proceedings

MDPI

Proceedings

Passive Visible Light Sensing of Retroreflective Foils on a Moving Object for Indoor Application †

Andreas Peter Weiss * and Franz-Peter Wenzl

Institute of Surface Technologies and Photonics JOANNEUM RESEARCH Forschungsgesm.b.H, 7423 Pinkafeld, Austria; franz-peter.wenzl@joanneum.at

* Correspondence: andreas-peter.weiss@joanneum.at; Tel.: +43-316-876-3605

† Presented at the 4th International Conference nanoFIS 2020—Functional Integrated nano Systems, Graz, Austria, 2–4 November 2020.

Published: 20 January 2021

Abstract: We present a novel approach to perform passive visible light sensing of retroreflective foils mounted on a moving object by utilizing low-cost hardware combined with a self-developed, low complex software algorithm with minimal training effort for successful classification. Therewith, we show the feasibility of utilizing the visible light spectrum not only for illumination, but also to perform sensing tasks, which consequently will lead to less energy consumption, no need for active sensors on the moving object, and finally no necessity of wireless radio frequency communication between the object and the processing device.

Keywords: passive visible light sensing; retroreflective sensing; photonic sensor

---

1. Introduction

The ever-increasing number of wirelessly connected devices, summarized under the term Internet of Things (IoT), is a fact in our modern lifestyle. Most of these connected devices utilize active sensors and communication to perform tasks like identification or detecting and transmitting parameters of the object they are placed on. These sensors need some form of energy supply and some certain amount of wireless communication. Predictions show that with the increasing number of devices, the wireless communication channels in the Radio frequency (RF) spectrum will face bandwidth problems. Furthermore, placing active sensors on an (especially moving) object adds additional problems like battery weight, the need for charging, and installation effort on the object.

Passive visible light sensing can relieve these problems by performing sensing functionalities utilizing the visible light spectrum with no active sensors placed on the object. By only detecting and rating the light intensity and its spectral composition reflected from an object sensing functionality can be performed, in addition to the still provided illumination [1,2]. In this contribution, we will deal with an indoor application, where the size of the reflective area must be kept as small as only a few centimeters, as compared to outdoor scenarios given in [1]. Furthermore, in an indoor scenario the applicable light intensity is also limited. In [3] we showed the successful classification of reflective foils on a static small cube utilizing a self-developed VLS unit, and a self-developed classification algorithm in such an indoor setting. In this contribution, a successful classification of a moving object equipped with retroreflective foils in different size configurations at various speeds is demonstrated.

2. Materials and Methods

The main block of our experimental setup is our self-developed VLS unit with its CREE MC-E LED with a reflector as the light source and the RGB sensitive photodiode Kingbright KPS-5130PD7C (also with a surrounding reflector) as the sensing device. The three channels of the photodiode are interfaced to three separate Trans Impedance Amplifiers (TIA), where each TIA output is connected to a channel on a Keysight DSOS404A Digital Storage Oscilloscope. Please see [3] for further details on the VLS unit. The moving object is a LEGO train platform moving on rails and thereby passes the light beam of the LED on its way. The LEGO train holds the reflective foils at a fixed position in the middle of the 22.4 cm long and 4.7 cm broad train platform. The distance between the LED and the surface of the reflecting area is 68 cm. The LED is supplied by an external power source with 3 V and 500 mA current. This leads to ~690 Lux on the reflective area. For our experiments, the size of the reflective area is varied from its maximum size of 2.8 cm width by 4.7 cm length. While the length is kept constant, the width is incrementally reduced by 0.7 cm to minimum overall dimensions of 0.7 cm by 4.7 cm. This results in 4 different sized configurations of the reflective area. The experiments were performed in a dark room with no windows, with only the LED of the VLS unit as the light source.

As reflective materials, commercially available retroreflective foils in different colors of the vendors 3 M and Orafol were used. All of them have the reflection class of RA3/C. The production code of the 3 M foils is 4090 with the colors white, green, yellow, red and blue, whilst for the Orafol foils the production code is VC170, with the colors white, red and yellow. Overall, the 8 different foils, each with 4 different size configurations, lead to 32 different scenarios for classification.

3. Algorithm

In order to classify the reflections of the moving object we developed an algorithm consisting of a Training phase and an Online phase. In the Training phase the algorithm stores the characteristic reflected values of the three output channels of the photodiode circuitry over time and builds a reference curve for each scenario. In the online phase, the unclassified dataset is then compared to the different reference curves of each channel, by computing the Euclidian distance of each sample point to the stored reference sample point. Finally, the sum over the Euclidian distances between the sample points is computed. The reference scenario, which has the minimal sum value for the corresponding color channel, is considered as the classification result of this color. Since we have three color channels, a simple majority vote will yield the final classification result. When there is no majority achieved, the result is reported as Undecided. Besides the final classification of the scenario, the algorithm also gives a very good estimate on how well different scenarios will be distinguishable against each other, based on their Euclidian distances.

4. Results

Exemplarily for the comprehensive experiments of our contribution the classification results for the previously described foils is discussed for a setup where the object (train) is moving at a speed of ~0.7 m/s. For the training of the algorithm, 10 runs per scenario were performed and the reference datasets were built. Afterwards, 10 runs of each scenario were evaluated in the Online phase. At this speed all of the 32 different scenarios were classified correctly. Only for the Orafol yellow reflective foil do the results show that the majority vote was not 3 out of 3, but was 2 out of 3 in three classifications with the reflective area of 1.4 cm × 4.7 cm. Correct classification is still achieved.

Funding: The authors gratefully acknowledge the financial support by the Austrian Bundesministerium für Verkehr, Innovation und Technologie (BMVIT), project "HIGH-Light".

References

1. Bloom, R.; Zuniga, M.; Wang, Q.; Giustiniano, D. Tweeting with sunlight: Encoding data on mobile objects. In Proceedings of the 38th IEEE International Conference on Computer Communications (IEEE INFOCOM 2019), Paris, France, 29 April–2 May 2019.
2. Wang, Q.; Zuniga, M. Passive Sensing and Communication Using Visible Light: Taxonomy, Challenges and Opportunities. April 2017. Available online: https://arxiv.org/pdf/1704.01331.pdf (accessed on 12 October 2020).

3. Weiss, A.P.; Madane, K.; Zahiri Rad, S.; Wenzl, F.P. Implementation of a Cost-Efficient Passive Visible Light Sensing Approach for the Determination of Surface Colors. In Proceedings of the 27th Austrian Workshop on Microelectronics (Austrochip 2019), Vienna, Austria, 24–24 October 2019.

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

© 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).