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# REVIEW PAPER ON AUTOMATIC IMAGE-BASED ROAD CRACK DETECTION METHODS

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**Abstract:** *Detection of road-level cracks is an important procedure for road maintenance and traffic safety. Traditionally, inventory of roads has been conducted through field surveys, and now it is being replaced by the evaluation of images of mobile cartographic systems. The obtained images remain an important source of the temporary road condition. The automatization of crack detection is highly necessary because it could decrease workload, and therefore, maintenance costs. Two methods for automatic crack detection from mobile mapping images were tested: step by step pixel based image intensity analysis, and deep learning. The objective of this thesis is to develop and test the workflow for the street view image crack detection and reduce image database by detecting no-crack surfaces. To examine the performance of the methods, their classification precision was compared. The best-acquired precision with the trained deep learning model was 98% that is 3% better than with the other method and it suggests that the deep learning is the most appropriate for the application. Furthermore, there is a need for faster and more precise detection methods, and deep learning holds promise for the further implementation. However, future studies are needed and they should focus on full-scale image crack detection, disturbing object elimination and crack severity classification.*

***Keywords****-Road construction, Cracks, bleeding, Road failure*

## I. INTRODUCTION

To gain knowledge of the magnitude of damages and how they evolve over time there is need for measure methods that better reflects the occurrence of damages and not only secondary effects. Track is an example of a functional conditioned measure that may originate from several decomposition mechanics. Ideally measurements would provide information about the technical condition in various parts of the roadbed. If these surveys could prove the underlying causes to the deficiencies, there's a better prerequisite to make the right decisions how to remediate the damages in question. Decisions that considers the possibilities to enhance drainage and to extend the lifetime of existing coating and to choose the right strategy for future remediates where time and place for more information of more extensive remediates is also considered [1].

Country roads are of particular importance compared to the entire road network. Absolutely most accidents with fatalities occur, the proportion of which is disproportionately high in the case of accidents with personal injuries. Serious accidents characterized by conflicts, which are often related to loss of vehicle control stand, are also influenced by the characteristics of the route and the environment. For rural roads, this leads to efforts to ensure safe and functional design through current regulations. The RAL (FGSV 2012) represent the current state of knowledge and represent the standardized design framework. At the moment, however, there is no knowledge of the safety effects of road design and types of operation that corresponds to the current guidelines, both for the general assessment and for deviations from the guidelines in line with the guidelines. The previous statements suffer from inadequate quality, insufficient differentiation or lack of topicality of the data [2].

The number of recent papers that discuss the pavement crack detection in images shows growing interest in automatic techniques. Authors attempt to find the most suitable image settings, more precise detection algorithms and faster and reasonable computation solutions, usually, as a result, presenting a model for a complete detection system. Published papers related to the road crack detection propose methodologies in the real time and post processing. In this thesis, only post processing methods are considered. A complete road crack detection system consists of three major parts: pre-processing, processing and classification [2-3].

### 1.1. Factors affecting the condition of the road

There are various factors that affect the condition of the road. The various factors are discussed in the following sub-headings.

#### 1.1.1. Road Construction

How the road is built and what materials are used in the planning of the road are of great importance for the condition of the road. Rigidity and thickness of the material are the factors that mainly affect the future condition of the road. When the life of the road body has expired or if it is under-dimensioned during the construction process, damage can occur as a result [4-5].

### A. Traffic

The amount of traffic, especially heavy traffic that travels on it, is one of the main causes of the road failures.

### B. Climate

Temperature and water are factors that contribute to the degradation of the road. Asphalt stiffness is affected by the temperature as it becomes softer during the summer, which increases the risk of deformation. During the winter, the asphalt is stiffer which increases the risk of cracking. Heavy rainfall can overload a road's drainage capacity to the level that the road body can lose stability resulting in damage.

