



**HAL**  
open science

## Remote sensing techniques to recognize road surface conditions for autonomous vehicles

Hongyi Zhang, Sheherazade Azouigui, Rabia Sehab, Toufik Azib, Cherif Larouci, Ahmed Chaibet, Moussa Boukhniher, François Balembois, Kostadin Beev, Gilles Planche, et al.

### ► To cite this version:

Hongyi Zhang, Sheherazade Azouigui, Rabia Sehab, Toufik Azib, Cherif Larouci, et al.. Remote sensing techniques to recognize road surface conditions for autonomous vehicles. Sia Vision Digital, Mar 2021, Paris, France. hal-04577355

**HAL Id: hal-04577355**

**<https://hal.science/hal-04577355>**

Submitted on 16 May 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

# REMOTE SENSING TECHNIQUES TO RECOGNIZE ROAD SURFACE CONDITIONS FOR AUTONOMOUS VEHICLES

HONGYI ZHANG, ELS



# Table of contents

- > Introduction
- > Current sensors implemented on autonomous vehicles and their limitations
- > Current techniques to detect road surface conditions
  - Polarimetry
  - Backscattering amplitude
  - Image processing and machine learning
- > Discussion and conclusion



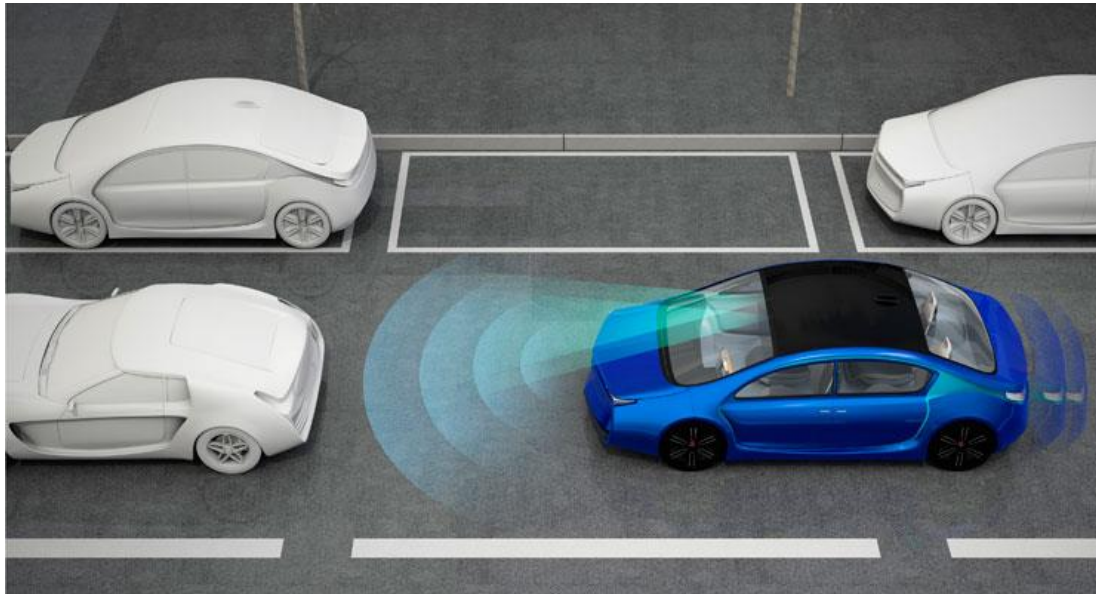
# Table of contents

- > **Introduction**
- > Current sensors implemented on autonomous vehicles and their limitations
- > Current techniques to detect road surface conditions
  - Polarimetry
  - Backscattering amplitude
  - Image processing and machine learning
- > Discussion and conclusion



# Introduction

- > Detecting obstacles is a crucial issue for autonomous vehicles.
- > Current systems have potential to be improved to detect changes in weather and road surface conditions.



