Available online at www.sciencedirect.com
ScienceDirect
Procedia Computer Science 113 (2017) 466–471
Procedia Computer Science
www.elsevier.com/locate/procedia

International Workshop on Connected & Intelligent Mobility (CIM 2017)

A Neural network approach to visibility range estimation under foggy weather conditions

Hazar Chaabani[a], Faouzi Kamoun[a]*, Hichem Bargaoui[a], Fatma Outay[b], Ansar-Ul-Haque Yasar[c]

[a]ESPRIT School of Engineering, ZI. Chotrana II, Tunis PO. Box 160, Tunisia
[b]Zayed University, Dubai P.O. Box 19282, U.A.E
[c] Hasselt University, Wetenschapspark 5 bus 6, Diepenbeek P.O. Box 3590, Belgium

Abstract

The degradation of visibility due to foggy weather conditions is a common trigger for road accidents and, as a result, there has been a growing interest to develop intelligent fog detection and visibility range estimation systems. In this contribution, we provide a brief overview of the state-of-the-art contributions in relation to estimating visibility distance under foggy weather conditions. We then present a neural network approach for estimating visibility distances using a camera that can be fixed to a roadside unit (RSU) or mounted onboard a moving vehicle. We evaluate the proposed solution using a diverse set of images under various fog density scenarios. Our approach shows very promising results that outperform the classical method of estimating the maximum distance at which a selected target can be seen. The originality of the approach stems from the usage of a single camera and a neural network learning phase based on a hybrid global feature descriptor. The proposed method can be applied to support next-generation cooperative hazard & incident warning systems based on I2V, I2I and V2V communications.

Peer-review under responsibility of the Conference Program Chairs.

Keywords: visibility distance; fog detection; intelligent transportation systems; meteorologcal visibility; driving assistance; neural networks; machine learning ; Koschmieder Law; computer vision; Fourier Transform

1. Introduction

Foggy weather conditions represent an imminent threat to road safety, often leading to fatal road accidents because degraded road visibility has the potential to (1) take even experienced drivers by surprise, (2) alter the motorists' driving behavior, and (3) distort drivers' perception of depth, distance, and speed[1]. Earlier research[1,2,3]

* Corresponding author. Tel.: +216-99-423-944; fax: +216-70-685-454.
E-mail address: faouzi.kammoun@esprit.tn

1877-0509
Peer-review under responsibility of the Conference Program Chairs.
10.1016/j.procs.2017.08.304

revealed that although foggy weather conditions are not very recurrent phenomena, the number of associated multiple colliding vehicles, injuries and fatalities are much higher than average. Since highway fog abatement technologies have not reached yet the desired level of maturity and economic viability, several roadway crash countermeasures and new vehicle design technologies have been proposed to assist motorists cope with foggy weather conditions. These include reflectorized paints on pavement edge striping, beaded lane delineators, blinking strobe lights, and onboard equipment including fog lights, Light Detection And Ranging (LiDAR) sensors and Autonomous Emergency Braking (AEB) systems, among many others.

Recently, there has been a growing interest in integrating variable speed limit signs (VSLMs) and Variable Message Sign (VMS) units into major highway infrastructures[4]. In addition, there has been considerable interest in cooperative situational awareness and collision avoidance systems based on I2V, V2V and I2I communications to warn drivers against low visibility and to recommend proper speeds that are adapted to the prevailing visibility conditions. The success of these solutions hinges on the ability to detect fog and estimate the visibility range in real-time. For this reason, fog detection and the estimation of visibility distance have been a major area of research study during the past few years.

In this contribution, we will begin by defining fog, outlining its associated light propagation models and introducing the notion of visibility distance. In section 3, we summarize the state-of-the-art approaches to estimating visibility distance in daytime fog. We will then present our neural network approach for visibility range estimation. In section 5, we present an experimental evaluation of the proposed solution and in section 6 we provide a summary of the key findings of this study.

2. Fog definition and visibility models

2.1. Definitions

Fog is a kind of cloud on the ground and is formed by the suspension of microscopic moisture dewdrops into airborne particles. According to the Meteorological Office 1969[5], fog is defined as the state of atmospheric obscurity where meteorological visibility falls below 1 Km. If visibility drops below 40 meters, fog is qualified as being "dense". A visibility between 40 meters and 200 meters corresponds to a thick fog situation[5]. For road safety applications, the visibility range of interest is between 0 and 400 meters. The luminous flux emanating from visible light (400 nm $\leq \lambda \leq$700 nm) gets scattered in all directions when it hits a water droplet and absorption is often negligible in this case. This scattering can severely impair drivers' depth perception and peripheral vision. The attenuation of visible light is characterized by the extinction coefficient k (m^{-1}) which is a factor of the droplets size and concentration[6]. The estimation of this coefficient has been the basis of many visibility range estimation methods.

2.2. Light propagation through fog

On the basis of Koshmieder luminance attenuation law[7], Duntley[7] proposed the attenuation law of atmospheric contrasts under uniform illuminance which states that an object with intrinsic contrast C_0 against its background will be perceived at a distance d with an apparent contrast C given by:

$$C = C_0 e^{-kd} \tag{1}$$

The above expression has been used as a basis for defining the "meteorological visibility distance" $d_{visibility}$ as the greatest horizontal distance at which a black object (C_0=1) of a moderate dimension can be seen on the horizon during daytime with a contrast threshold ε=5% , as recommended by the International Commission of Illumination (IEC[8]):

$$d_{visibility} = -\frac{1}{k}\ln(0.05) \cong \frac{3}{k} \tag{2}$$