Engineering and Technology Journal
Journal homepage: engtechjournal.org

Utilizing Artificial Intelligence to Collect Pavement Surface Condition Data

Hasan H. Joni [a], Imzahim A. Alwan [b*], Ghazwan A. Naji [c]

[a] Department of Civil Engineering, University of Technology, Baghdad, Iraq. 40317@uotechnology.edu.iq

[b] Department of Civil Engineering, University of Technology, Baghdad, Iraq. 40164@uotechnology.edu.iq

[c] Department of Civil Engineering, University of Technology, Baghdad, Iraq. 41233@student.uotechnology.edu.iq

*Corresponding author.

Submitted: 24/04/2019 Accepted: 16/06/2019 Published: 25/1/2020

K E Y W O R D S

Pavement surface condition, High speed camera, Artificial intelligence.

A B S T R A C T

Nowadays, data collection mechanisms are developed from ancient methods, including visual surveying to modern methods, which rely on digital imaging devices and laser scanning. This is expensive, delay of the pavement maintenance management and consuming of time. In this paper, a robust method proposed for automotive detection of linear distresses from real life movies of Iraqi highways. In the suggested method, common types of cracks, potholes and raveling are distinguished and collected automatically using high speed imaging techniques. The data extracted using the suggested method can be used for selecting priority of management maintenance of country roads and making decisions for treatment or rehabilitation.

How to cite this article: H. H. Joni, I. A. Alwan and Gh. A. Naji "Utilizing Artificial Intelligence to Collect Pavement Surface Condition Data," Engineering and Technology Journal, Vol. 38, Part A, No. 1, pp. 74-82, 2020.

DOI: https://doi.org/10.30684/etj.v38i1A.251

1. Introduction

In a pavement maintenance management system, the evaluation of pavement surface failure is one of the serious tasks for improving maintenance and rehabilitation strategies. Cracks, potholes, and raveling are some types of pavement surface failures whose evaluation is essential in any roads [1]. In Iraq, Most of the institutions responsible for the management, assessment, and maintenance of roads suffer from a significant lack of equipment for collecting road data. Therefore, this study is an attempt to use simple and new equipment using artificial intelligence applications to collect the maximum amount of information with high accuracy to improve road evaluation and maintenance procedures.

Priority ranking, as used in PMS, is a process used to status the road sections in order of emergency case for maintenance or rehabilitation. The prioritization process is the foremost step of pavement management system before the decision makes the final decision on the execution of treatment plans. The priority ranking process depends on various factors like (1) traffic volume, (2) pavement condition, (3) desired performance standards, (4) environmental effects, and (5) budgetary constraints. As the decision to carry out maintenance depends on two parts, the highest percentage of damage to each section of the road as well as the level of financial funding for maintenance or rehabilitation. In the present study, an effort has been made to broadly classify various approaches/methods for prioritization of pavement maintenance and the applications of these models made by different researchers at the global level.

2. The Objective of the Study

The main objective of this study is to develop new automated surface linear distress measurement tools and algorithms to data collection of images with high precision and resolution.

3. Related Researches

Various sensors have been used for Automated Image Collection Systems by highway agencies. The senor types of the AICS's fall into five categories: photographing, videotaping, digitizing through visual ray area scan camera, digitizing through visual ray line scan camera, and digitizing through laser line scan camera [2].

The AICS's adopting the different types of sensors are discussed below.

The PASCO Roadrecon system is the first AICS used to capture pavement images [3]. This system consists of a 35-mm camera mounted on cantilever structure at the top of a bus and produces a continuous filmstrip recording of the pavement surface. The images are taken at night with an artificial light system to control its illumination condition. The vehicle can be operated at speeds up to 50 mph, and an image covers an area of 16 ft. in width and 50 ft. in length. Manual interpretation of the images is required to evaluate pavement distress.

In the repudiate 1980s, the Japanese group Komatsu manner an automotive road failure survey system [4], including a survey vehicle and data analysis system on the monitor to simultaneously detect and measure cracks, rutting, and longitudinal profile of the road. The maximum resolution of [2048 x 2048] is acquired at a speed of 10 km. Komatsu system worked just at night to take control of the intensity of lighting. However, the Komatsu system does not determine the distress type and requires sophisticated hardware technologies.

