ATINER's Conference Paper Proceedings Series
CIV2019-0138
Athens, 8 August 2019

A Vision-Based Method for Determining Degradation Level of a Road Marking

Kuo-Liang Lin and Jyh-Bin Suen

Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10683 Athens, Greece

ATINER's conference paper proceedings series are circulated to promote dialogue among academic scholars. All papers of this series have been blind reviewed and accepted for presentation at one of ATINER's annual conferences according to its acceptance policies (http://www.atiner.gr/acceptance).

ATINER's Conference Paper Proceedings Series
CIV2019-0138
Athens, 8 August 2019
ISSN: 2529-167X

Kuo-Liang Lin, Professor and Head, Department of Civil and Ecological Engineering, I-Shou University, Taiwan
Jyh-Bin Suen, Department of Digital Media Design, I-Shou University, Taiwan

A Vision-Based Method for Determining Degradation Level of a Road Marking

ABSTRACT

Road marking provides informative guidance for vehicle drivers and is a critical aid in maintaining road safety. Quality of road marking plays an important role in providing satisfactory functional condition of a road pavement. Pavement marking degrades as traffic goes, so quality inspection must be made regularly to ensure its serviceability. This paper proposes a quality inspection method for determining the level of degradation of a road marking utilizing machine vision technologies. The method is executed by a determination unit including a processor, a database of reference image, and an image- capturing device having a plurality of shutter speeds. An analytical algorithm is incorporated with the system so that the method can adapt to different illumination situations. After receiving examined road marking image, the analytical algorithm generates an image according to the selected shutter speed by assessing surrounding illumination level, then retrieves one of the reference data from the database that has the same shutter speed as the examined road marking, and next performs a difference determination procedure between the retrieved reference data and the examined data. Finally, the processor outputs a normalized result of the level of degradation of the examined road marking. As such, accurate determination on the level of degradation of the examined road marking can be achieved. The proposed method is demonstrated through several real cases to show how it works. In the end, a test comparing the inspection results between the proposed method and expert inspection is conducted to prove the accountability of the proposed method.

Keywords: computer vision, road marking, quality inspection, analytical algorithm, pavement maintenance.

Acknowledgments: The research team wants to thank Ministry of Science and Technology (Taiwan) for its generous financial funding to this research project.

Introduction

Road marking provides informative guidance for vehicle drivers and is a critical aid in maintaining road safety. Quality of road marking plays an important role in providing satisfactory functional condition of a road pavement. Pavement marking degrades as traffic goes, so quality inspection must be made regularly to ensure its serviceability.

Field inspection is usually made by properly trained personnel. Eventually all pavement markings degrade to reach the end of their useful service life. End-of-service-life inspection is used to determine whether markings must be restriped. The end-of-service life of a pavement marking may be defined as the point when the marking has deteriorated so that it no longer provides suitable visibility to drivers. According to Tex-828-B “Determining Functional Characteristics of Pavement Markings” by Texas Department of Transportation (TxDOT), three methods are used for determining the end-of-service life of pavement markings:

1. subjective daytime visual evaluation: This evaluation aims at determining the maximum daytime visibility distance of existing markings when viewed from a vehicle. This evaluation should occur at least once per year.
2. subjective nighttime visual evaluation: This evaluation aims at determining the maximum nighttime visibility distance of existing markings when viewed from a vehicle with the headlamps on. Same as daytime evaluation, nighttime inspection should occur at least once per year.
3. retroreflectivity evaluation: This evaluation is performed by taking a series of retroreflectivity measurements and the results are compared with guidelines for minimum in-service retroreflectivity. Based on the FHWA draft recommendations, TxDOT has suggested that average pavement marking retroreflectivity values of 80-100 mcd/m2/lux measured. The minimum value is 30 meter geometry retroreflectomete which indicates that markings should be considered for replacement.

Among the three major evaluation methods, reflectivity is measured with a scientific device which is considered a reliable process. On the other hand, daytime and nighttime visual evaluation primarily rely on experts’ vision which is a subjective inspection. It is arguable that pavement markings easily visible to someone with good eyes could be invisible to others with poor sightedness. Visibility to some expert should not be considered the perfect inspection method.

To improve current road marking inspection practice, this study proposes a computer-vision based method for determining degrading level of a road marking, instead of the visibility level. The degradation level is defined as the difference between its existing state and its original condition, and the degradation level of a road marking is evaluated by the computer instead of an expert, so that a more reliable inspection can be assured.

