ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/atlr

A Review on Road Distress Detection Methods

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Abstract

This paper reviews techniques on identification of road distress. The main key of this paper is to identify road distress and types of road distress. A literature reviews on the types of distress, detection techniques and methods used to identify road distress are presented. Hence, the advantages and disadvantages of current techniques such as laser scan, mobile mapping, stereo camera and uses of UAV used for road distress identification were to be out and gap in their techniques was identified. For many years, broad research has been conducted on road distress detection in order to maintain road surface to a high standard. Quick and accurate detection is required to maintain the road maintenance. A method using 2D images with supported 3D information is one of the best ways to get accurate results on identifying road distress. To keep up with the current technology, UAV with mounted camera is recommended to be used in order to provide quick and effective data capturing.

Keywords: road distress, detection, literature review, maintenance, UAV

Introduction

Roads in Malaysia can be classified into two categories, i) State roads and ii) Federal roads (JKR, 2009). Road maintenance is important in order to conserve the road in its original user safety, protect adjacent resources and constructed condition, and provide convenient and efficient travel along the road (Powell, 2016). Every year, government spent more than a billion in road maintenance and the amount keeps increasing year by year. Road distress is known as the visible imperfection on the surface of the road due to environmental, normal wear and overloading.

In order to make decision about the road maintenance planning, the road conditions need to be identified. Techniques to identify can be dividing into three

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
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ways which is manually, semi manual and automatically. As manual road inspection is reliant on the inspector and labour intensive, it is high in labour costs and prone to subjectivity. Latest developments in technologies offer many possibilities for automated and semi-automated detection along with classification of road distress. Therefore, automated and semi-automated distress road condition evaluating is used to define state of the road and distress detection. Afterward detection, automated data processing is used for reviewing and classifying.

An extensive studies has been conducted on automated condition assessment, it focus more on data processing instead of data collection equipment. This paper therefore aimed at the techniques used to identify road distress and classify types of road distress along with the current technologies.

This review paper defines techniques to identify road distress and types of road distress. Also, the road distress data collection devices are state here along with the road distresses these devices can capture. Finally, the recent limitations and achievements of road distress data collection are recap. Based on gap analysis the fields of study and research challenges which are open for subsequent research is determined.

Classification of Road Distress

Each of road distress can be classified based on shape, width, and depth. Distress identification should be detected as soon as possible before they develop into more serious problem. The road distresses were generally classified into three groups:

ISSN: 2622-5778 (online)
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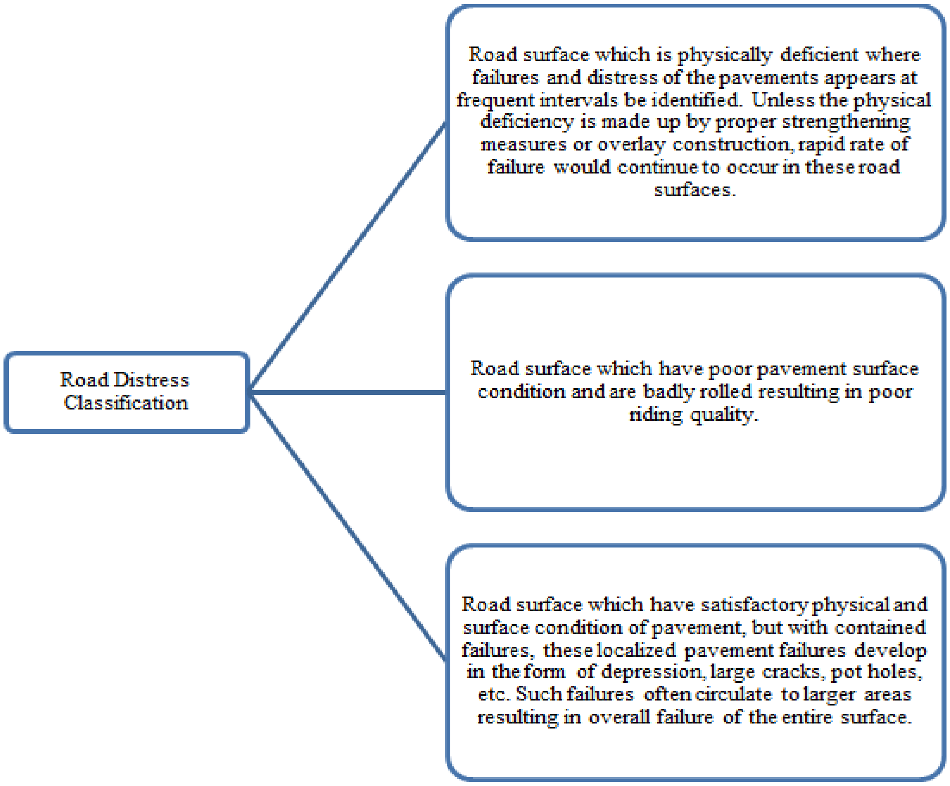

