is to show how slippery road conditions could be classified and how this information could be presented. In Section 2 the Road eye sensor and the classification algorithm are described as well as the communication system. Section 3 describes the measurement and the measurement conditions. Thereafter the results are shown and discussed in Section 4 and the paper is ended with some conclusions.

2 MESSURING PRINCIPLE

The environmental sensor Road eye provides a classification of road conditions at short distance 0.5-1.5 m and has a Short Wave InfraRed (SWIR) active illumination consisting of three laser diodes emitting at wavelengths λ_1=1550 nm, λ_2=1310 nm and λ_3=980 nm. The Road eye's focusing optics gives an illuminated spot with a radius of 10 mm on the road surface at a distance of 0.8 m. In order to acquire data from the reflected light, a lens focuses the reflected light on a photodiode. The amplitude-modulated signals are sampled at 20 Hz. The output signal consists of three voltages (mV) representing the reflected intensity of the three wavelengths, respectively. The active amplitude modulated illumination ensures insensitivity to disturbances, such as other vehicle's headlights or daylight.

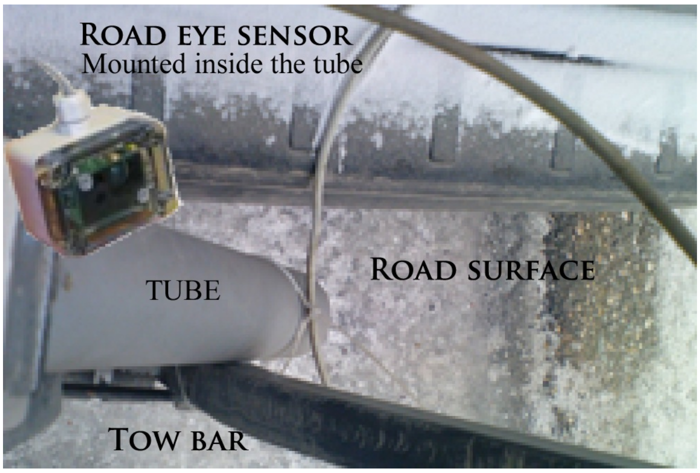

Figure 1 Mounting of the Road eye sensor on the tow bar of the vehicle.

For this investigation the Road eye sensor is mounted in a tube on the tow bar of an ordinary car measuring in the right wheel track as shown in Figure 1. The tube is used to keep the sensor clear from splash and pollutions. This is only a mounting to enable easy access, the main idea is to mount the sensor in front of the right front wheel of the vehicle and therefore this has been tested on both cars and trucks. Due to the sampling rate of the Road eye sensor and the simple classification algorithm the response time of the system ensures a preview measurement even when measuring only 0.8 m in front of the wheel. However, the response time is too short for preview information to the driver but systems as the ESC, ABS and TCS could benefit from the information.

The three intensity outputs from the Road eye sensor, hereafter named λ_1, λ_2 and λ_3, represent the reflected light from the road surface. These three quantities are implemented in the classification algorithm by computing the three magnitudes s, q_1 and q_2 as:

$$s = \sqrt{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}\,, \qquad (1)$$

$$q_1 = \frac{\lambda_1}{\lambda_2}\,, \qquad (2)$$

$$q_2 = \frac{\lambda_3}{\lambda_2}\,. \qquad (3)$$

Where s is the total reflected intensity and q is the ratio of absorption between the wavelengths. The s magnitude will explore the differences in the surface structure meaning if the surface is rough (dry asphalt and snow) more light will be reflected back compared with if the surface is smooth (Water and Ice). For the q magnitude the differences in absorption coefficient for different road conditions will be explored. For example dry asphalt will have a value of 1 for q_1 as the absorption is almost equal for the two wavelengths, while for snow it will be close to 0 as almost all light for λ_1 will be absorbed.

The three magnitudes s, q_1 and q_2 are then use to draw up a volume where s represents the x-axis, q_1 the y-axis and q_2 the z-axis. In Figure 2 the four different road conditions dry, wet, icy and snowy asphalt is shown for four distinct responses. Notable is that the clusters are separate from each other. These measures are then implemented in a K-mean [17] clustering algorithm as starting values. Thereafter, for each new set of values a transformation is computed and the K-mean algorithm will affiliate the new measurements to a certain cluster, i.e. classify the road conditions. The output from the algorithm is one number representing which cluster the measurement belongs to and one Euclidean length, i.e. the distance from the measured point to the centre of the cluster. The distance is then used to calculate a validity of each classification. The limits of the distances are calculated with a 90% confidence interval. This limitation is set to disregard outliers; hence if the distance is too large the classification can't be "trusted". If the distance is outside the confidence interval the validity is set to 0 otherwise it is 1.