### C. Time

Even if a road is not congested or otherwise loaded, degradation occurs. The binder in the asphalt oxidizes in contact with the oxygen in the air and then the binder becomes brittle and shrinks. This gives rise to small cracks, so-called micro cracks.

The economic evaluation of the accident is part of the economic investigations of road construction investments according to which represent an objective and understandable decision-making aid for the implementation of planned construction measures. The increase in the level of security can be expected through the modification of the infrastructure, taking into account the unity of design, construction and operation. The economic gain results from the proportion of accident costs avoided in the comparison of different variants [6].

## II. LITERATURE REVIEW

A break or fracture can be considered as a failure in any infrastructure. It can be caused by internal or external factors that harm the surface with the time. Usually, the surface distress is related to exceeded load applied on pavements. Road deterioration is a gradual process that at one point reaches maximum and leaves irreversible consequences, like deformations or cracks.

According to Standard Nomenclature and Definitions for Pavement Components and Deficiencies surface distress is defined as any indication of poor or unfavorable pavement performance or signs of impending failure; any unsatisfactory performance of a pavement short of failure" (Highway Research Board, 1970). Surface distress classification is based on the morphological type or shape and the degree of severity [7].

In every country road construction and maintenance are managed by the relevant governmental authority (usually transport, traffic or road administration). They are also responsible for the defining of pavement distress types. This thesis focuses on the documentation issued by the Swedish authorities and also considers different manual examples from other countries. Swedish transport administration has determined six damage types for asphalt-concrete roads. Compared to the manuals in other countries (Norway and the USA) the classification and categorization in the Pakistan source are incomplete and, therefore, a handbook from The National highwayAuthority is used. 14 different road pavement damage types are mentioned. The author distinguishes both asphalt and concrete road cracks from all mentioned distress types (and groups them into 5 classes according to classes presented in Miller and Bellinger, 2014 [8-9].

A crack is a damage and disruption in asphalt pavement surface that forms due to physical tensions. In other words, a crack is a break in the surface that according to its severity level influences traffic safety. To understand the crack impact on the vehicles, an important measure is a crack width. Figure 1 depicts that the width is determined from the top of the surface, where a sudden and steep recess starts to the end of the damage.

**Figure 1: Longitudinal cracking**

Measurements can be obtained from the cross section or from the top view. Cracks are also distinguished according to their morphological properties and the placement on the pavement surface. Morphological and physical properties also determine the severity level and the distress spread. Five different types are described in the next paragraphs. Unfortunately, neither of catalogues offers the action plan for each severity level. It is unclear if low or moderate level should be repaired or only the high severity should be scheduled for maintenance [10].

 

**1. Longitudinal cracking**
i. wheel path longitudinal cracking
ii. joint reflection cracking
iii. edge cracking
a) Transverse cracking
b) Fatigue cracking
**2. Potholes and patching**
a) patch deterioration
b) potholes
**3. Surface deformation**
a) Rutting
b) shoving
**4. Surface defects**
a) Bleeding
b) polished aggregate
c) ravelling
**5. Other distresses**
a) separation
b) other

**Fatigue cracking:** Fatigue cracking is the next stage for wheel path longitudinal cracking. It is a set of interconnected longitudinal, transversal and diagonal cracks (Figure 2) that form rectangular pattern cracks with many-sided, sharp-angled pieces, usually less than 0.3 m on the longest side . The main causes are unsuitable concrete thickness for the ongoing traffic level and deformation in road construction [11].

