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Image-Based Remote Measurements of Retro-Reflectivity of Roadway Assets During Daytime

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This research project explores and presents the possibility of an inexpensive, safe, and cost-effective computer vision method for remotely measuring the retro-reflectivity of traffic signs during daytime using High Dynamic Range (HDR) images. By capturing two images simultaneously during the daytime, the method simulates nighttime visibility for each sign and measures retro-reflectivity at a level of accuracy that is mandated by FHWA guidelines. An experimental test was conducted on different types of traffic signs with different levels of retro-reflectivity which are located at different distances in real-world conditions to validate the performance of the method. The proposed technique is faster, cheaper, and safer as neither requires nighttime operation nor manual sign inspection, particularly for overhanging signs which are hard to reach. The developed technique allows inspectors to carry around and measure retro-reflectivity levels during the daytime on foot. This study will provide an effective way to inspect and replace/repair defective signs while avoiding expensive retro-reflectometers and nighttime visibility inspections.

Study Methods

A combination of computational photography and carefully tuned hardware are used to generate realistic photos of the night during the daytime. This method involves a process of merging multiple LDR images at varying exposures to create HDR images. The proposed method uses HDR images taken during the daytime, while the surroundings of the luminance measurement are recorded placing the measurements in context. A consumer-level camera equipped with a flashing device is required. To synthesize a night photo; it is needed to remove the sun and all of its reflections while adding a controlled light source. By capturing two images almost simultaneously, the method simulates nighttime visibility and allows retro-reflectivity to be measured at a level of accuracy and granularity mandated by FHWA. First, two images are captured from a scene; one with a controlled artificial light source, produced by a commercial flash, and one without. Then, the two images are processed to remove all the light sources from the scene except for the controlled light source. Since all natural light sources including the sun are removed, the output image resembles a night photo where only the controlled light source is present as shown in the figure below.

All elements in the images must be perfectly registered and aligned. A bright edge that is misaligned by one-tenth of a pixel produces a significant artifact around the edges of objects. In real-world conditions, both the camera and objects can move within several pixels. For example, a camera that is fixed on a tripod may be affected by some degree of vibration due to the wind and other factors. Furthermore, some objects such as moving cars and pedestrians may move a few pixels between the times that the two images are being captured. A camera that is mounted on a vehicle or a camera that moves could exhibit a greater degree of such misalignments. To minimize the effects of vibrations and movements, the images are automatically aligned in two steps of global alignment and local sub-pixel alignment.

Findings

To check the reliability of the proposed method, several experiments have been carried out. Four different traffic signs with different levels of retro-reflectivity were used to test the performance of the image-based method for retro-reflectivity measurement in the daytime. The retro-reflectivity of each sign at different times of day and for different distances were measured in cd/lx*m2 and are compared with the ground truth. In a few cases, the measured retro-reflectivity numbers are below the ground truth. These are mainly due to distance and the time of day when data was collected. By contrasting measurements obtained from the proposed method with lab measurements (ground truth), the method shows an accuracy of 88.8% in terms of correctly clarifying the measured retro-reflectivity levels. Based on current hardware and software settings, the proposed method can measure retro-reflectivity with signs at 97.70% accuracy for all distances between 25 ft and 100 ft and at any time between 9:00 AM to 3:00 PM.

Policy Recommendations

Compared to the current practice of using the retro-reflectometer where only a few measurements are conducted (typically four point-level measurements on sign background, and four point-level measurements on sign text), the method considers the entirety of the traffic sign surface and results in a more comprehensive retro-reflectivity measurement. This is important as traffic signs exhibit heterogeneous deterioration rates, whereby point-level measurements may not be the best representatives for the entirety of the sign surface. The method at 97.70% accuracy shows significant promise for large scale applications. Such a mobile setup can significantly facilitate the current process by allowing inspection vehicles which are widely used in the U.S. to measure retro-reflectivity levels during the daytime. This method can also minimize the challenges associated with inspecting overhead and difficult-to-reach ground-mounted signs.

About the Authors

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