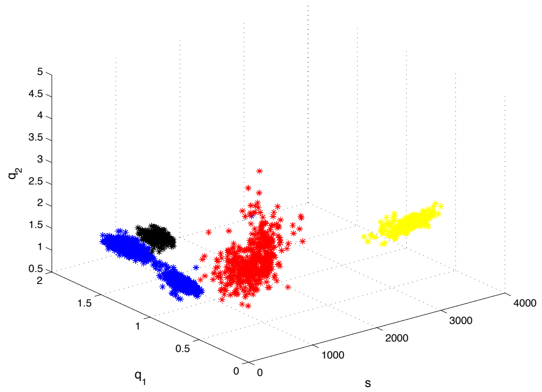

Figure 2. The four different road conditions plotted against the three wavelengths. Black is dry asphalt, blue is wet asphalt, red is icy asphalt and yellow is snowy asphalt.

In this investigation the Road eye sensor is connected to a Mulle that is a miniature wireless Embedded Internet System (EIS) suitable for wireless sensor networking using Bluetooth and standardized protocols, see Figure 3. The Mulle platform has low power consumption and its large number of I/Os makes it ideal as a building block for wireless sensors. The Bluetooth version is capable of communicating with most Bluetooth-enabled devices, e.g. computers, PDAs and mobile phones. The use of TCP/IP enables the Mulle to transmit sensor data directly to the Internet and the small size factor allows it to be easily embedded in any device.

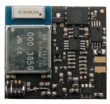

Figure 3. Mulle a miniature wireless Embedded Internet System in actual size.

The network architecture consists of up to seven Mulle devices, and one access point. During the experiments, a standard consumer mobile phone is used to enable Internet-access to the Mulles. One Mulle is used as a router, and start by initiating a Bluetooth connection towards the mobile phone's access point service. When the router Mulle has established a Bluetooth PAN connection and acquired an IP-address, it starts its own access point service. Other Mulles could now connect to the router Mulle using the PAN-NAP profile on the router, and PAN-U on the sensor Mulles. When a sensor Mulle has an established connection, DHCP is used on both router and sensor Mulles in order to distribute IP addresses. The router Mulle also featured a NAT (Network Address Translation) service, allowing up to seven sensors (clients) to share one Internet-connection. As a result, a sensor network consisting of one mobile phone, one router Mulle and up to seven client Mulles is formed. All Mulles uses the NTP protocol in order to correctly time stamp sensor data. One GPS device and one Road eye sensor is used during the experiments. All collected sensor data is transmitted to a public server on the Internet and stored in a SQL database for later analysis and visualization.

3 MEASUREMENTS AND RESULTS

The measurements in this investigation are carried out on ordinary Swedish road during both summer and winter, i.e. the roads where dry asphalt and asphalt covered with different depths of water, ice and snow.

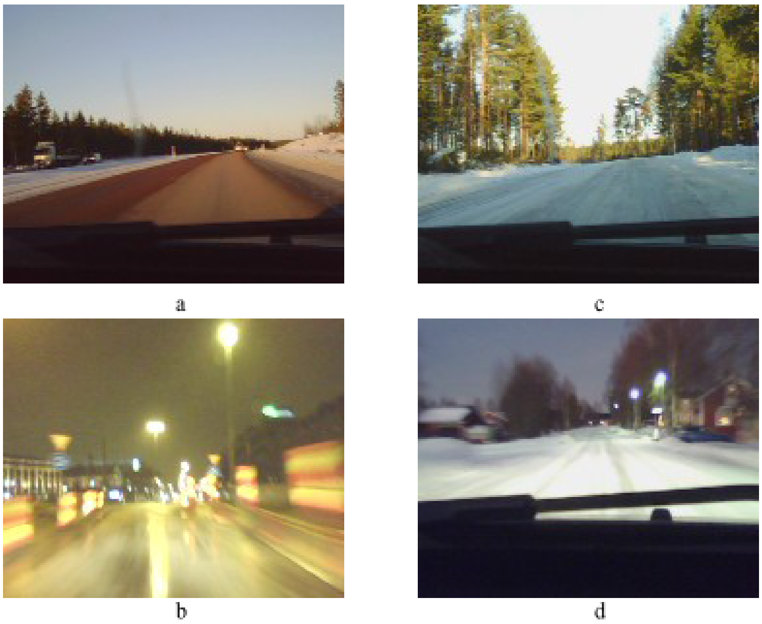

Figure 4. Picture of the different road conditions included in the investigation

In Figure 4 some of the different road conditions are shown, Figure 4 a) shows moist asphalt in the left lane and dry asphalt in the right lane. Figure 4 b) shows a wet road and the picture is blurrie due to heavy rain. The water depth on the asphalt is estimated to 3-4 mm water. The ice in Figure 4 c) is a grey ice with a rough surface because of the studed tires, there is also some parts of snow that is driven on for a long time so it have become dense and smooth. Figure 4 d) shows new fallen snow that is just driven on a few times. Except these road conditions there is a black ice surface that looks like moist asphalt and two more depths of water 1-2 mm and 2-3 mm.