# Table of contents

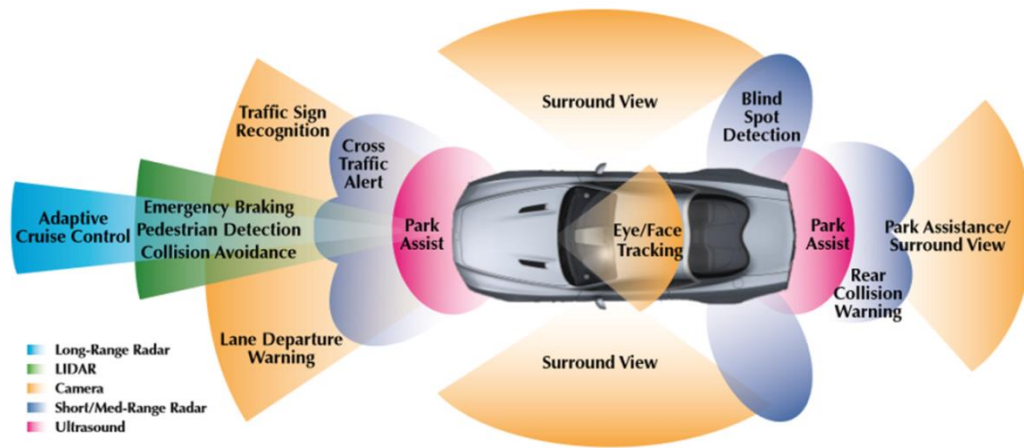
- > Introduction
- > **Current sensors implemented on autonomous vehicles and their limitations**
- > Current techniques to detect road surface conditions
  - Polarimetry
  - Backscattering amplitude
  - Image processing and machine learning
- > Discussion and conclusion





# Current sensors implemented on autonomous vehicles and their limitations

- > 4 kinds of sensors are implemented on autonomous vehicles: **Camera, Lidar, Radar and Ultrasonic sensors.**
- > All these sensors have their **advantages** and their **limitations.**
- > Currently **road surface identification system** is not yet developed and embedded



	Video	Lidar	Sonar	24 GHz Radar	>77 GHz Radar
Operation in rain, fog or snow	-	-	+	++	++
Operation at night	--	++	++	++	++
Range	++	+	-	+	++
Angular resolution	++	+	--	--	-
Range resolution	+	+	++	+	++

++ Ideally suited      + Good performance  
 - Feasible              -- Impossible

[1] A. Bystrov, et al., "Sensors for Automotive Remote Road Surface Classification," 2018 IEEE International Conference on Vehicular Electronics and Safety (ICVES). IEEE, 2018: 1-6.



# Table of contents

- > Introduction
- > Current sensors implemented on autonomous vehicles and their limitations
- > **Current techniques to detect road surface conditions**
  - Polarimetry
  - Backscattering amplitude
  - Image processing and machine learning
- > Discussion and conclusion

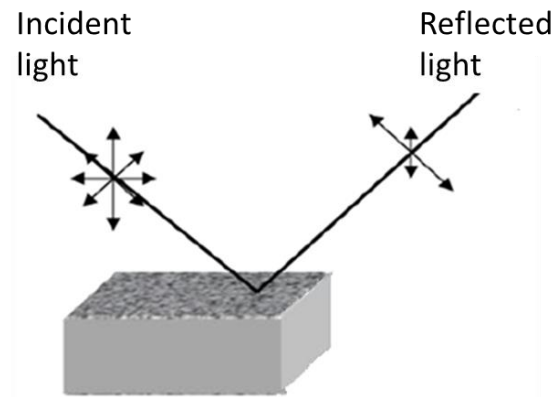




# Polarimetry

## Principle

- > The **polarization state** of light is changed when light is reflected on different road surfaces.
- > **Sensors (camera / photodiode) with polarizers** or **Radar** are needed in this technique.
- > **Different wavelengths of signal (light/radar)** can be exploited.