Earth Technology Corporation developed an AICS called Pavement Condition Evaluation Services (PCES) system from the late 1980s to the early 1990s [5]. The automated system created by PCES first adopted 512-pixel resolution line scan cameras to collect pavement data. The images captured by this system covered pavement of 8 ft in width. The PCES system was intended to work at daytime with an artificial light system and collect images at normal highway speeds. The PCES system used a digital signal processing board with built-in imaging algorithms to analyze its images in real-time.

Roadware Corporation developed an AICS called Automatic Road Analyzer (ARAN). An ARAN supplies data to support better management decisions by accumulating consistent, precision, cost-effectively in addition to data quickly. It can measure more than 15 of various data items in each pass, with very high accuracy. This information can be collected continuously, at traffic speeds from 22 kmph up to highway speeds. Roadware Corporation also developed an AIAS called "WiseCrax" to analyze pavement images collected by the ARAN automatically. The analysis requires a high degree of human intervention after collecting images. It was reported that the analysis rate was approximately 2-3 mph.

The Road Assessment Vehicle (RAV) [6] was developed by W.D.M. Limited in 2000. This system is done by connecting the cameras and sensors to a vehicle and setting its speed by 100 km / h where the recorded video worked in slow motion and monitored visually to know the distresses areas. Then it was developed by adding the possibility of categories of images containing cracks of all kinds. This system is one of the systems adopted in the collection of data on pavement surfaces in the United Kingdom. Currently, there are two new systems measures specified by the [SCANNER research] in the UK that have been inserted into the output results of the RAVs.

CSIRO developed an AICS system called RoadCrack [7]. The system includes cameras in addition to image analysis and processing equipment that discovers categories of cracking in the surface road.

Unlike other systems, special cameras are fixed in the lower part of the vehicle and a video is recorded on the road, and then cut into frames to be analyzed.
Researchers at the University of Texas at Austin developed an AICS system called TxDOT Pavement Survey Vehicle. The system consists of a high-speed frame grabber, computer, digital line scan camera, and image analysis software called “VCrack” [8]. The system could work at speeds up to 70mph and records images of 2048 x 512 pixels covering an area of 10 feet in width by 3 feet in length on the pavement. The system first used natural lighting and later adopted LED linear lighting unit for consistent illumination and operation at nighttime. [9] This system can classify longitudinal crack, transversal crack, block and alligator cracks for asphalt pavement, and longitudinal crack, transversal crack and punch outs for concrete pavement.
Swedish PAVUE data collection equipment consists of four cameras mounted at the rear of the vehicle, a proprietary lighting system, in addition to four videocassette recorders [10]. Image analysis software of the PAVUE can generate crack maps. It is synchronized with distance data. After the videos are filmed by the cameras installed on the vehicle, the video is then analyzed and processed through a complex interface attached to the vehicle itself. The analysis parameters have to be manually selected to extract crack data without excessive noises from the images.
Researchers at the University of Arkansas developed an AICS system called [Digital Highway Data Vehicle (DHDV)]. This system consists of a video camera with four specialty light mounted at the rear of the vehicle. The system can acquire images with 1300 × 1024 pixel resolution at the maximum frame rate of 15 per second while traveling at speeds up to 60 mph [11]. The camera and strobe lights are synchronized to obtain high-quality images at high shutter speed [12].

4. Experimental Works and Results

I. High-speed camera

The use of this type of camera is significant to increase the speed of the field survey and to avoid the problems of vibration resulting from the engine of the vehicle carrying the camera or the presence of defects in the pavement, which causes a vibration of the vehicle and thus shaking the camera. If using a camera at a speed of 240 FPS, it can survey road, and the speed of the vehicle carrying the camera is 80 km / h. Figure 1 illustrated this type of camera.
Figure 2 illustrated the shape of movie in one second of many different settings:
Installing one → capturing of 10 frames in each second.
Installing two → capturing of 15 frames in each second.
Installing three → capturing of 30 frames in each second.
Installing four → capturing of 45 frames in each second.
Installing five → capturing of 60 frames in each second.
In Figure 3 illustrated, the influence of frame rate on moving in the movie depend on the number of FPS.