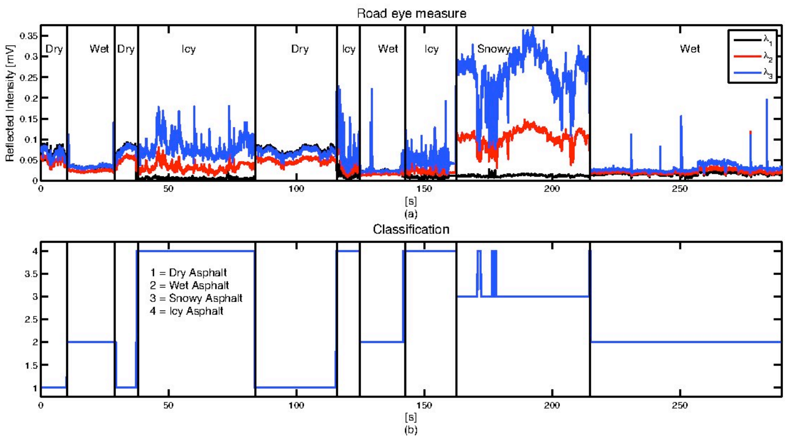

Figure 5. Road eye signals shown in a) for the three wavelengths. b) The classification based on the Road eye signals.

The output of the Road eye is shown in Figure 5 a). To be able to compare all different road conditions the different measurements is put together in a test file were the first part with dry-wet-dry between 0-40 s is from Figure 4 a) were the wet part is moist asphalt. The next icy part is taken from Figure 4c) and is a grey ice measurement between 40-80 s. Then there is a dry part between 80-120 s. After that we have an Icy-Wet-Icy section between 120-160 s, where the icy section is a black ice that has the same appearance for the human eye as the wet section but is has much lower friction. The water in the wet section is between 1-2 mm. After that section the new fallen snow from Figure 4 d) is between 160-220 s. Then the test file is ended with two different depths of water, 2-3 and 3-4 mm.

Given the three intensities, λ_1, λ_2 and λ_3, a classification is estimated and shown in Figure 5 b). Here it can be seen that the classification works satisfactory with only one wrong classification. Note that the first two classifications of icy in the snowy section at 170 s and 180 s are correct classifications, there is some ice emerging in the snow. The wrong classifications appear at the change between snowy and wet at 220 s. This is mostly caused by the moving average filtering of the raw signals and the fact that the test file is cut and pasted together.

By connecting the Road eye to a Mulle and incorporating a GPS in the network architecture it is then possible to measure road conditions synchronized with a position making it possible to plot the different road conditions on a map using different colours, as in Figure 6.

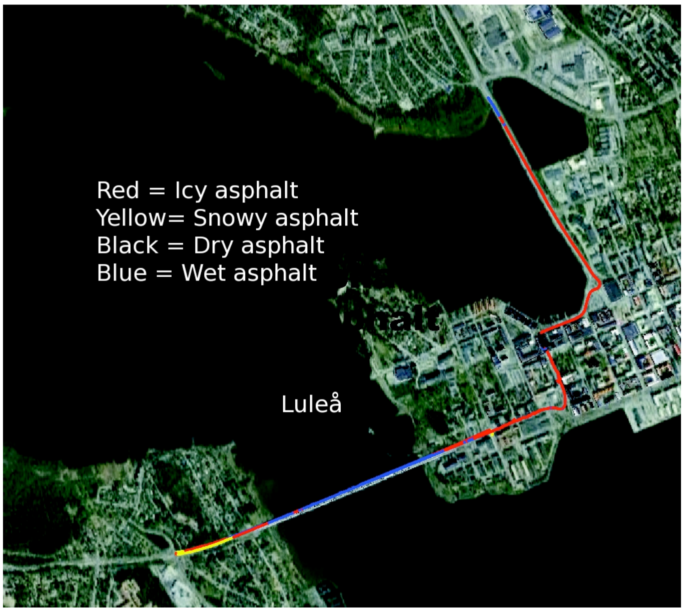

Figure 6. Road conditions plotted on a map. Black is dry asphalt, blue is wet asphalt, red is icy asphalt and yellow is snowy asphalt.

4 DISCUSSION AND CONCLUSIONS

The classification works in a satisfactory way and by connecting it to a Mulle and getting internet access makes it possible to distribute the information to all road users that have a smart phone and internet access. This enables a lot of new services that could benefit from this information and it also assumes that a plurality of vehicles is equipped with this technology so there is a large amount of data available.

- Road entrepreneurs could use this information when distributing salt. The benefit would be that the trucks would only distribute salt where it is needed, i.e. where there is ice. This road condition information also indicates when the salt water freezes so entrepreneurs gets an indication when its time for redistribution.
- Road users could plan their trips based on how the road conditions are at the moment.
- The information could be used as driver alert. In the sense that vehicles in front of the own vehicle send data if there are slippery road conditions ahead. Both the driver as well as active safety systems in the vehicle could use this information.
- Road weather forecasts would also benefit of knowing what medium is present on the road for their slippery road conditions estimations.

These are just a few suggestions of applications and what they all aim at is to improve the safety on winter roads.

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