**Figure 2: Fatigue cracking**

**Patching and potholes:**Patch deterioration considers areas that have been already replaced by a patch due to some previous damages. Also patch itself can be considered as a distress in case of high surface difference or roughness. Damages can be caused by improper road renovation or ongoing problems in the fundament. The severity level is for patched and patch deterioration is defined:

a. Few narrow cracks around the patch and the pavement, visible and damaged joint, a little shoving.
b. Cracks larger than 5mm around the joint, many parallel cracks, medium shoving.
c. Many wide cracks in the joint that can progress as fatigue cracking, potholes or high shoving Furthermore, the level of spread is defined the same as for longitudinal cracks: 1. Local - the length of the crack is shorter than 20% of the road profile width 2. Intermediate - the length of the crack is between 20% to 50% of the road profile width

**Figure 3: Potholes**

**Surface deformation:** Shoving (abrupt wavy changes and rutting are road deformation types that can be spotted in a longitudinal profile or in a cross section for the latter. Long single pavement depression is not considered as an important and severe damage but the shorter depression gets the higher effect on the road safety it obtains. The changes can be produced from the subgrade, with ongoing water and therefore road material erosion. Rutting always follows the wheel path and is caused by studded car tyre. Both deformation types are not considered in the thesis due to their representative nature that can only be seen in cross sections but not in the pavement surface images [12].

**Figure 3:Surface deformation**

Another deformation type that is mentioned is level differences between slabs that are only visible in the road profile where every plate has different altitude. Usually it is caused by ground erosion and the impact from traffic. The deformation is always visible in the road profile measurements but also can be seen as a transverse crack (see Transversal cracking).

**Surface defects**: Surface defects occur only in the pavement exterior and can be detected in places where the road texture changes. Bleeding is usually shiny darker surface on the wheel paths. Polished aggregates are areas where the surface binder worn way to expose coarse aggregate. Another surface problem can be ravelling - that involves the lack of asphalt particles and binder.

**Other distresses**: Distress types that were not mentioned in the previous descriptions belong to the other damages. Separation can appear in asphalt pavements as small strings where more coarse material detaches from better material. A distress type that does not consider road cracking, deformation or deterioration is fading of road marking. It is neither interesting that nor the US or Norwegian transport authorities consider it as a noteworthy damage, despite the importance of road surface marking in the traffic safety [13-14].

## III. METHODOLOGY

### 3.1. Image processing and analysis

This thesis deals with two digital imaging problems. The first concerns mathematical operations with pixels that produce altered and enhanced images with the respect to the original (image processing), and the second uses the enhanced image for the information extraction, producing decision values (image analysis). The tool for image processing and analysis is Crack IT toolbox, the toolbox offers a set of crack detection and characterization algorithms, allowing customizing input values for every manipulation. The toolbox is divided into 3 stages (Figure 4). First, the image is pre-processed using included algorithms for pixel smoothing, normalization and white line detection. Then the detection is performed by carefully selected pattern decision set, and finally, the detected damage is classified based on its morphological features. Since the thesis is focused on the detection, not the classification or characterization of road cracks, only the first two steps were considered. The image preprocessing prepares the image in a way that only low-intensity pixels stand out and can be easily subtracted.

The toolbox produces two different set of outputs:

a. Pixel-based image
b. Block based binary image


**Figure 4: Steps of crack analysis**

 