Figure 1: Road Distress Classification
Souces: (Rashid & Gupta, 2017)

Types of Distress

There are several types of road distress, such as potholes and patching, surface defects, surface deformation, cracking and miscellaneous distresses (Miller & Bellinger, 2003). Distressed road is a result of a combination of factors, rather than just one root cause.

Table 1 Types of Distress

Sources: National Corporate Highway Research Program

Types	Description	Example
Fatigue (Alligator) Cracking	A series of interconnected crack that caused by a fatigue failure of the hot mix asphalt surface under repeated traffic loading.	

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Block Cracking	A pattern of cracks that divide the pavement into approximately rectangular pieces or blocks	
Corrugation and shoving	Corrugation and shoving is a form of plastic movement typified by corrugation (ripples) or an abrupt shoving (wave) across the pavement surface.	
Potholes	Potholes can be described as small or bowl-shaped depressions in the pavement surface that penetrate all the way through the asphalt layer down to the base course.	
Raveling	Raveling is loss of bond between aggregate particles and the asphalt binder.	
Patching	Patching is an area of pavement that has been replaced with new material to repair the existing pavement. A patch is still considered a defect no matter how well it performs.	

Techniques in Road Distress Identification

Abundant research has been carried out in order to overcome the drawbacks of current methods of road distress detection. There are several techniques to identify road distress. It can be classified into 3 categories which are manual techniques, semi-automated techniques and automated techniques. Each of the techniques has their own advantages and disadvantages. There are several methods that perform real-time crack analysis, crack depth estimation, crack

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
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detection, crack sealing and crack classification. The methods are image classification, image processing, image analysis and hybrid technique.

