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Improving the Results of Asphalt Mixture Density Derived from CT Images Using Fuzzy Thresholding

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ABSTRACT: Density, as a one of the important factors affecting the performance of asphalt mixture has a significant impact on the pavement serviceability. Numerous studies on computed tomography (CT) scan images of asphalt mixtures are done; however, due to the ambiguous nature at the edge of aggregates, the processing of images contains uncertainty. Static and dynamic thresholding techniques that have been conducted by previous studies were also unable to resolve and handle the ambiguity. The aim of this study is enhance the results using a new fuzzy thresholding model for separation of components and analyze the density of asphalt mixture. The analysis indicates that fuzzy threshold provides more accurate results. It was also found that, the density of asphalt mixture were determined with less than 2% error.

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1- Introduction

X-ray computed tomography (CT) is used for imaging inner asphalt cores within compact aggregates and extracting the information and knowledge from images. Also, it is widely applied to the pavement area such as acquiring 3-D particle images, reconstructed pore geometry, void-distribution segregation in mixtures, and scanning three-dimensional internal structure of hot-mix asphalt. Researchers have developed several approaches and techniques for image segmentation and thresholding that can be generally classified into four major categories: adaptive threshold, edge-based segmentation, region-based segmentation, and watershed segmentation.

The main objective of the present work is to apply X-ray computer tomography (CT) to scan the particles non-destructively. Efforts to acquire interior properties, aggregate characteristics (aggregation chart, coarse aggregate content and particle size) and air voids distribution of asphalt mixture also led to investigate the microstructure of asphalt concrete [1-17].

2- Methodology

The objectives of this paper are to present fuzzy base method for: (1) segmentation of the three different phases in asphalt concrete (AC); (2) determination of air voids and its distribution; (3) determination of aggregates particle size gradation and scattering; (4) decreasing the effects of edge blurring of material boundaries and calibration of gray levels and reducing penetration capability toward center of core and image artifacts; and (5) increasing the capability of interpretation.

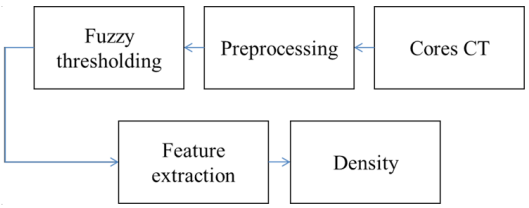

Figure 1. Overall the process

3- Materials

Using a detailed mix design, the highway density asphalt concrete (AC), which widely used as an asphalt pavement upper layer in Iran was selected as the research object (Tehran - Save highway [km: 55+350 to 110+975] section in the Tehran City, Iran). In these sections, 60 samples were organized in a cylindrical shape in 7 cm × 10 cm dimensions and then used for test and X-ray CT scanning. The asphalt pavement relative density was 2.489 gr/cm3 and the designed air void was 5.1%. The as-built bitumen content (%) and air-void content (%) are listed in data base. Asphalt pavement samples were selected randomly from the laboratory of the construction company. At first, the samples were selected in cuboid shape (100×100×100 mm) from Amirkabir University Laboratory, but images were not clear enough due to the

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scanning restriction of X-ray CT device [14].

4- Preprocessing

Preprocessing is used to improve the quality of images and noise rejection. The radiation power of the sample around its core center is the main problem that affects the processing and accurate thresholding. This is due to radiation in the horizontal direction and has no significant changes in altitude. For this purpose, function or feature set based on the distance from the center and the correction factor is used. This paper examines and compares four different thresholding methods, which in turn are:

- Fixed threshold
- Dynamic threshold
- Fuzzy linear threshold
- Fuzzy non-linear threshold

5- Fuzzy Thresholding

In order to model the uncertainty and ambiguity the fuzzy method is used. The main rules are:

Hypothesis 1: The pixels are white, stone materials and bitumen or air show highlights.

- Rule 1: If the pixel is turned on, then the aggregate.
- Rule 2: If the pixel is dark, then the air.
- Rule 3: If the pixel is almost dark, then the bitumen.

Choosing a membership function based on the parameters, plays an important role in the success of a fuzzy approach. The following rules were used to determine the type of function and its parameters:

- Rule 4: Total membership functions for each pixel is equal to 1
- Rule 5: For points over the range of 0 to 255, the membership value is zero.

In this paper, two kinds of fuzzy logic membership functions are used. The linear and non-linear membership functions, is used to model the problem.

6- Experiment and Analysis

The results showed that the sum of the squares of the differences for non-linear algorithm is proved to have 77% improvement. This ratio is 65% for linear fuzzy algorithm. The results showed that fuzzy non-linear algorithm is maximum 34% improvement and the linear fuzzy is 21%. It must be noted, although the laboratory results indicates fixed air-void distribution along sample height, test results show different results. Table 1 shows the measured bitumen and air-void content

Table 1. Comparison results of different algorithms bitumen and air-void content (%) for 60 samples

Number	std	Max Er	p-value
Fixed threshold	70.03	2.7	0
Dynamic Threshold	61.21	2.5	0
Fuzzy linear threshold	24.58	2.2	0.023
Fuzzy non-linear threshold	15.83	1.84	0.728

7- Conclusions

In addition to the density extracted based on the image, the the distribution of the air were evaluated and showed that air distribution is dependent on density. In addition we concluded that:

- CT scan is a powerful tool to investigate the micro-structural properties of the asphalt mixture.
- Fuzzy Logic is a very effective method in reducing vagueness of CT images.
- Segmentation of asphalt components using nonlinear fuzzy threshold than the other methods tested (linear fuzzy threshold, dynamic threshold and fixed threshold) shows better results.
- Air distribution is dependent to the mixed compression method and it should be considered for compression method selection.

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