Remote sensor technologies for RWIS Applications

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ABSTRACT

There is currently considerable interest among road authorities of remote, also called non-contact or non-intrusive, sensor technologies. This interest is based on the fact that remote sensors are easier to install than road mounted sensors. The remote sensors are usually infrared (IR) temperature sensors or IR road status sensors. The road status sensors usually differentiate between dry, wet, icy or snowy road surfaces. This paper describes the techniques used for IR thermometry and road status detection. Furthermore, the pros and cons are discussed with this new sensor technology

Keywords: Non intrusive, remote sensors, infrared sensors.

1 INTRODUCTION

It is important to detect the winter road conditions in order to minimize the accidents caused by snow and ice on the road surface. The knowledge of road conditions initiates appropriate road maintenance tasks that will increase the traffic safety. In Sweden the accident rates are 3 to 16 times higher on icy and snowy roads compared to dry roads [1]. A similar situation is noted in Finland where many of the fatal accidents occur on winter roads [2]. Traditional methods of measuring temperatures involves air temperature probes and surface temperature probes mounted in the road body [3]. The installation of sensors in the road surface is time consuming and requires a closure of one ore more traffic lanes. Another aspect of installing sensors in the road surface is that they may not measure the topmost layer of the road body. Therefore, with the progress of the cost effective InfraRed (IR) technology, new methods of determining road temperature and road surface status has been made possible. There are mainly two approaches that are used for IR technology in RWIS, namely road surface temperature measurement and road status detection. It has been shown that temperature measurements with IR technology correlate quite well with in-situ sensors, but they have an accuracy of less than 2 degrees centigrade [4]. This deviation is small, but it may still cause severely incorrect tasks for example when preventing slippery roads during an icing situation.

The road condition determination with IR technology seems to be quite promising, even though some underestimation was done probably due to the small detection area [4]. Tests performed by the Aurora consortium showed that the matching rate of correct surface statuses was more than 85% [5]. The previous results referred above covers the remote temperature sensor Vaisala DST111 and the surface status sensor Vaisala DSC111. A comparison of different remote surface status sensors was done in Sweden during the winter 2009-2010, and it was found that the Vaisala DSC111 gave promising results while the LIWAS sensor required further evaluation [6]. Further work regarding IR temperature measurements showed that IR temperature measurements give a faster response to weather changes compared to traditional in-situ temperature sensors [7].

2 MATERIALS AND METHODS

When considering IR thermometry, a suitable wavelength region for IR thermometry should be selected. The things that need to be considered is impact from the atmosphere and the detection performance. The atmospheric absorption is shown in Figure 1, and it can be seen that there are regions where the absorption is low and thus suitable for thermometry [8, 9].

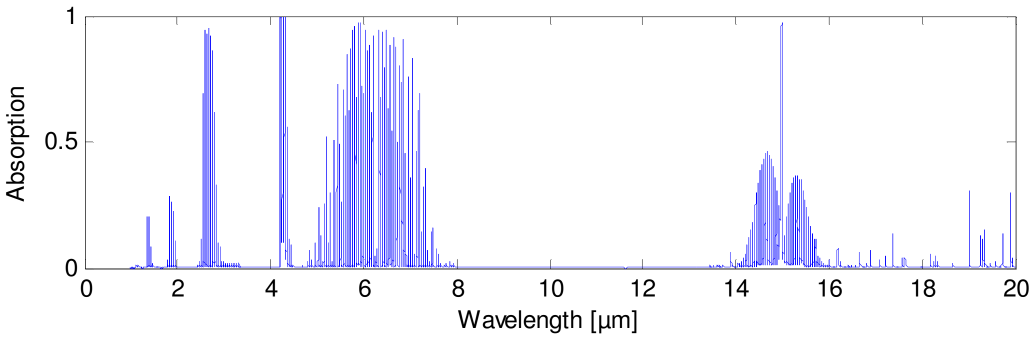

Figure 1. Absorption of IR light by common atmospheric gases. It can be seen that the atmospheric absorbance is low in some wavelength bands, for example between 8-14 µm.