Machine vision technology is the use of optical non-contact sensing to acquire and interpret images automatically, by obtaining information and/or control machines or processes. Machine vision has been successfully applied to several industrial inspection problems, allowing faster and more accurate quality control. The manufacturing industry uses machine vision in detecting defects and controlling and calibrating its manufacturing process, which results in better products quality with lower manufacturing and inspection cost. Semiconductor manufacturing is one of the major industries that use machine vision optimally and profoundly. Machine vision-based inspection systems were applied in various stages of IC manufacturing for many years [1, 2].

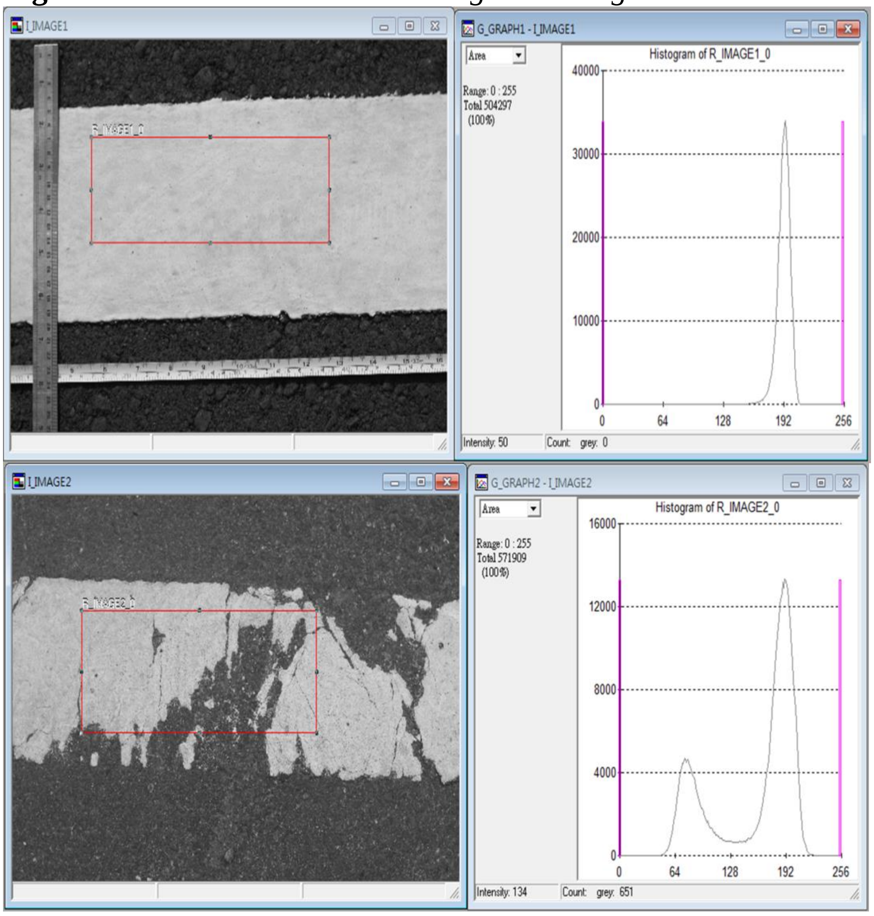
In construction industry, machine vision was also applied widely in several fields. In construction automation, machine vision has been an important part integrated in automated pavement crack sealing [3, 4], bridge inspection [5], concrete surface grinding [6], and sewer pipe and tunnel inspection [7]. Other researchers used machine vision technologies for automated construction progress monitoring [8, 9]. Machine vision and related video technologies are also gaining increasing popularity in intelligent transportation systems (ITS) applications. For example, Rabie et al. used a Mobile Active-Vision Traffic Surveillance System for incident detection and management [10]. In geotechnical engineering, Suaw et al. used machine vision for debris-flow monitoring [11].

Comparison between Good and Bad Markings

This study uses computer vision technologies to examine degradation level of a road marking when it is used for a certain period of time. In our method, an image capturing device is used to capture existing image of a road marking, and then it is compared with a reference image which represents its original state. The deviation between the two is compared to determine its degradation level so that the decision whether the road marking is in a condition that needs renovation could be made.

To use machine vision for automatic determination of road marking degradation level, a mechanism to differentiate between a good marking and a bad one must first be determined. Figure 1 shows the comparison between a good marking and a degraded one. It appears that a degraded marking has considerable amount of paints faded away so that its gray scale image histogram has two peaks. It can be concluded that the more the gray scale deviates from its original state, the poorer the quality is. This study hence uses gray scale deviation as the degradation level indicator for whether the marking is still in good condition or not.

