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Road condition analysis using NIR illumination and compensating for surrounding light

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ABSTRACT

An investigation of a NIR camera system for road surface classification has been conducted for several road conditions. The surfaces were illuminated with three wavelengths, 980 nm, 1310 nm and 1550 nm and a halogen lamp, to simulate a real environment application with surrounding light. A measuring scheme to deal with surrounding light has been implemented enabling road condition classification from NIR images in a real environment. The retrieved camera images have been analyzed and an RGB representation of the different surfaces has been created to classify the different road conditions. The investigation shows that it is possible to distinguish between dry, moist, wet, frosty, icy and snowy road surfaces using a NIR camera system in a disturbed environment.

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1. Introduction

Statistics regarding road accidents show that slippery road conditions often are the cause of severe crashes or road departures [1–4]. In [5] it is pointed out that information about the road ahead of the vehicle is of importance to avoid road accidents. Such information could be road geometry or surface adhesion, i.e. road condition. One of the problems with slippery winter roads is that several road conditions can appear at the same time, resulting in a large variation of the surface adhesion depending on the position on the road. Fig. 1 shows a typical situation often encountered in subarctic regions. Snow in the middle of the road and wet or even dry road in the wheel tracks means that a classification of the road condition covering the whole road is of interest.

Today more and more information can be communicated to vehicles from for example road weather information stations (RWIS) [6]. If information about road condition could be classified automatically and included in such information it would be helpful for the driver and for autonomous systems assisting the driver. Nowadays, there are often cameras mounted on RWIS stations, these cameras use visible light and the road conditions are classified manually so it is hard to communicate this information.

During several years research has been focused on new methods to classify road conditions in an attempt to decrease accidents caused by slippery roads. There are nowadays many non-contact prototype sensors utilizing optical characteristics to make classifications of different road conditions [7–15]. These prototype sensors can be classified into two distinct categories; those mounted on the vehicle and those mounted on a stationary weather station, i.e. on a RWIS.

The main optical techniques for road condition classification are combinations or separately solutions of cameras or Near InfraRed (NIR) techniques. The main differences between the different techniques are the detection area and the computational time of the analysis. One example of a NIR technique and camera solution is the IcOR [16]. This technique covers the complete road area and uses a stereocamera system and NIR polarization filters to classify the road conditions. The disadvantage of the IcOR is that it requires computational power and that it does not have any illumination source. For stationary measurements this is not a problem, since computers and lights usually are easy to install at road side locations. Another example is the Road eye [17] using NIR-lasers and a photodetector to classify the road conditions. The area covered by this sensor is approximately 10 mm in diameter which makes the classification of an entire road width impractical. However, the solution is fast and can classify changes in the road condition with high resolution at high speed, making it perfect for vehicle mounting. In [18] some of the advantages and disadvantages of road classification with the Road eye and the IcOR are discussed.

To classify different road conditions with an optical non-contact sensor the variation in intensity of light scattered from the surface is explored. The scattering of light is dependent on the roughness of the illuminated surface and the absorption of the illuminated material. In Fig. 2 both surface scattering and internal

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scattering are shown for a dry asphalt surface and for asphalt covered with water. As can be seen the surface scattering in the backward direction will be higher from a rough surface (Fig. 2a) as compared to the surface scattering from a smooth surface (Fig. 2b). This makes it possible to distinguish the rough surfaces, dry asphalt and asphalt covered with snow, from the smoother surfaces, asphalt covered with water or clear ice solely based on the intensity.

To distinguish between the two rough surfaces and the two smooth surfaces, respectively, the scattering taking place below the surface is considered. This scattering results in a spectral response which means that the amount of scattered light from the road material and the material on the road, i.e. water, ice and snow, depends on the wavelength of the light.

The wavelength dependent absorption coefficients for water and ice [19] are shown in Fig. 3. Notable is the differences in absorption between the wavelengths $\lambda \simeq 1300$–1450 nm and the reversed condition above $\lambda \simeq 1450$ nm. Previous work [17,20] have shown that by considering the absorption and scattering properties of the materials the classification of road conditions is enabled by measuring the light intensities of the wavelengths marked in the figure.

In a real environment there will also be surrounding light disturbing the signal from the light source used for the measurements. This surrounding light will increase the intensity level of the NIR light that the classification depends on and due to different types of surrounding light sources the gain will not be constant. Example of such disturbing light sources could be head lights, street lights and the sun. The disturbing gain from the sun can also vary due to differences in cloud thickness because the NIR wavelengths from the sun will be absorbed in the water molecules in the clouds.

