Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 168 (2016) 19 – 22

Procedia Engineering

www.elsevier.com/locate/procedia

30th Eurosensors Conference, EUROSENSORS 2016

Road surface classification using automotive ultrasonic sensor

Aleksandr Bystrov[a,]*, Edward Hoare[a], Thuy-Yung Tran[b], Nigel Clarke[b], Marina Gashinova[a], Mikhail Cherniakov[a]

[a]University of Birmingham, Birmingham, B15 2TT, UK
[b]Jaguar Land Rover Research Department, Coventry, CV3 4LF, UK

Abstract

This work examines the method of road surface classification, based on the analysis of backscattered ultrasonic signals. The novelty of our research is the extraction of signal features for separate swathes of illuminated surface (segmentation) and the use of a wide range of statistical methods in real on-road and off-road driving conditions. The errors caused by the influence of environmental conditions and the vehicle movement were analysed, and ways to reduce them were suggested. The results demonstrate the feasibility of reliable surface classification using the proposed methodology.

Peer-review under responsibility of the organizing committee of the 30th Eurosensors Conference

Keywords: sonar applications; remote sensing; sensor fusion; classification algorithms; artificial neural networks

1. Introduction

The current demand and still unsolved challenge is to provide remote real-time identification of road surface conditions in both complex environments (off-road terrain, liquid dirt etc.) and weather conditions (rain, spray, fog, snow etc.). In this paper the feasibility of a short-range ultrasonic sensing system is investigated. Along with other sensor technologies such as infrared, radar, LIDAR and visible light [1], the use of ultrasonic signal for surface classification by roughness and surface textures has been investigated in many studies [2-5].

In paper [2] time delay spectrometry and neural networks were used to identify 12 indoor surfaces with different periodic profiles by their frequency response characteristics. A broadband, frequency modulated sonar sensor was

* Corresponding author. Tel.: +44-121-414-4241; fax: +44-121-414-4291.
E-mail address: a.bystrov@bham.ac.uk

Peer-review under responsibility of the organizing committee of the 30th Eurosensors Conference
doi:10.1016/j.proeng.2016.11.119

effectively used to extract information about the geometry and types of certain surfaces in [3]. In [4, 5] the distinguishing between asphalt, grass, gravel, plastic, and carpet was achieved with success rate approaching 100%. The application of ENDURA (Energy-Duration-Range) method [6] allowed differentiation between different types of surfaces by matching measured echo-energy and echo-duration maps with the templates. Sonar performance in distinguishing between surfaces with random and periodic textures has been studied in [7]. In [8] the neural network has been trained to differentiate between wood, carpet, curtain, ceiling, and water covered surfaces. In the most studies the analysis has been made in attempt to distinguish between several surfaces that are typical when using relatively slow mobile robots in a controlled environment. In this paper the most challenging off-road conditions will be investigated, such as driving on gravel, dirt, and grass covered roads, requiring real-time control of the car suspension. In contrast to our previous work [9], in this study we analyze in more detail surface classification using only ultrasonic sensor by means of an extended set of classification algorithms. The factors that influence the accuracy of surface recognition while driving have been discussed.

2. Terrain recognition using statistical classification algorithms

The procedure of surface classification involves a three-stage process: segmentation, feature extraction, and classification. In Fig. 1a the scheme of surface identification in front of the vehicle is shown, where Θ_b =55° is the antenna half power beamwidth, Θ_1=20° is the central grazing angle, and H=0.65 m is the antenna height over ground. In the developed system six signal features were used for surface recognition. Four basic features apply to the entire range from 1.5 m to 4.0 m; they include mean signal power PA (Fig. 1b), signal duration above the threshold DT (Fig. 1c), signal power above the threshold PT (Fig. 1c), and the standard deviation of the signal envelope. Two additional features represent mean power of the signal in the near range (1.5-2.5 m) and in the far range (3.0-4.0 m).

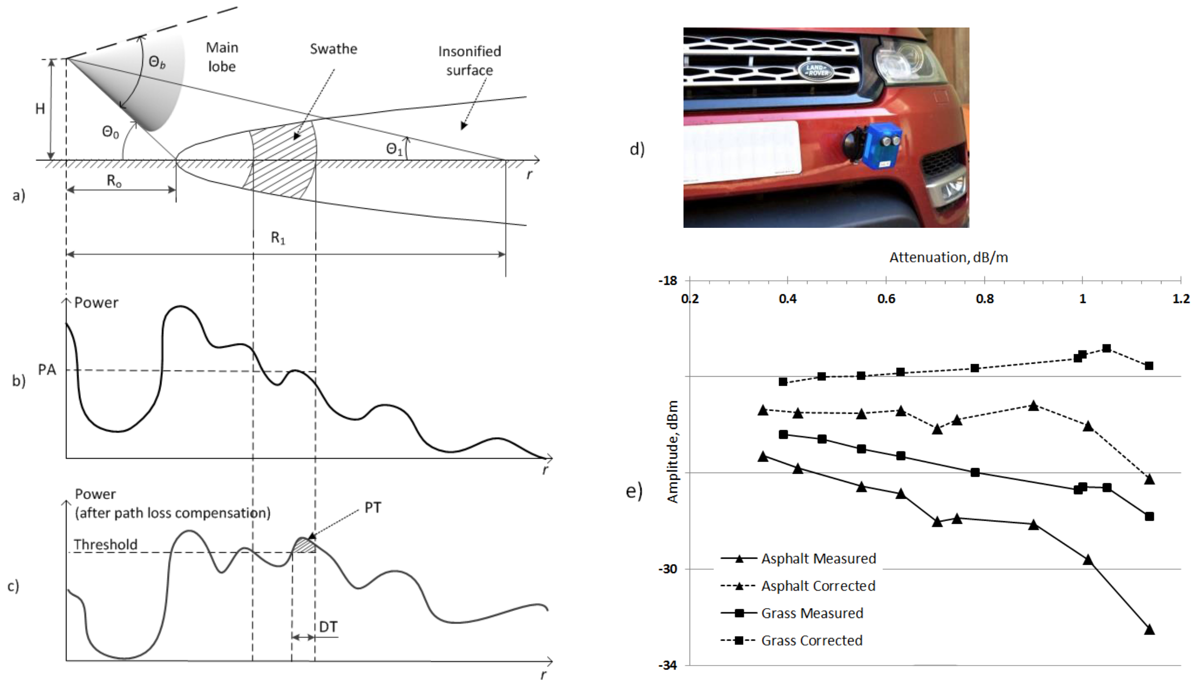

Fig. 1. Surface identification in front of a vehicle using ultrasonic sensor: a) measurement setup, b) power of the backscattered signal, c) power of the backscattered signal after path loss compensation, d) sonar mounted on a vehicle, e) average amplitude of the signal reflected from asphalt and grass in the range from 1.5 m to 4.0 m at different weather conditions: solid lines show the experimental results, dashed lines show the results, environmentally corrected to compensate the signal absorption