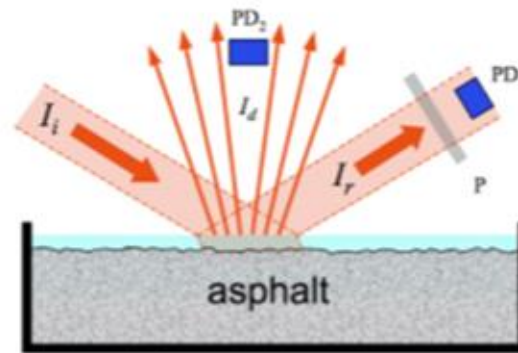
# Polarimetry

Visible light



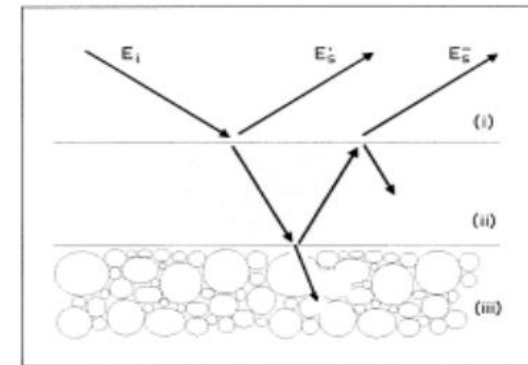
Dry and wet road surface can be distinguished [2]

IR light



By combining the diffused intensity and polarization contrast, dry wet, water and ice can be distinguished [3]

Millimeter wave (Radar)



A bistatic fully polarimetric Radar at 76GHz can be used to distinguish dry road and black ice on the road surface [4]

[2] M. Yamada, et al., "A study of the road surface condition detection technique for deployment on a vehicle," JSAE review, 2003, 24(2): 183-188.

[3] L. Colace, et al., "A near-infrared optoelectronic approach to detection of road conditions," Optics and Lasers in Engineering, 2013, 51(5): 633-636.

[4] R. Finkle, "Detection of ice layers on road surfaces using a polarimetric millimetre wave sensor at 76 GHz," Electronics Letters, 1997, 33(13): 1153-1154.



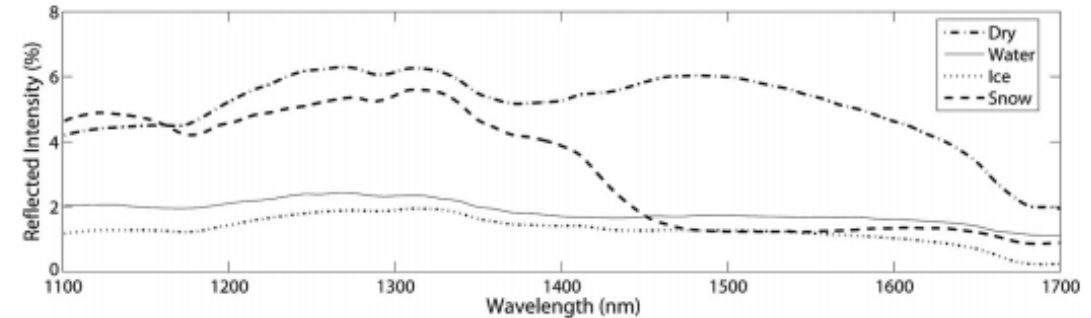
# Backscattering signal

- > The principle of backscattering technique is that **the amplitude of backscattered signal depends on the road conditions for certain wavelengths.**
- > For this technique, **a source and a sensor** to receive the signal are required.

