第 48 卷 第 7 期
2021 年 7 月

湖南大学学报（自然科学版）
Journal of Hunan University（Natural Sciences）

Vol. 48. No. 7.
July 2021

Open Access Article

Artificial Intelligence Application for Road Paving Assessment Using 360 Mobile Mapping

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Abstract: Maintaining and repairing the roads is crucial to prevent unwanted incidents from happening. Inspecting the paved roads is required to identify any maintenance needed and costs incurred. Usually, the roads, especially flexible paving will not last forever once built. As a result of cracking, cutting, and polishing, the road surface will wear out after being used constantly. The automation of road crack detection is highly essential due to reducing workload and maintenance costs. With modern technology, artificial intelligence applications can help create a better-quality environment. The visual condition of paved roads will be identified - by using artificial intelligence applications to improve road maintenance operations. In this study, the paved road images are acquired by using 360 camera mobile mapping system images (MMS) technology. This technology creates a 3D view and can provide vital information for many applications. Therefore, using artificial intelligence applications is a potential technology that could be applied for paved road management using 360 mobile imagery.

Keywords: mobile mapping, road, artificial intelligence.

使用 360 移动地图进行道路铺设评估的人工智能应用

摘要：维护和修理道路对于防止意外事故的发生至关重要。需要检查铺砌的道路，以确定需要的任何维护和产生的成本。通常，道路，尤其是柔性铺路，一旦建成，就不会永远持续下去。由于开裂、切割和抛光，路面在不断使用后会磨损。由于减少了工作量和维护成本，道路裂缝检测的自动化非常重要。借助现代技术，人工智能应用程序可以帮助创造更优质的环境。铺设道路的视觉状况将被识别 - 通过使用人工智能应用程序来改善道路维护操作。在这项研究中，铺砌道路图像是通过使用 360 相机移动测绘系统图像（彩信）技术获取的。该技术可创建 3D 视图，可为许多应用程序提供重要信息。因此，使用人工智能应用程序是一种潜在的技术，可以应用于使用 360 移动图像的铺砌道路管理。

关键词：移动地图、道路、人工智能。

Received: April 12, 2021 / Revised: May 13, 2021 / Accepted: June 17, 2021 / Published: July 31, 2021

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1. Introduction

Usually, paved road failure is defined by: the formation of potholes, ruts, cracks, localized depressions, settlements, etc. The main issues to be considered in the paved road shape are - climate, geometry, the position of the road, traffic, drainage, and more [1]. According to Nasradeen [2], Malaysia is one of the developing countries with a high level of road damage because of heavy trucks, which contribute to high levels of wear and tear of roads during particular periods. Unplanned road construction for heavy vehicles creates safety issues that require more expenditure to repair the damaged roads [3]. Paving plays an important role as a part of the road as it comes in direct contact with vehicles, this needs to be considered. The paved roads need to be planned, built, and maintained at an affordable price. The type of road users needs to be considered, as it will determine the road quality. This statement is supported by Marwan Hafez et al. [4], who mentioned that paving performance is the first strategy to maximize the overall maintenance budget. In addition, the paving surface pressure inspection is important before the maintenance plan to determine the paving condition operations [5]. This reduced costs significantly for road management, whose job is to maintain the budget and have optimum road conditions for its users [6].

It is important to prepare compliance between the value of the relevant features used in the design and subsequent quality control of each construction [7]. Indirectly, it allows the unification of the interests of road users with the needs of the environment protection because the development of road infrastructure relates to the natural environment [8]. Presently, the common practice to assess the road pavement condition and structure is physically measured by an engineer. Despite assistance from the global positioning system (GPS), conventional road assessment systems based on the pavement conditions require manpower to collect road data manually. However, because this method requires manpower and is thus time-consuming, many cities are neglected or rarely inspected [9]. Mobile Mapping System (MMS) is one of the latest technologies being used to obtain geospatial information. Alternatively, the proposed 360-degree camera mobile mapping technology provides significant data since this technology can also capture the conditions of the area surrounding the road.

This study uses the Artificial Intelligence (AI) applications to detect the road pavement condition using 360-degree mobile imagery. Using artificial intelligence applications is an effective approach to infrastructure management as computer software systems come closer to human intellectual [10]. This is achieved by studying how the human brain thinks, learns, works, and makes decision while trying to solve problems and subsequently using the result as a basis for developing smart software and systems [11]. Artificial intelligence has become an innovative application in various fields such as operations and supply chain management [12], water domain [13], construction [14] and transportation [15].

In order to improve the efficiency and sustainability of these innovative solutions, this application system becomes an advanced system capable of generating a new industrial paradigm, while reducing costs [16]. The present study uses the AI system to assess road conditions using the continuous image from 360-degree camera view technology.

2. Methodology

There are several factors to evaluate the road surface condition. In this study, the artificial intelligence application is used to assess the road pavement condition. In this study, the quantitative method was conducted in data acquisition and processing, using an experimental approach. It consists of four stages which include preliminary study, data acquisition, data processing, and result. The preliminary stage deals with determining the study area. Stage two addresses the data acquisition by using the 360-degree mobile mapping technology to capture the road structure. Stage three discusses on data processing of images derived from a 360-degree camera. Finally, stage four presents the result and discussions.

