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# Presentation of a new surface drainage assessment method based on image processing

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**ABSTRACT:** Improvement of the pavement surface texture characteristics and drainage quality is an important issue in the field of increasing roads safety and reducing the rate of accidents, especially in rainy weather conditions. The assessment of the pavement surface features and their relation with the accident rate is a common research topic, but no extensive research has been carried out on the evaluation of the pavement surface drainage. In this research, a system has been developed to assess the surface drainage of the pavements. For this purpose, hardware is designed which can saturate the surface and capture the drainage process under constant conditions without the effects of environmental factors. The basis of the presented system is based on digital image processing techniques. Using image processing methods, three time-related indexes including Entropy, Energy and pixels proportion have been determined for the assessment of surface drainage quality of the pavements. Providing a proper combination of the indexes, the pavements are classified as appropriate, normal and inappropriate in terms of surface drainage performance using C5.0 data mining algorithm. The validation of the results of the proposed system shows that this system can evaluate the surface drainage situation with 95.7% accuracy. The presented system results can be used in the pavement management systems at project and network levels as a suitable measure for the evaluation of pavement safety in the rainy conditions as well as improving roads safety.

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## 1. INTRODUCTION

The condition of the pavement surface characteristics is of great importance in ensuring the safety of the roads and the comfort of the users of these facilities [1]. The surface drainage condition, which is related to the pavement surface texture, is an important parameter that controls road safety in rainy weather conditions [2]. Microtexture and macrotexture of pavement surface are two effective parts on surface drainage. Macrotexture affects the skid resistance and water drainage at high speeds, but at low speeds, microtexture is the determinant factor [3]. There are several methods for measuring the surface characteristics of pavement that can be categorized as the laboratory and field methods [4]. Recently, researchers are more inclined to offer intelligent methods that assess surface characteristics of the pavement with a high accuracy and speed. Elunai et al. proposed a method based on image processing to determine the distribution of pavement surface roughness [5]. Other researchers used image processing methods for measuring the pavement surface texture [6, 7].

In this paper, a method is proposed for the Assessment of the pavement surface drainage using image processing techniques and manufacturing hardware in accordance with the proposed method. It is noticeable that several factors, such as transverse gradient and surface distresses affect surface drainage, but this paper examines the impact of pavement texture on the drainage quality.

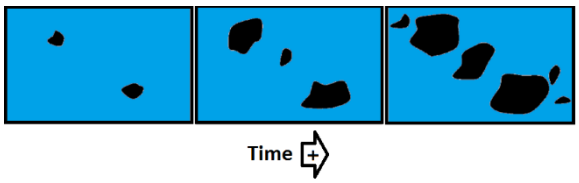


**Fig. 1. Pavement surface drainage process**

## 2. METHODOLOGY

Surface drainage operation of the pavement involves major processes that will help us to assess the surface drainage of the pavement. As shown in Figure 1, Surface water volume decreases with time, which indicates the surface discharge outflow index. Also, the number and area of surface aggregates Protruding from the surface of the water increase over time.

Figure 2 shows a flowchart to introduce the process of the proposed method for pavement surface drainage assessment based on these facts. The first step is image acquisition and enhancement of images taken by the proposed device with the help of preprocessing methods, then, extracting morphology indexes to evaluate the drainage performance

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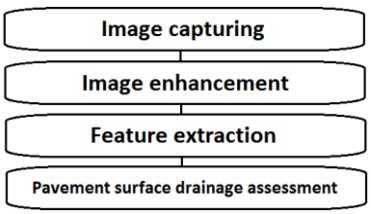


Fig. 2. Flowchart of the proposed method

Table 1. Comparison of models

| Algorithm | Accuracy | Precision | Sensitivity | Specificity |
|---|---|---|---|---|
| C5.0 | 95.7 | 93.7 | 93.3 | 96.7 |
| Random Forest | 90.8 | 86.7 | 86.7 | 92.9 |
| KNN | 95.5 | 93.7 | 93.3 | 96.4 |
| Naïve bayes | 85.8 | 82 | 80 | 88.8 |

of the pavements and finally assessing the pavement surface condition and method validation.