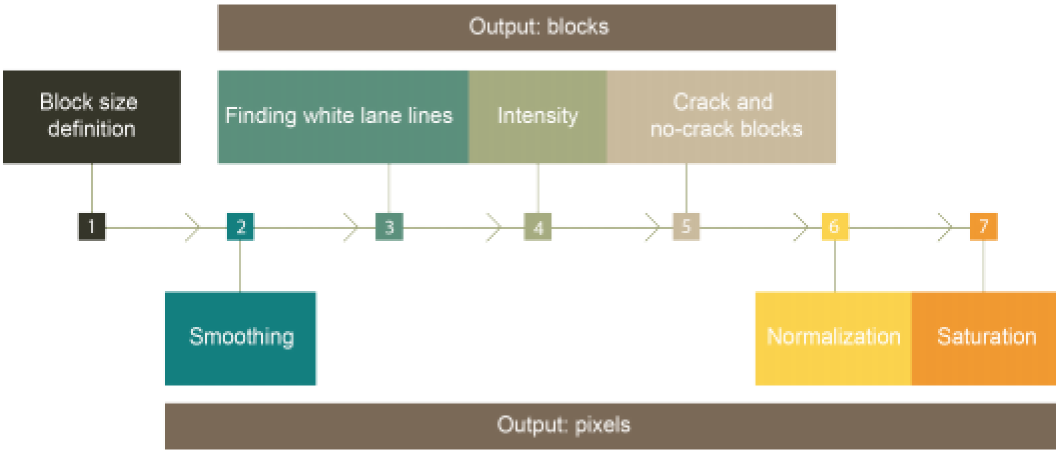


**Figure 5: Image pre-processing**

Afterwards, a global image smoothing (2) is performed. Smoothing decreases pixel intensity variance, without significantly affecting the intensity of pixels belonging to cracks (Oliveira and Correia, 2014). The smoothing technique used is anisotropic diffusion, presented in Perona and Malik (1990). The smoothing technique takes into account edges, lines, and high contrast objects that could have significant importance in the object segmentation. It also reduces noise without eliminating important data. The diffusion coefficient depends on the spatial location in the image, adjusting to the meaningful global information (Perona and Malik, 1990). As a result, pixel variation is decreased within certain limits and without excluding crack pixels. The next function (3) uses the smoothed image as an input and determines blocks with white lines, using high-intensity thresholding that responds to the white lines. Thereafter average intensity of each block is calculated, which supports the preliminary crack detection process (5). Image normalizations (6) are also based on preliminary crack detection results. The unaffected surface is transformed into the same average pixel intensity, but the damaged one is normalized according to the neighborhood. Finally, the saturation (7) changes are implemented. The average value of background or unaffected blocks is calculated and used as a threshold for high-intensity pixel elimination. The values of threshold exceeding pixels are replaced with the same average used for thresholding. The results eliminate solar reflections and overexposed pixels.

(a) Crack images (b) No-crack images

**Figure 2.8: Crack detection with neureal networks (Deep Systems, 2015)**

## IV. CONCLUTION AND RECOMMENDATION

### 4.1 Conclusions

The literature study also provided extensive information about the causes, morphologies and types of road cracks and their severity classification. Moreover, the existing crack detection methods were outlined. It has been acknowledged that the majority of available algorithms investigate only the detection, leaving out the important part - severity classification. As a result, two different approaches were tested. The first involved an image processing toolbox Crack IT and the second a neural network training system Digits. Crack IT is an easily modifiable toolbox, where every parameter can be adjusted; whereas, in Digits only a few model related parameters can be modified. The study has also examined whether procedure based image processing is effective in comparison to big scale data analysis with deep learning. The main objective was to decrease the acquired street view image database by detecting road surfaces in perfect condition. Three different input data sets were distinguished. The first one was street view images without any disturbances, the second was normal street view images, and the third, clipped surface images were used. In the second case, the Crack IT toolbox was extended with automatic feature exclusion functions. The precision in detecting perfect surface was 95, 30%, 86, 00% and - 98, 41% accordingly. However, the last can be increased by just extending the database. Exploring the deep learning as a most suitable future research strategy could facilitate the whole inventory process. The case study described the manual procedure of the crack detection, where a person inspects every road image and makes notes in the computer. So, the automated detection would sort out images without cracks, leaving only the reduced database that would need a manual inspection. A proposed workflow for the crackdetection or more precisely, no-crack detection, would include a trained deep learning model with at least 10 000 images in each class. Once the model is created, it could be applied to any crack detection project. The obtained results file could be exported as a text file and merged with an image meta-data file, pointing out the location of the image with the detected crack.