Figure 1: High-speed camera (HSC 240 FPS)

Connectivity	Wifi, HDMI
Zoom	4K Video
Resolution	12 MP Resolution
Resolution Available	3840x2160 Pixels (2160p),1920x1080 Pixels (1080p HD),1280x720 Pixels (720p HD)
Fps	2160p Frame rate : 601080p Frame rate : 24, 25, 30, 60720p Frame rate : 24, 25, 30, 60

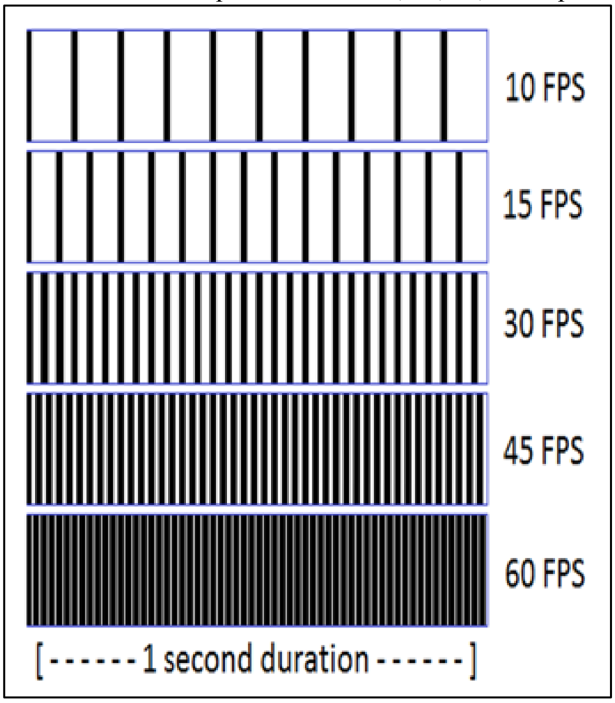

Figure 2: Difference between many types of movies in number of frames per second (FPS) [13]

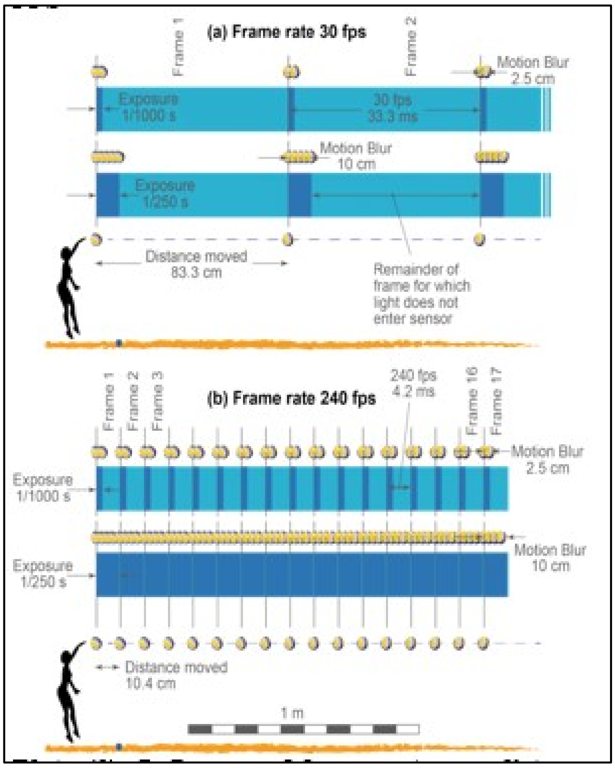

Figure 3: Influence of frame rate per distance [12]

II. Road surveying

Depending on the specifications of the camera used in the video recording of the field survey of the road. The dimensions assigned to the camera site were selected for the pavement face as appear in the Figure 4. From the below table that the field of view (FOV) of the camera with the current setting are

a. Horizontal field of view (HFOV) = 122.6°

b. Vertical field of view (VFOV) = 94.4°

c. Diagonal field of view (DFOV) 149.2°

Mode	Vertical FOV	Horizontal FOV	Diagonal FOV
4x3 Wide (Zoom = 0%)	94.4°	122.6°	149.2°
4x3 Wide (Zoom = 100%)	49.1°	64.6°	79.7°
4x3 Linear (Zoom = 0%) EIS OFF	70.0°	86.0°	98.7°
4x3 Linear (Zoom = 0%) EIS ON	71.0°	86.7°	100.0°
4x3 Linear (Zoom = 100%) EIS OFF	38.7°	50.0°	60.5°
4x3 Linear (Zoom = 100%) EIS ON	39.4°	51.0°	61.6°
16x9 Wide (Zoom = 0%)	69.5°	118.2°	133.6°
16x9 Wide (Zoom = 100%)	35.7°	62.2°	70.8°
16x9 Linear (Zoom = 0%) EIS OFF	55.2°	85.8°	93.7°
16x9 Linear (Zoom = 0%) EIS ON	56.7°	87.6°	95.5°
16x9 Linear (Zoom = 100%) EIS OFF	29.4°	50.0°	56.3°