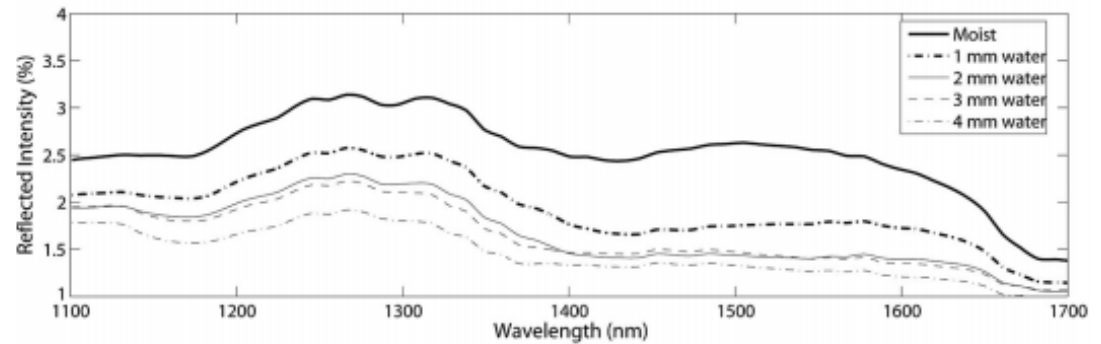


# Backscattering signal - Near infrared

- > Average spectral responses of ice, snow and water on asphalt are different.
- > This is due to the absorption difference of IR light of ice and water.
- > Using 2 or 3 wavelengths in near infrared, wet, water, dry, snow and ice could be distinguished.



(a)



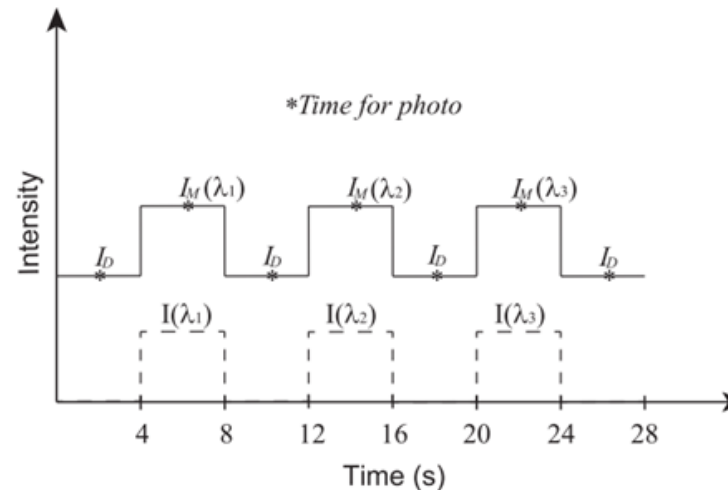
(b)

[5] J. Casselgren, et al., "Angular spectral response from covered asphalt," Applied optics, 2007, 46(20): 4277-4288.



# Backscattering signal - Near infrared

- > As the spectral response of the source is investigated in this technique, **ambient light** should be taken into account.
- > **Modulated signal of the IR source** can be exploited to eliminate the influence of the ambient light.



[6] J. Casselgren, et al., "Road condition analysis using NIR illumination and compensating for surrounding light," *Optics and lasers in engineering*, 2016, 77: 175-182.



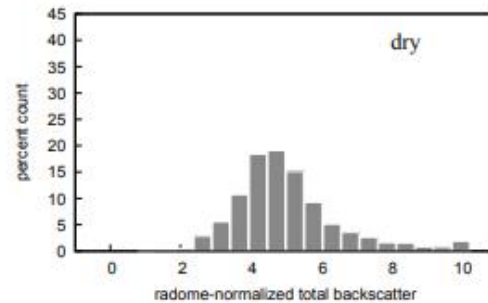


# Backscattering signal - Radar

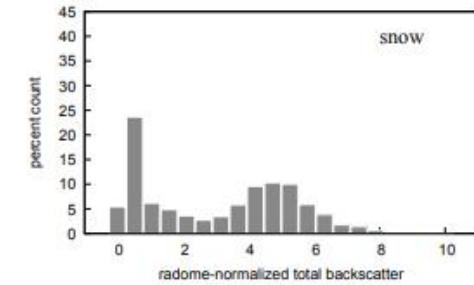
- > **Backscattering of Radar** on autonomous vehicles can distinguish the road condition by the **distribution of normalized amplitude**.