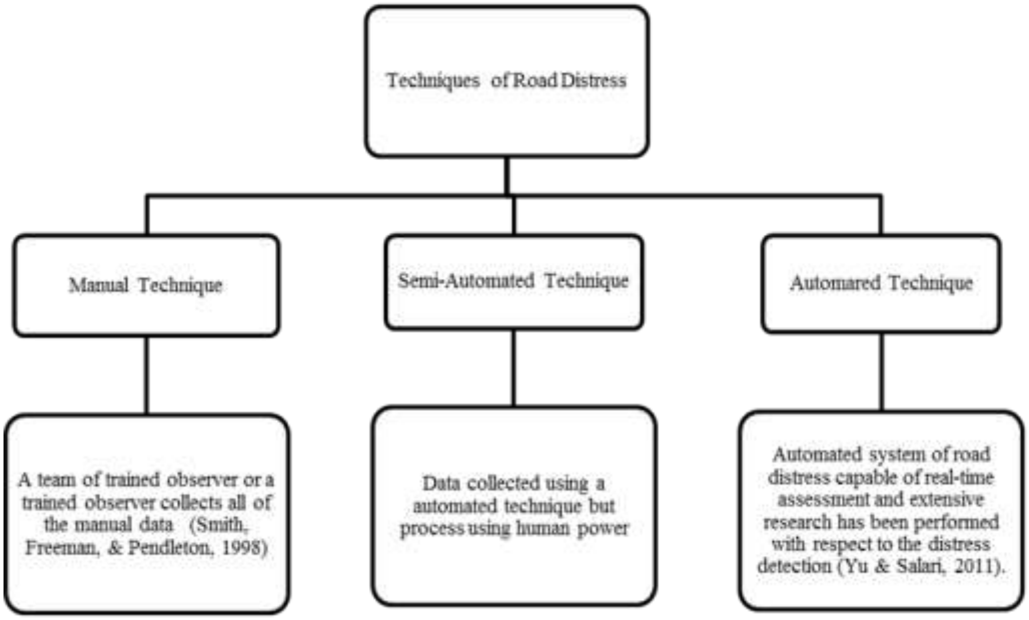

Figure 2: Techniques of Road Distress
Sources: Authors

Image Classification

Surface distress detection such as raveling, potholes, and patching in 2D images has been explored. Method that has been recognize for rating and evaluating the road distress is based on Support Vector Machine (SVM) classification (Christodoulou, 2016). The method is explore regarding SVM prepared and verified using feature vector based on image captured into a square blocks. Though, only patches can be detected using this method. Another method, cracks need an automated detection and classification, therefore efficient computer algorithms is required (Kapela, Sniatała, Błoch, & Atrem, 2015). Next, Lins and Givigi invented a vision-based system for automating the crack measurement process. The automatic crack detection and measurement were done by merging the RGB color model through particle filter, with camera installed in a robot. By using this method, it can approximate the number of pixels in a cross section and infer it as a crack's dimension output (Lins & Givigi, 2016). An image-based

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pothole detection system based on 2D images is creates. It is expected to help Intelligent Transportation System (ITS) service and road management system (Ryu, Kim, & Kim, 2015).

Image processing

Image processing is a technique that used to identify the classification of the road distress. Image preprocessing and representation for road distress analysis method likely based on neural network (Salari & Bao, 2010). Besides that, performing binary crack matric can be done by using local statistics after tiling the image to tag tiles. The matrix is the figured along the X and Y axes, to form two histogram vectors. The vector is then produced as multilayer perceptron (MLP) for classification (Lee, 2003). Besides that, another neural network for invariant technique and crack classification for feature extraction is has been describe (Hsu et al., 2001). Classification stage can be used since the moment invariant technique lowers a 2D image pattern into feature vectors. Another 2D pavement distress detection method based on neural network has been done by (Bao, 2010), the images is captured using camera installed in front of testing vehicle while driving around the city. The detected crack is assigned into a different group by using neural network based classifier. Moreover, a multiple high level context driven method to detect cracks with image processing is proposed by using physical context and structural or geometric context (Wang, Xiong, Finn, & Chaudhry, 2016). A sparse decomposition problem was invented to combine the context and it was the operated for automatic inspection of aircraft's subsurface and surface defects. This technique helps to lessen the false detection.

Image Analysis

Image analysis can done using several ways. Nonlinear image analysis using the data collection is defined as semi-automatic techniques is one of the ways (Battiato, Rizzo, Stanco, Cafiso, & Graziano, 2006). The image captured is corrected for the geometric distortions and then preprocessed. However, the system fails to classify even though the system analyses both crack and patch. It is because the system does not address the issues due to existence of shadow in the

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image. Another method based on block based analyses, by using Portuguese Distress Manual for classifying the detected crack (Oliveira & Correia, 2013). It needs large data set for system training and time consuming process. The next method based on vision-based system is used to analyses the road distress. Mohan and Poobal, gave a good review of vision-based road crack detection presenting that this field of automatic road analysis systems is essential and beneficial (Mohan & Poobal, 2017).

Hybrid Technique

Hybrid technique is a technique where the combination method of 2D and 3D techniques are combined together to attain a high detection accuracy (Garbowski & Gajewski, 2017; K. Wang, 2011). It is becoming trend in the current increasing of the road condition evaluation tools although the concept is already acknowledged for almost two decades (Laurent, Talbot, & Doucet, 1997). Laser Crack Measurement System (LCMS) is one of the techniques that use 2D images that known as intensity data and a 3D point cloud that known as range data to combined as 3D profile. These can automatically extract road distress such as alligator cracks, raveling, traverse, ruts, and longitudinal. Another method that use a mixed approach of road distress detection, due to fusion of 2D gray-scale image and 3D laser scanning methods, it produced a high detection accuracy (Huang, Liu, & Sun, 2013). Nevertheless, mixed approach required more advanced algorithm, instrumentation and combined the two different measurement fields to operate a complex data. An unmanned aerial vehicle (UAV) has been consumed for many purpose these day. Application of UAV mounted 2D camera for detection of road distress is created. The images is captured and then obtain the 3D information of the classified, and matched the feature points (Mathavan, Kamal, & Rahman, 2015; Zhang & Elaskher, 2012). A-contratrio modeling-based strategy for crack detection using UAV also presented (Aldea, 2015). The strategy presented by them reduces the need of defining various thresholds during crack segment detection and cause more convenient to reconnect each crack segment

