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ScienceDirect

Procedia Engineering 140 (2016) 195 – 202

Procedia Engineering

www.elsevier.com/locate/procedia

MRS Singapore – ICMAT Symposia Proceedings

8th International Conference on Materials for Advanced Technologies

A Noise Cancellation Approach for an illuminating LEDs based Short-range Visible Light Sensing System

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Abstract

In this paper, an illuminating LEDs based short-range visible light system is proposed and investigated. The LEDs are used not only as illuminating devices but also as ranging and detecting sensors. In this system, the optical rays emitted from the LEDs are modulated with a predetermined signal at a constant frequency with an initial phase, illuminating to a target. The spatial position information of the target is obtained by measuring and analyzing the backscatter signals form the target. To extend the sensing distance as well as reduce the estimation error, a noise cancellation approach by using multiple periods averaging technique is adopted in this system. The fundamental characteristics of the system employing a commercial available illuminating LEDs have been simulated and analyzed. The numerical results show that with this approach, the sensing distance and the accuracy of the position estimation are significantly improved. As a cost, certain reduction of the acquisition rate is also obtained. However, this acquisition rate is acceptable for the system in a realistic scenario.

Selection and/or peer-review under responsibility of the scientific committee of Symposium 2015 ICMAT

Keywords: illuminating LEDs, visible light sensing, backscatter measurement, noise cancellation, multiple periods averaging and position estimation.

1. Introduction

Lighting is a major source of electric energy consumption. Recent reports estimate that about one third of the global electricity utilisation is spent for lighting purposes [1, 2]. This has resulted in an increased awareness on green

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Selection and/or peer-review under responsibility of the scientific committee of Symposium 2015 ICMAT
doi:10.1016/j.proeng.2016.07.345

lighting technologies in many countries around the world. In line with the governmental plans worldwide, it is predicted that LEDs will gradually replace both incandescent and fluorescent lights and be the ultimate light source in the near future. Besides indoor illumination, LEDs will be widely used in outdoor lamps, traffic signs, advertising displays, car headlights/taillights, etc. Therefore, the wide-scale introduction of LEDs lighting offers a great opportunity for developing different types of new applications: visible light communications (VLC) [3-5], visible light positioning (VLP) [6-10] and visible light sensing (VLS). Simultaneous use of LEDs for lighting, communication and sensing purposes is a sustainable and energy-efficient approach that has the potential to revolutionize how we use light.

In the past decades, many techniques for objects/obstacle ranging and detecting systems have been proposed and investigated. A number of laser based systems have been introduced in [11-13]. A most common Lidar system operates on the time of flight principle by sending a laser pulse in a narrow beam to the object. By measuring the backscatter light from the target object, the propagation time as well as the distance of the pulse can be obtained. Compared to a LEDs based system, Lidar has a larger modulation bandwidth so that a very narrow pulse can be modulated, which results a better measuring accuracy. Due to narrow divergence angle of the laser, Lidar can operate for a longer distance then the LEDs based system. However, there are some drawbacks of this system as well. If the surface of the object reflects a great portion of the laser beam it receives toward the detector, it is efficient. But if the surface of the object is not exactly at a right angle to the beam and it has some specular reflection effects, most of the reflected light will be oriented to another direction rather than the direction to the detector. In contrast, a LEDs based system is more robust for the short distance sensing because the reflection surface on the object is much larger than a Lidar system. By utilizing the off-the-shelf LEDs lighting infrastructure, the LEDs based system has a lower cost as well as a better energy-efficient compared to a Lidar system.

On the other hand, the techniques such as ultrasonic [14, 15] and infrared (IR) [16, 17] based ranging and detecting systems were proposed and studied as well. However, considering the factors of cost, accuracy, coverage and energy efficiency and exploiting the existing LED based lighting infrastructure capabilities; the VLS scheme would be the most promising technique to achieve a reliable, high accurate, energy-efficient and widely available sensing system for most indoor environment. With the widespread use of LEDs-based illuminations in indoor as well outdoor applications, VLS could be utilized as obstacle/collision avoidance system for vehicles and robots, optical barrier for security, bulk volume measurement sensor for conveyor belts, etc.

In this paper, we proposed and investigated a white LEDs based visible light short-distance ranging and detecting system for a typical indoor environment. The LEDs are used not only as illuminating devices but also as ranging and detecting sensors. In this system, the optical rays emitted from the LEDs are modulated with a predetermined signal at a constant frequency with an initial phase, illuminating to a target. The spatial position information of the target is obtained by measuring and analyzing the backscatter signals form the target. To extend the sensing distance as well as reduce the estimation error, a noise cancellation approach by using multiple periods averaging technique is adopted in this system. The numerical results show that with this approach, the sensing distance and the accuracy of the position estimation are significantly improved. As a cost, certain reduction of the acquisition rate is also obtained. However, this acquisition rate is acceptable for the system in a realistic scenario.

The paper is organized as follows. In Section 2, theoretical model and channel characteristics of the proposed system are introduced. The performances of the system are evaluated in Section 3. Based on the simulation results, the sensing distance as well as the estimation error for different scenarios are compared and discussed. The performances of the system are evaluated. The conclusions are given in Section 4.

2. System modeling

2.1. System overview