Figure 1. *A Good Pavement Marking and a Degraded One*



Adjustment to Ambient Lighting

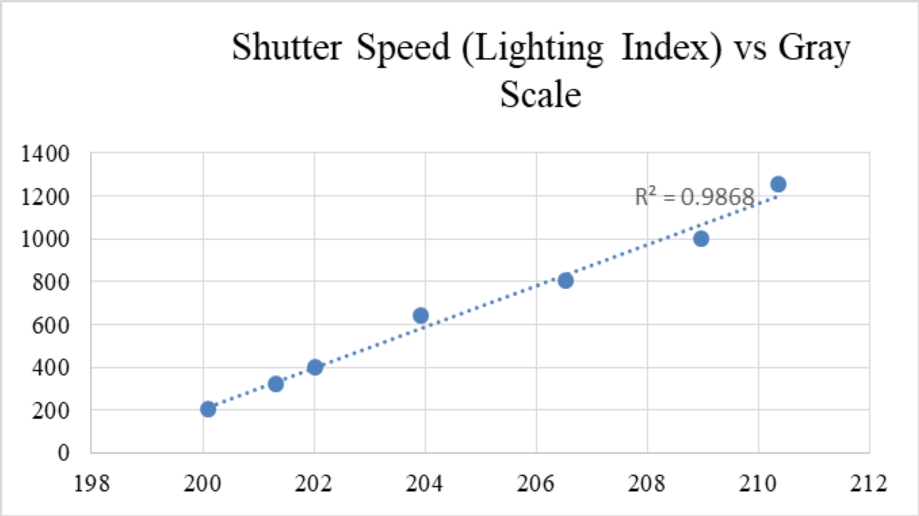
To determine degradation level, gray scale image histogram of a road marking is used for comparing the difference between existing state of the marking and the reference image. However, gray scale value at a pixel in a captured image can vary due to different ambient lighting conditions. For example, the image captured in a sunny day would look brighter than the one captured in a cloudy day, and the gray scale values would appear higher. To resolve the ambient lighting problem, shutter speed of the image being captured is used to justify for the gray scale value variation.

We take pictures of a good marking at different lighting conditions and record average gray scale of each picture (as shown in Table 1). We find that the gray scale is positively correlated to the reciprocal of shutter speed with a coefficient of determination (R^2) of 0.9868. Therefore, we can choose the correct reference gray scale level based on the shutter speed at shooting to justify the effects of ambient lighting.

Table 1. *Gray Scale at Different Lighting*

Shutter Speed	1/1250	1/1000	1/800	1/640	1/400	1/320	1/200
Gray Scale	210.38	208.98	206.54	203.93	202.04	201.32	200.11
Ambient Lighting	Lighter <-->Darker						

Figure 2. *Lighting Index vs Gray Scale*



System Implementation

The steps to evaluate road marking degradation level with computer vision are described as follows:

(1) Capture Road marking image
We use an entry level Canon SLR with 50mm standard lens to capture exiting road marking images. The camera is mounted on a tripod to minimize image blurring.
(2) Prepare image through preprocessing

We use two commercialized image processing software packages (Photoshop® and Inspector ®) to prepare the captured images for further analysis. Distortion calibration, Gray-scale image transform, image enhancement, and noise reduction are the procedures required for this preparation. These procedures are described as follows:

(a) Calibrate image distortion: distortion is the effect when a straight line running near one of the edges bows inward (pincushion) or outward (barrel). All current camera lenses have some level of distortion, especially super-zooms. To allow accurate image presentation, the captured image underwent a distortion correction process from Photoshop® to restore the image to a true horizontal and vertical alignment.

(b) Gray-scale image transform: Color images were transformed into gray scale by using Photoshop® because later analysis required only gray-scale images.

(c) Image enhancement and noise reduction: Image processing techniques, such as median filtering, contrasting, brightness, and edge sharpening by Inspector ® were applied to enhance the quality of interested points and to remove noise.

(3) Calculate degradation level and final score

Gray scale deviation is defined as the difference between the existing gray scale level and the reference gray scale and it is calculated at each pixel points. Average deviation is computed to represent the overall degradation level. A MATLAB program is implemented for this calculation procedure.

D_i (deviation at pixel *i*) = reference gray scale value – gray scale of pixel *i*
D_{ave} (average deviation) = $\sum_{i=1}^{n} D_i/n$,

where *n* is the total number of pixels at the inspected marking area.

When the deviation is negative, it means that the marking condition is better than the reference condition, and the deviation is compulsorily set at 0, meaning no degradation is found` at the pixel.

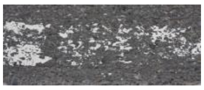
Final Score = 100 – D_{ave}

A final score is assessed to each image representing its marking condition which can range from 0 (complete ripped-off marking) to 100 (perfect marking with no degradation at all).