Figure 4: The specifications of camera

Figure 5 describe the location of horizontal and vertical FOV. The default width of road lane is 3.5 m Therefore the height of camera from the face of pavement (H)

H= $\frac{3.5m}{\tan(0.5HFOV)}$ = 0.96 m the minimum distance =1m

Other dimension of frame (Y)

Y = tan *(0.5VFOV)* 0.96*2*= 2.07m

As shows in the next Figures. Figures 6, 7, 8, 9, 10 and 11 illustrated the conditions and specifications of the experimental works in the field of surveying.

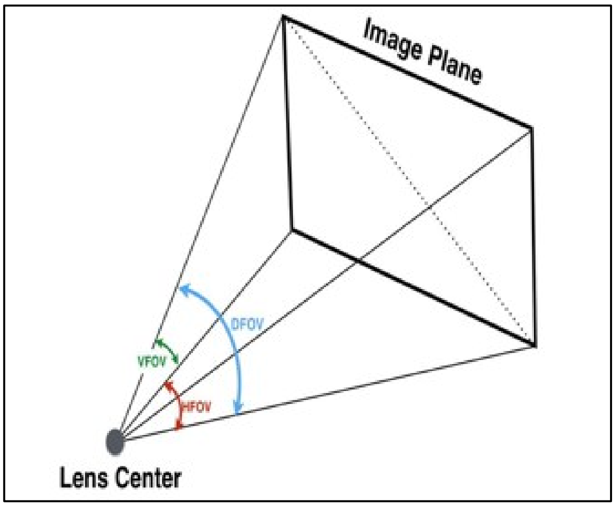

Figure 5: The VFOV, HFOV and DFOV

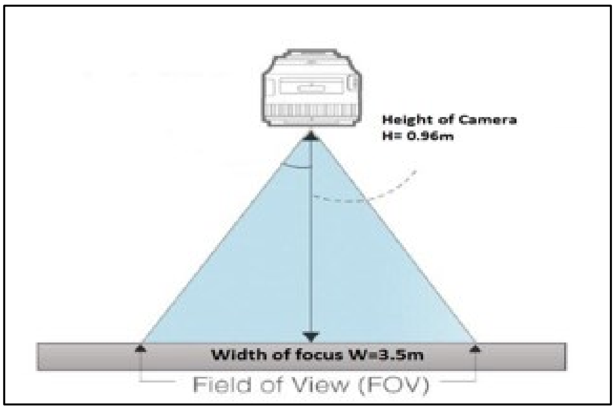

Figure 6: The height of camera from the face of pavement

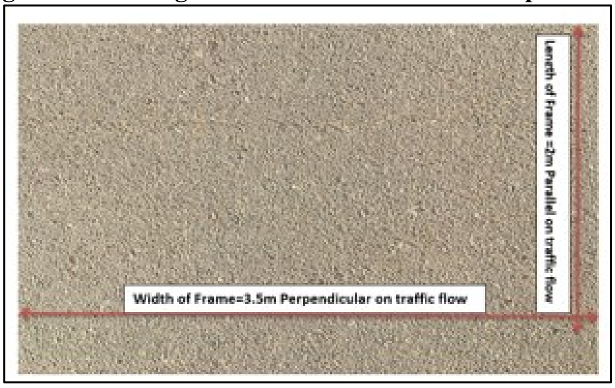

Figure 7: The dimensions of frame

Figure 8: The stand of camera on the vehicle

Figure 9: The height of camera from the face of pavement (96cm)

Figure 10: The length of camera stand

Figure 11: The cruise control of vehicle speed on 80kmph

III. Selection of frames

As mentioned, the speed of the camera previously is 240 fps, which means that if the length of the movie is 100sec, that means have 24000 frames, and if the speed of the vehicle that carried the camera is 80 kmph, the length of segment 2200m.
Speed of vehicle =80kmph $\longrightarrow$ 22m/sec
Speed of camera =240 fps
That means 240 fps for 22m
The length of the frame is 2.07 m
Therefore, the number of frames for 22m is approximately 11 frame
$\frac{1\ sec}{11\ frame}$
Need to analysis frame from every 22 frames captured.