In this paper the aim is to develop a method that makes it possible to classify road conditions on large areas with a simple and fast algorithm using NIR illumination in combination with a NIR camera. This will be done in two steps, first to be able to use the technique in a real environment the system needs to be able to handle surrounding light of varying kind, thus a measuring scheme is developed to manage this problem. Secondly a classification algorithm will be established by exploring the variations in the scattered light intensity. The focus of the paper is to investigate the idea and the algorithms developed to be able to present information both for manually and automated classification. In this first step the idea is that the system should be mounted on a RWIS station for stationary use. At this point the choice of hardware has been of less significance. The paper is divided into sections, were Section 2 describes the method used to solve the problem, Section 3 describes the experimental setup and the experiments and in Section 4 the results are shown and discussed. The paper is ended with some conclusions.

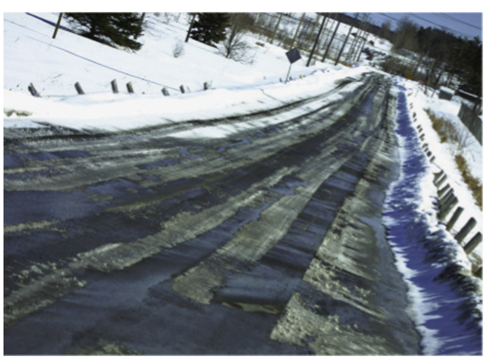

Fig. 1. Different road conditions on a road section.

2. Method

In this paper we have chosen to illuminate the surfaces with the wavelengths $\lambda_1 = 980$ nm, $\lambda_2 = 1310$ nm and $\lambda_3 = 1550$ nm. These wavelengths are marked with circles in Fig. 3. There are two reasons for choosing these particular wavelengths even

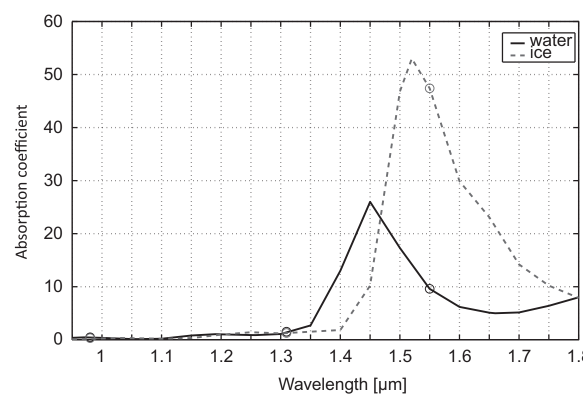

Fig. 3. Absorption of ice and water according to [19]. The markers show the wavelengths used in this paper.

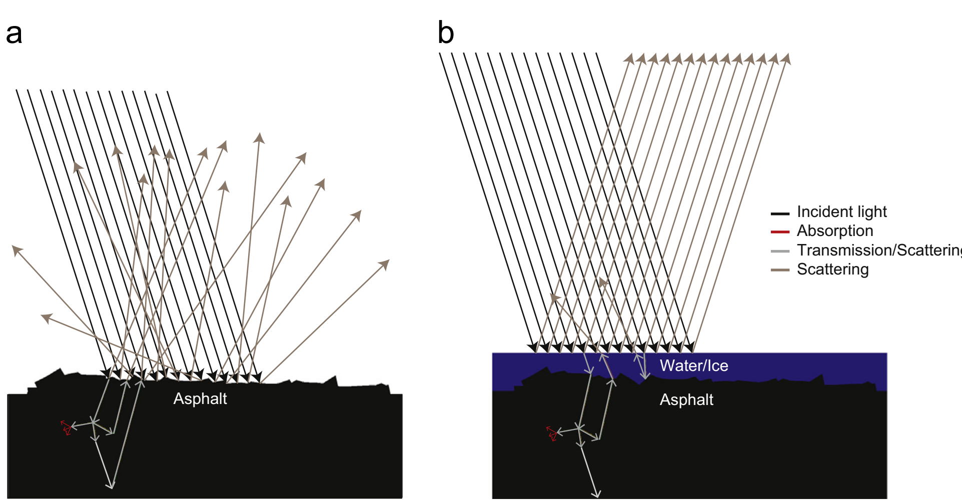

Fig. 2. Scattering of light incident on (a) rough and (b) smooth surfaces, respectively.

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