## 3. RESULTS AND DISCUSSION

After enhancement of the images, morphological indexes have been extracted for assessing the surface drainage manner of the pavements. These indexes are Entropy, Energy and the ratio of the number of black pixels to total pixels (RBT). Entropy is a statistical measure of randomness that can be calculated by [8]:

$$Entropy = -\sum_{i=1}^{M}\sum_{j=1}^{N} p(i,j)\log_2 p(i,j) \quad (1)$$

Energy is a measure of information. Energy of an image can be measured by [8]:

$$Energy = \sum_{i,j} p(i,j)^2 \quad (2)$$

The ratio of the number of black pixels to total pixels is another indices that can be measured by:

$$RBT = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} p(i,j) = 0}{\sum_{i=1}^{M}\sum_{j=1}^{N} p(i,j) \geq 0} \quad (3)$$

The rate of changes in extracted indexes is properly correlated with the surface drainage speed. Considering the nature of the topic of study as well as surveying the manner of drainage for different pavements, a contractual time was set as an acceptable time for the turning point. This point was set at 10 sec. Afterward, the rate of changes before 10 sec divided by the rate of changes after 10 sec for the three features. The surface drainage performances of these pavements were studied by experts and classified into three categories as appropriate, Normal, and Inappropriate. To

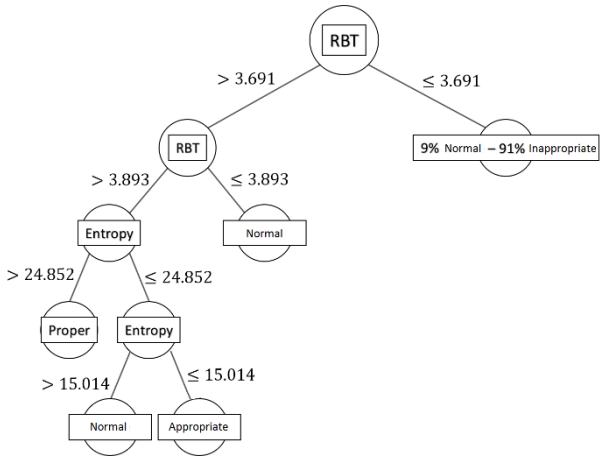


Fig. 3. The decision tree of the classification of pavements based on their surface drainage quality

Table 2. Model performance evaluation

| Type | Accuracy | Precision | Sensitivity | Specificity |
|---|---|---|---|---|
| appropriate | 97 | 100 | 90 | 100 |
| Normal | 93 | 90 | 90 | 95 |
| Inappropriate | 97 | 91 | 100 | 95 |
| system | 95.7 | 93.7 | 93.3 | 96.7 |

provide a model for assessing the drainage of the pavement and the classification of different pavements in terms of surface drainage condition, various data mining algorithms have been implemented by RapidMiner software and their performances have been compared. Table 1 shows the result of this comparison.

As shown in Table 1, the best performance belongs to the C5.0 algorithm. So this algorithm has been used for the classification of pavements based on their surface drainage condition. Figure 3 shows the decision tree of the pavements classification.

The evaluation of the performance of the proposed classification model indicates the efficiency of extracted indexes and model in pavement surface drainage assessment.

Table 2 presents the magnitude of the performance evaluation parameters.

## CONCLUSIONS

An image processing based procedure was presented in this paper for the automatic assessment of asphalt pavement surface drainage. The main results of the research can be summarized as follows:

- Providing hardware for observation of the surface drainage behavior of the pavement.

- Quantitative assessment of the surface drainage quality of the pavement using the indexes obtained from the analysis

of images.

- Qualitative assessment and classification of pavements based on surface drainage by C5.0 Data Mining algorithm.

Overall, the method proposed in this work can be implemented for the surface drainage evaluation as a part of the pavement management systems.

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