2.1. Study Area

The study area comprises the main road of Puncak Iskandar area, Perak, located at latitude 4º 22' 26.4" N and longitude 100º 57' 30.24" E (Fig. 1). This study area was chosen because of its relatively increasing development since 2012 was developed.

Fig. 1 Study area located at Puncak Iskandar, Seri Iskandar, Perak

Puncak Iskandar is among the attractive residential neighborhoods in Seri Iskandar. It is provided with a modern layout, housing design, and multiple types of residential to cater to the population's needs. The methodology process is organized into three stages: data acquisition, data processing, and results.

2.2. Data Acquisition

Several processes are involved in road pavement data acquisition, such as using the 360 mobile mapping system, smartphone, and dashcam (Fig. 2). In this study, the 360 mobile mapping is used to acquire road pavement conditions along the Puncak Iskandar main roads. This technology provides a high-resolution image and flexibility in displaying geospatial data. This technology is integrated with a high-precision Global Navigation Positioning Satellite System (GNSS), Inertial Measurement Units (IMU), and 360 camera, capable of capturing road condition information efficiently.

(a)

(b)

(c)

Fig. 2 Data acquisition of road pavement: (a) 360 mobile, (b) smartphone, (c) dashcam

Fig. 3 shows the process during data collection, (a) data acquisition for road pavement information along the main road, and (b) the end of collecting data using the 360 mobile process. The road conditions and all visible targets are collected into a data input file with x and y coordinates. All the road information captured by 360 cameras in continuous image or video was uploaded into the cloud artificial intelligence application.

(a)

(b)

Fig. 3 Process of collecting data (road data)

2.3. Data Processing

All the entire images captured from 360 mobile mapping were uploaded into the processing software. The raw data image from 360 mobile mapping is processed using CV image creator software. Fig. 4 shows the raw data image captured from the 360 camera. Several processes are required to conduct such as image masking, locate the GPS position for matching the GPS time and images before the final output of the movie is produced.

Fig. 4 Raw data from 360 Mobile Mapping System

2.4. Output from 360 Mobile Mapping System

All the entire raw images obtained from a 360-degree mobile camera were processed and produced video or movie data. This video data can display the

surrounding of the street road, such as front, back, right, and left view (Fig. 5).

Fig. 5 Video data from 360 Mobile Mapping System

3. Result and Discussion

The video generated from a 360-degree camera was uploaded into the artificial intelligence application, as shown in Fig. 6. The artificial intelligence application will identify information from the video accurately. This application detected the road pavement condition, such as cracked and broken roads, potholes. Hence, it is no longer necessary to be at the location to know the road pavement condition.

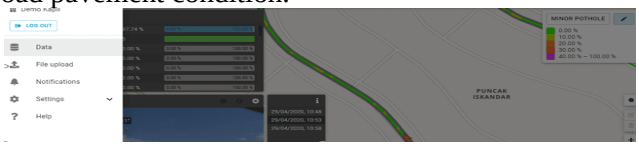

Fig. 6 Data uploading into cloud artificial intelligence application

In this study, road pavement conditions such as cracking and potholes were detected along the road of Taman Puncak Iskandar. This artificial intelligence application shows the condition results in the rating, which acts as an indicator to assess the road pavement condition. The assessing pavement depends on the observed and recording its condition on the surface. Fig. 7 illustrates the road pavement condition based on the pavement condition rating.

Fig. 7 The condition of payment road using artificial intelligence application

In this study, the pavement condition index was used to assess the condition of the road surface. This method was applied by several researchers such as [17], [18], [19], [20]. In this study, an attempt was made to assess a major road of Puncak Iskandar, the rating of artificial intelligence based on the pavement condition class is categorized into five color classes (Fig. 8a). The pavement condition class was established to describe the pavement condition using the calculation provided by the artificial intelligence application in percentage. A pavement condition has a range of 100%, represent a perfect pavement with no defect, while the pavement condition of 0% represents a very poor condition (Fig. 8b).

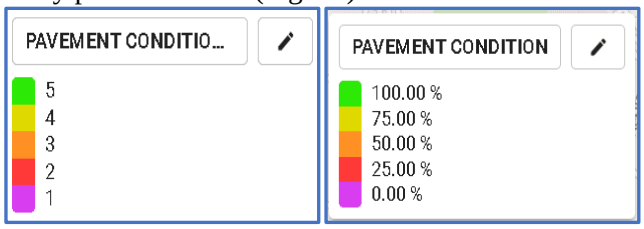

Fig. 8 (a) Pavement condition class and (b) distress percentage

Pavement criteria are the description of the road condition based on five pavement condition classes. The green color illustrates the very good pavement condition; the yellow color shows good pavement condition; the orange color represents a fair pavement condition; red represents poor road pavement condition; the magenta color represents a very poor pavement condition. Table 1 shows the pavement condition index used in the artificial intelligence application.