According to Wien´s displacement law far infrared wavelengths, 6-40 µm, should be used when measuring temperatures near 273 K [10]. By combining this information it can be seen that a suitable region for IR temperature measurements for road surfaces is in the wavelength region 8-14 µm. This is also the region in which there exist many commercial IR temperature sensors. Another issue to be concerned is the emissivity of the materials being measured. As the road surface may be dry, wet icy or snowy the emissivity differs according to Table 1 [11]. When examining these emissivity values in the Stefan-Boltzmann law, it can be seen that the various emissivity values only affect the temperature reading by only 0.1%. It is thus possible to use IR sensors operating in the wavelength region 8-14 µm without the need to adjust them due to precipitation building up on a road surface.

Material	Emissivity
Asphalt	0.93
Water	0.96
Ice	0.97 - 0.99 (at 273K)
Snow	0.8 - 0.9

Table 1. Emissivity at 300 K

When determining road conditions using IR, a different property needs to be evaluated instead of the radiation from the surface. One way of determining the road surface is to examine the absorption of water, thus by utilizing a feature that was highly undesirable in IR thermometry. In this case the thermal effects is not used and should be minimized, why a wavelength region should be selected where there is a high absorption of IR light by water and where the thermal effects are low in the temperature range where the road conditions are to be determined. From Wien´s displacement law it can be found that the NIR region is most suitable, 1.2-3.0 µm. By examining the absorption of water it can be seen that there are some characteristic peaks that could be utilized for these measurements, approximately at 1.5 µm and at 1.9 µm [12], see Figure 2.

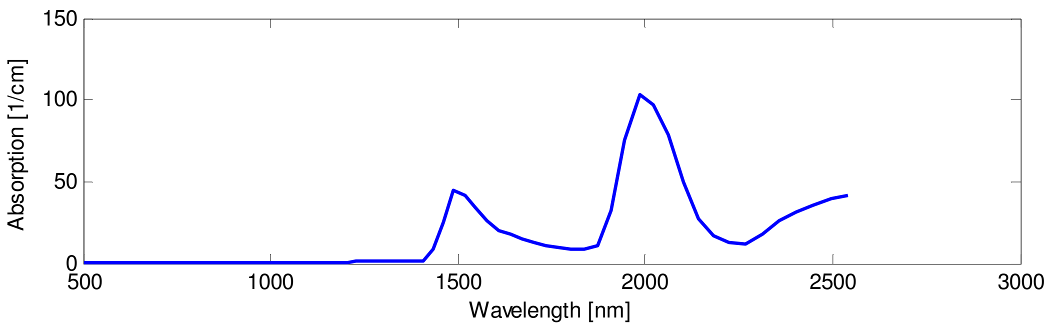

Figure 2. Absorption of water in the NIR region. Some characteristic peaks can be seen.

By utilizing these properties water can be detected. In order to distinguish between water, ice and snow, further analysis must be performed. According to Casselgren, different road conditions can be distinguished by this method [13]. Laboratory tests shows that this method makes it possible to distinguish between dry, wet, ice and snow on a surface [14]. As the commercial surface status sensor manufacturers do not state how they perform the road condition determination, we can only guess that they utilize parts of the described method. Some sensors states to be able to distinguish between different road conditions, and some of the sensors were evaluated by the Swedish Transport Administration [6].

1 CONCLUSIONS

Infrared sensors are clearly easier and more cost effective to install compared to traditional in-situ sensors. A big problem with traditional in-situ sensors is the need of closing the lanes when installing sensors in the road surface.

It has been discovered that IR temperature sensors show good results, but they need to be calibrated in order to give exact temperature readings. Therefore, they can´t directly replace the traditional in-situ sensors. Even discrepancies of 1C can cause severe problems, as the road maintenance personnel may perform incorrect road maintenance tasks, causing ice to build up on the road surface. On the other hand, IR temperature sensors give a faster response to weather changes compared to in-situ sensors which can be helpful for performing correct road maintenance tasks.

The detection of different road conditions can also be done by IR technologies. According to tests performed by road authorities, their performance is quite good, more than 85% correct road status classifications. There are though some road surface status situations that may be incorrectly classified, why further research should be done. One observed reason for incorrect classifications is the spot measurements of these sensors. A larger area coverage of both thermal sensors and road condition sensors should give a more descriptive picture of the road status.

The fast development of IR technology and possibility to use microcomputers for analyzing purposes makes the IR sensor field very promising for the future. The feeling is that it should be a great development in the IR sensor field in the near future.

ACKNOWLEGEMENTS

The authors would like to thank Combitech AB and the Swedish Road Administration for support during this research.

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