IV. Time of road surveying

Because the image processing of the frames depends on the intensity of the reflected light from the pavement surfaces, the surveying time should be determined based on the time taken to capture the images on which the code was trained. In addition, an algorithm has been added to the code that restricts the optical intensity within a specific range as preliminary processing of images to illuminate the image.
It is not possible to determine the fixed value of the intensity of light, because it is affected by many circumstances which be mentioned as most important.
The time in the day.
The day in the season.
Effect of weather conditions.
The presence of dust on the surface of the pavement.
The presence of engine oil or fuel on the surface of pavement.

The only source of light is the sun, so it is not possible to fully control its intensity. Therefore, intensity variation has the most significant impact on the analysis and processing of the captured images and thus affects the accuracy of the determination.
As an attempt to obtain constant illumination intensity, the road survey was carried out in the evening, and a fixed intensity light was used.
The advantages of evening surveying are summarized in the next points.
No influence for variation of sun light.
No influence on weather conditions.
Have a biggest period for surveying than the day surveying.
A fixed amount of light intensity is used and installed with the camera.
The disadvantage of evening surveying is the influence of other vehicle lights on the intensity of surveying.

5. Results

1. Advances and disadvances of this type of data collection

As with most artificial intelligence applications, there are many benefits because of its use.
Most of the advantages of automotive data collection are below.
High speed in completing surveys.
Works with one resolution.
No need for committees.
Easy to operate, application and work.
Real-time obtaining results.
The disadvantage of automotive data collection is as below.
Because of using a single camera, therefore the results represent the 2D pavement distress.

II. Time of surveying

There is a huge difference in the time needed to survey each method where the Automative data collection method requires less time than the method of visual and a ratio of (89% to 92%) for the examination of ten sections of pavement.

6. Conclusions

The automatic method in the detection of distresses and data collection of roads is very rare in Iraq, and researches are almost none. They do not exceed the stage of theoretical researches in some countries of the world. With simple equipment and tools, it is possible to collect information (images of deference pavement failures) of a road segment with the right level of precision. In addition to the consumption, time is less than the manual vision by (89%- 92%).

References

[1] MORTH Ministry of road transport and highways/ Indian roads congress, on behalf of the Govt. of India.

[2] K. H. McGhee, “Automated pavement distress collection techniques,” NCHRP Synthesis 334. National Cooperative Highway Research Program,Transportation Research Board, Washington D.C. 2004.

[3] R. C. G. Haas, W. R. Hudson and J. P. Zaniewski ,“Modern pavement management,” Krieger Publishing Company, Malabar, Florida, 1994.

[4] T. Fukuhara, K. Terada, M. Nagao, A. Kasahara and S. Ichihashi. “Automatic pavement distress survey system,” Journal of Transportation Engineering, Vol. 116, No. 3, pp. 280-286, May/June 1990.

[5] K. C. P. Wang, “Design and implementation of automated systems for pavement surface distress survey,” ASCE Journal of Infrastructure Systems, Vol.6, No1, pp.24-32, 2000.

[6] WDM.http://www.wdm.co.uk/surveying/4-surveying/5-rav-scanner-surveys.Accessed February 1, 2011.

[7] CSIRO. http://www.csiro.au/solutions/RoadCrack.html Accessed February 1 2011.

[8] Y. Huang and B. Xu, “Automatic inspection of pavement cracking distress,” FHWA/TX-06/5-4975-01-1, Texas Department of Transportation, Austin, Texas, 2006.

[9] B. Xu, “Linear lighting system for automated pavement distress measurement,” FHWA/TX-06/0-4958-1, Texas Department of Transportation, Austin, Texas, 2006.

[10] M. Monti. “Large-area laser scanner with holographic detector optics for real-time recognition of cracks in road surfaces,” Optical Engineering, Vol. 34, No. 7, pp 2017-2023, July 1995.

[11] K. C. P. Wang and W. Gong, “Real-time automated survey system of pavement cracking in parallel environment,” Journal of Transportation Engineering, Vol. 11, No. 3, pp. 154-164, 2005.

[12] K. C. P. Wang and W. Tee, http://www.airporttech.tc.faa.gov/naptf/att07/2002%20TRACK%20P.pdf. Accessed February 12, 2011.