Case Study

After the prototype system is implemented in the MATLAB, we take the program to field to see how it works. Thirty pavement markings with various conditions are collected and tested. We rank these markings from best to worst as shown in Figure 3. These tests convincing results with great deal of accuracy.

Case	Image	Shutter Speed	Reference Gray Scale	Average Deviation	Score
1		1/500	203	6	94
2		1/1600	214	7	93
3		1/1600	214	11	89
4		1/1000	208	13	87
5		1/500	203	13	87
6		1/400	202	15	85
7		1/400	202	19	81
8		1/1000	208	22	78
9		1/800	206	24	76
10		1/1000	208	24	76
11		1/1000	208	27	73
12		1/800	206	28	72
13		1/1250	210.5	28	72
14		1/500	203	33	67
15		1/1600	214	35	65
16		1/500	203	37	63
17		1/800	206	38	62

18		1/800	206	38	62
19		1/1250	210.5	38	62
20		1/400	202	42	58
21		1/1250	210.5	42	58
22		1/800	206	43	57
23		1/500	203	44	56
24		1/500	203	48	52
25		1/800	206	48	52
26		1/1000	208	54	46
27		1/1000	208	57	43
28		1/500	203	64	36
29		1/1000	208	66	34
30		1/1000	208	88	12

Conclusions

This paper presents a machine vision-based road marking inspection tool for determining degradation level of a road marking. The tool makes use of various image processing technologies for image enhancement, noise reduction, and edge detection. The authors successfully developed a quantitative mechanism for measuring road marking degradation level by using average gray scale deviation and an ambient lighting justifying mechanism. The system has been tested with real cases and appears to deliver reasonable and accountable results. We believe that application of the proposed mechanism can effectively increase the productivity and accuracy of road marking inspection.

Currently the prototype system has been completed with commercial software packages (Photoshop® and Inspector ®) for image enhancement and noise reduction. The offering capabilities of these packages provide adequate preprocessing flexibility. However, if a commercialized version of our system is to be carried out, required image enhancement and noise reduction capabilities as well as a dedicated camera with accurate shutter speed recorder should be integrated to the proposed degradation calculation algorithm and scoring mechanism to ensure seamless automation.

Through the examination of various real cases, we have disclosed the fact that even an expert may have trouble making up his mind when the degradation level is at margin if he is not provided with better measurement tools. The computer scoring system described in this paper might just be the perfect tool to improve his decision-making when serviceability aspect of road marking is at hand.

References

[1] Kimura I. In-process inspection of IC under packaging by single laser beam and photosensors. Sensors and Actuators. 1990; 5: A21-A23.
[2] Wang MJ, Wu WY, Liu CJ. IC codes inspection by similarity matching technique. International Journal of Industrial Engineering- Applications and Practice, 1997; Vol 4: 34-41.
[3] Haas CT.Evolution of an automated crack sealer: a study in construction technology development. Automation in Construction. 1996 Jan; 4(4): 293-305.
[4] Kim YS, Yoo HS, Lee JH, Han SW. Chronological development history of *X–Y* table based pavement crack sealers and research findings for practical use in the field. Automation in Construction, 2009 Aug; 18(5): 513-524.
[5] Oh JK, Jang G, Oh S, Lee JH, Yi BJ, Moon YS., Lee JS, Choi Y. Bridge inspection robot system with machine vision. Automation in Construction. 2009 Nov;18(7): 929-941.
[6] Moon S, Yang B, Kim J, Seo J. Effectiveness of remote control for a concrete surface grinding machine. Automation in Construction. 2010 Oct; 19(6): 734-741.
[7] Victores JG, Martínez S, Jardón A, Balaguer C. Robot-aided tunnel inspection and maintenance system byvision and proximity sensor integration. Automation in Construction.2011 Aug; 20(5): 629-636.
[8] Roh S, Aziz Z, Peña-Mora F. An object-based 3D walk-through model for interior construction progress monitoring. Automation in Construction. 2011 Jan; 20(1): 66-75.
[9] Zhang X, Bakis N, Lukins TC, Ibrahim YM, Wu S, Kagioglou M, Aouad G, Kaka AP, Trucco E. Automating progress measurement of construction projects. Automation in Construction, 2009 May; 18(3): 294-301.
[10] Rabie T, Abdulhai B, Shalaby A. Mobile Active-Vision Traffic Surveillance System for Urban Networks. Computer-Aided Civil and Infrastructure Engineering. 2005; Vol. 20: 231-241.
[11] Suaw H, Yamakoshi T, Sato K. Relationship between debris-flow discharge and ground vibration. Proceedings of the second International Conference on Debris-flow Hazards Mitigation: Mechanics, Prediction and Assessment. 2000 Aug 16-18; 311-318; Taipei, Taiwan.