**4.2 Recommendation**

As it was discussed in conclusions, deep learning has more advantages and future perspectives and therefore, the technique should be investigated further. Many ways of extending the research could be distinguished. At first, regarding the current model, the database can be extended up to 10 000 images in every class, that would give a more precise and broad classification model. To this extent, more variation in images could be included, for example, images with manholes, sidewalks, and road borders. The next issue concerns the real application implementation. For now, only a small part of whole image scene is analyzed. In order to obtain a complete solution for the end user, the analysis should be extended. Furthermore, the object detection develops rapidly using deep learning algorithms and can be used in complete crack recognitions tasks. Another attractive research field would be manhole, road lining or road sign detection using deep learning. All mentioned groups have more distinct geometry with clear borders and therefore the learning pattern would be easier to obtain. The mentioned object detection could also help later to eliminate them from the road surface, facilitating the crack recognition. Eventually, the author predicts that future years will bring commercially available software with deep learning road asset analysis systems.

**References**

[1] Oliveira, H., &Correia, P. L. (2009, August). Automatic road crack segmentation using entropy and image dynamic thresholding. In 2009 17th European Signal Processing Conference (pp. 622-626). IEEE.
[2] Amhaz, R., Chambon, S., Idier, J., &Baltazart, V. (2016). Automatic crack detection on two-dimensional pavement images: An algorithm based on minimal path selection. IEEE Transactions on Intelligent Transportation Systems, 17(10), 2718-2729.
[3] Yu, S. N., Jang, J. H., & Han, C. S. (2007). Auto inspection system using a mobile robot for detecting concrete cracks in a tunnel. Automation in Construction, 16(3), 255-261.
[4] Yu, S. N., Jang, J. H., & Han, C. S. (2007). Auto inspection system using a mobile robot for detecting concrete cracks in a tunnel. Automation in Construction, 16(3), 255-261.
[5] Nguyen, T. S., Avila, M., & Begot, S. (2009, August). Automatic detection and classification of defect on road pavement using anisotropy measure. In 2009 17th European Signal Processing Conference (pp. 617-621). IEEE.
[6] Chambon, S., &Moliard, J. M. (2011). Automatic road pavement assessment with image processing: review and comparison. International Journal of Geophysics, 2011.
[7] Zhang, W., Zhang, Z., Qi, D., & Liu, Y. (2014). Automatic crack detection and classification method for subway tunnel safety monitoring. Sensors, 14(10), 19307-19328.
[8] Kapela, R., Śniatała, P., Turkot, A., Rybarczyk, A., Pożarycki, A., Rydzewski, P., ...&Błoch, A. (2015, June). Asphalt surfaced pavement cracks detection based on histograms of oriented gradients. In 2015 22nd International Conference Mixed Design of Integrated Circuits & Systems (MIXDES) (pp. 579-584). IEEE.
[9] Zakeri, H., Nejad, F. M., &Fahimifar, A. (2017). Image based techniques for crack detection, classification and quantification in asphalt pavement: a review. Archives of Computational Methods in Engineering, 24(4), 935-977.
[10] Li, H., Song, D., Liu, Y., & Li, B. (2018). Automatic pavement crack detection by multi-scale image fusion. IEEE Transactions on Intelligent Transportation Systems, 20(6), 2025-2036.
[11] Ai, D., Jiang, G., Kei, L. S., & Li, C. (2018). Automatic pixel-level pavement crack detection using information of multi-scale neighborhoods. IEEE Access, 6, 24452-24463.
[12] Dare, P., Hanley, H., Fraser, C., Riedel, B., &Niemeier, W. (2002). An operational application of automatic feature extraction: the measurement of cracks in concrete structures. The Photogrammetric Record, 17(99), 453-464.
[13] Sorncharean, S., &Phiphobmongkol, S. (2008, January). Crack detection on asphalt surface image using enhanced grid cell analysis. In 4th IEEE International Symposium on Electronic Design, Test and Applications (deltaChambon, S. (2011, March). Detection of points of interest for geodesic contours: Application on road images for crack detection. 2008) (pp. 49-54). IEEE.

 