Table 1 Pavement condition index

Pavement Condition Class	Pavement Criteria
5	Very Good
4	Good
3	Fair Poor
2	Poor
1	Very Poor

The assessment method is based upon visual inspection recorded using a 360-degree mobile mapping system against pavement distress. In this study, the artificial intelligence application detected road pavement conditions such as cracking, potholes, edge, fretting, and bleeding, as shown in Fig. 9.

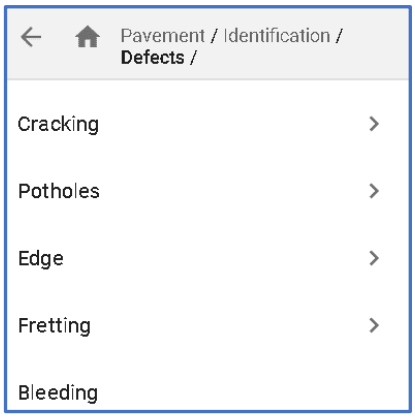

Fig. 9 Road pavement categories

The pavement condition result represents the defect percentage using artificial intelligence application: 65.30% of road pavement conditions covered all roads at Puncak Iskandar. This result indicates in class 4, which the road pavement is in good condition (Fig. 10).

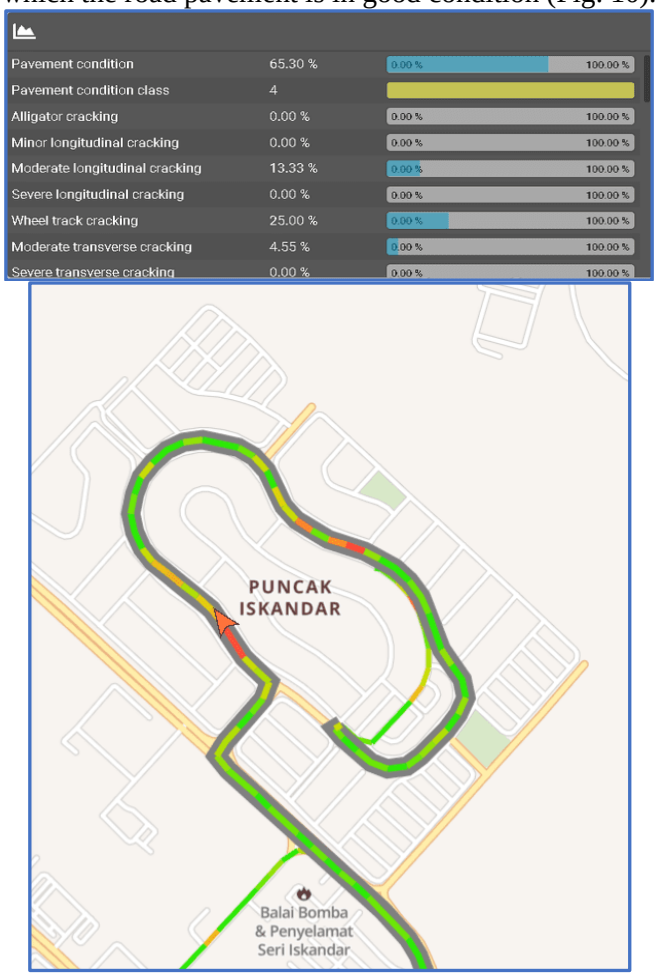

Fig. 10 The result of road pavement condition along the road of Puncak Iskandar

4. Hypothesis, Limitation, and Contributions

In this study, the great combination technology applied in 360-degree camera mobile mapping and artificial intelligence technology helps in effective road pavement condition management. Most of the time and

manpower is spent on field and office work when the pavement condition is collected using field survey methods. Moreover, challenges are also present in producing 3D modeling and limited processing for data migration to servers. The approach proposed in this paper helps pavement management systems to utilize the results of a non-destructive test to identify the pavement condition, rather than using a manual field survey and relying on visual inspection by the inspector.

This 3D mobile mapping system undoubtedly offers several advantages for many applications, especially those that pertain to road conditions, thereby providing a good accuracy of collected data and the ability to produce 3D models. However, this technology has limitations such as poor image quality due to interference from sunlight. In this situation, it is difficult to interpret the image with an optical camera. However, this technology strongly supports research and development in related fields by providing high-accuracy and real-time 3D road data with all data enhanced to meet user needs; moreover, it is feasible in a wide range of fields.

5. Conclusion

This artificial intelligence (AI) approach has the potential to be applied in practice as it is flexible and easy to customize; moreover, it offers the best pavement management for road networks in terms of budget and investment. Due to financial constraints, this application is made more economical by using the 360-degree camera mobile mapping for data collection, which facilitates working directly with 3D model data. This study was a success as the data obtained from the 360-degree camera mobile mapping helped capture the road pavement at Puncak Iskandar to assess the pavement condition using the application. The pavement condition rating is used to measure road conditions as well as to provide better means to monitor and coordinate construction projects. Thus, this paper proposed a new intelligent and automated process for the assessment of the condition of the roads at Puncak Iskandar. It presented a process for the estimation of the pavement conditions based on the pavement surface deflections.

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