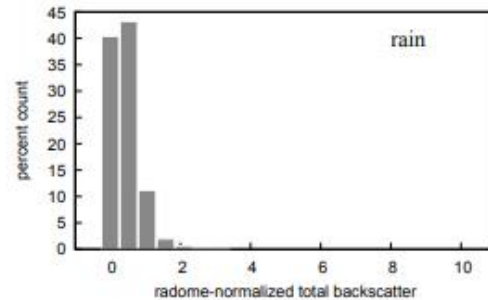
(a) dry



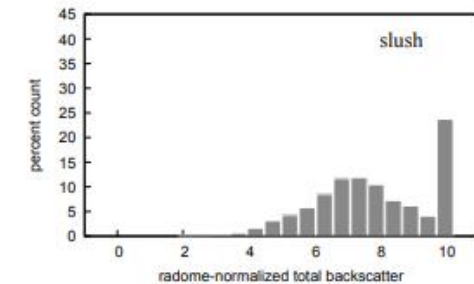
(c) snow



(b) rain



(d) slush



6. Snapshots of road conditions for moving vehicle test scenario

Fig. 7. Histogram distribution of integrated radar backscatter for various road conditions

[7] P. Asuzu, et al., "Road condition identification from millimeter-wave radar backscatter measurements," 2018 IEEE Radar Conference (RadarConf18). IEEE, 2018: 0012-0016.





# Image processing and machine learning

- > In 1990s, the image processing methods to recognize the road surface condition was based on **morphological and texture analysis** [8].
- > In recent years, **machine learning** has been a promising technique to distinguish road conditions thanks to the growth of computer performance.
- > **SVM (Support vector machine)** and **Deep learning** are two mostly investigated techniques to distinguish road surface conditions and their accuracy can be up to 97% [9][10].

[8] Y. Chen, "Image analysis applied to black ice detection," *Applications of Artificial Intelligence IX. International Society for Optics and Photonics*, 1991, 1468: 551-562.

[9] J. Zhao, et al., "Road surface state recognition based on svm optimization and image segmentation processing," *Journal of Advanced Transportation*, 2017, 2017.

[10] S. Roychowdhury, et al., "Machine Learning Models for Road Surface and Friction Estimation using Front-Camera Images," *2018 International Joint Conference on Neural Networks (IJCNN). IEEE*, 2018: 1-8.



# Table of contents

- > Introduction
- > Current sensors implemented on autonomous vehicles and their limitations
- > Current techniques to detect road surface conditions
  - Polarimetry
  - Backscattering amplitude
  - Image processing and machine learning
- > **Discussion and conclusion**



# Discussions and conclusions

## > Polarimetry

- **Sensors (camera / photodiode / radar) with polarizers** are needed.
- In **visible band**, **dry and wet** can be distinguished.
- In **IR band**, **dry, wet, water and ice** can be distinguished.
- In **millimeter band**, **black ice** can be recognized from dry asphalt.
- **Specular reflection** must be fulfilled, thus this technique is difficult to be mounted on the vehicles.
- Roadside infrastructure is a more appropriate solution.



# Discussions and conclusions

## > Backscattering of IR signals

- **Near infrared sources and sensors** are needed based on the spectral responses of different road conditions.
- **Modulated signals** can be applied to the sources to eliminate the influence of the ambient light.
- The cost of the sensors might be a problem.

## > Backscattering of millimeter signal (Radar)

- **Distribution of the backscattering signal** can be exploited to distinguish the road conditions. The accuracy needs to be improved.



# Discussions and conclusions

## > Image processing and machine learning

- **No supplementary sensor or source** needs to be installed on the autonomous vehicles.
- **Data from any sensors can be exploited.**
- **Data from the camera is easily influenced by illumination conditions.** At night, **the detection range and accuracy** would be weakened due to the low illumination and illumination range of headlamps compared to sunlight.



# Discussions and conclusions

- > In conclusion, a system to recognize the road surface conditions will indeed increase the driving safety of autonomous vehicles.
- > Three main techniques have been identified: polarimetry, backscattering signal and image processing/machine learning.
- > In order to make the system work in daytime and nighttime and obtain an appropriate accuracy, a combination of the techniques seems to be a promising method.



# THANK YOU FOR YOUR ATTENTION

*HONGYI.ZHANG-EXT@ESTACA.FR*