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/atlr

despite different conditions of images and different structures degradation (Siriborvornratanakul, 2018).

Achievements and Challenges

Table 2 compares several of applicable technology techniques offered for detection of a number of normally found road distress with methods. The advantages and disadvantages for individually technology, as reviewed in the earlier section and its subsections, are assessed in order to create the recommendations given in Table 2. Table cell will leave blank whenever a specific technique unable operated to image as distress.

The comparison is took out by only counting the geometrical shapes of the several road distress and the effects of imaging these with the numerous method and technologies offered in this paper. Though numerous proper application methods can be obtained in practice, most of these methods cover exclusive laser-based techniques. However, low-cost but less precise techniques are rarely found. The most assuring technique looks like the use of the low-cost sonar sensors. The practical application, however, has not been combated enough and hence this technique might need some additional research to optimize for consistent detection of surface deformations.

Each of the technologies are expected to consume practically good image sensor, optical systems such as beam splitters, lens and mirrors, and illumination setups such as LEDs and lasers. There are several things that affect precision of data obtained from imaging system, which are the lighting used, quality of algorithm and quality of the optics.

For potholes, laser-based techniques provides a faster and accurate result, but since the limitation of laser-based technique has been discuss above another method has been found to replace laser based technique. Stereo imaging and UAV mounted with 2D camera gives a faster, thus more convenient, imaging procedure compare to laser-based technique. In contrast rutting is smaller depth compared to

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
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pothole. Therefore it offers better chance for stereo imaging and UAV to be used. Their smaller size and easy to carry also gives a better chance for imaging.

For cracks, mobile mapping technique is better than sensor technique as it requires fewer images. Longitudinal crack is the tedious crack to identify. Therefore, resolution of the camera give influence in identifies cracks. Hence, mobile mapping camera can be used to focus on a small area of the road. Width assessment can be covering proportional to the number of sensor. Besides that, raveling is a defects where aggregates are absent over a local road area. Therefore, suitable exposure in technique and method involved is important, in order to make the result in raveling defect is identify. A technique with high depth resolution will be need such as UAV with mounted camera, stereo camera and laser scanning.

Table 2 Potential Technology Techniques against Distresses Method

		Laser-Scan	Mobile Mapping	Stereo Camera	UAV with Mounted Camera
Types of Road Distress	Rutting	√		√	√
	Raveling		√	√	√
	Cracking	√			√
	Patching	√	√	√	
	Pothole	√	√	√	
Method Used	Image Processing		√	√	√
	Video Processing		√		√
	3D Information	√			√
	2D Image		√	√	√

** Paper/Journal involved use the technique and method.

ISSN: 2622-5778 (online)
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Future Directions

This paper presents a review on techniques of identify road distress that can be used to outline road distress. Its start by identifying different types and categories of road defects by considering their shape and characteristics. Also, a review of the methods that have been used for identify road distress is presented directing to evidence that only a few methods are frequently used by researchers and developers, laser scanning is most used by them. Since, uses of UAV have been widely used for other technology such as agriculture, surveying and military. However, UAV with mounted camera, with the 2D images and 3D information has rarely been studied directly, therefore more studies will be approach using this techniques and method to identify road distress.

Recommending other possible methods that can be used for several situations, it then continues to offer a technical overview for 2D and 3D imaging methods and techniques used. The paper also offers a selection procedure by considering the characteristic properties of another imaging techniques and the dimensional details of the distresses. This work recommends the possible acceptance of these technologies and targets them against each other. Therefore, it will be advantageous for others with non-imaging backgrounds in feasibility analyses, selection and deployment of different imaging methods.

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