ESTIMATING PAVEMENT MACRO-TEXTURE MEAN PROFILE DEPTH FROM ONE IMAGE

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1. Introduction

- Pavement surface texture can provide important information regarding pavement friction and safety
- The primary index used to characterize macro-texture is mean profile depth (MPD)
- Researchers found that more work is needed to better ways of quantifying texture
- The analysis of pixel intensities of one image can be used to measure how rough the surface is although it requires multiple images to recover the three dimensional heights of a surface.
- This research presents a method to estimate MPD from one image of the pavement
- The test site is a new Portland cement concrete pavement section with 14 types of texturing at the south extension of the north-south tollway (I-355), east of Joliet – Illinois. US

2. Types of Pavement Texturing

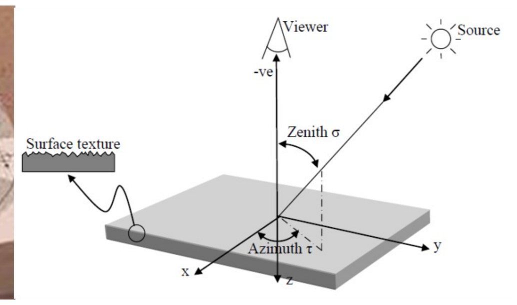
Label	Texture description	Real lable	MPD [mm]
1	Heavy turf drag	1B	0.4
2	Heavy turf drag	1A	0.5
3	Turf drag + shallow longitudinal tine	6	0.5
4	Longitudinal tine + turf drag	5A	0.9
5	Longitudinal tine	2	1.0
6	Longitudinal diamond grind	3	1.0
7	Longitudinal diamond grind + groove	14	1.2
8	Longitudinal tine + heavy turf drag	5B	1.4
9	Longitudinal groove + turf drag	8	1.4
10	Longitudinal groove + burlap drag	7	1.8
11	Transverse tine + burlap drag	9	0.5
12	Transverse tine + burlap drag	11	0.5
13	Transverse tine + burlap drag	10	0.8
14	Transverse skewed tine + turf drag	12	0.8

3. PhotoTexture 2.0

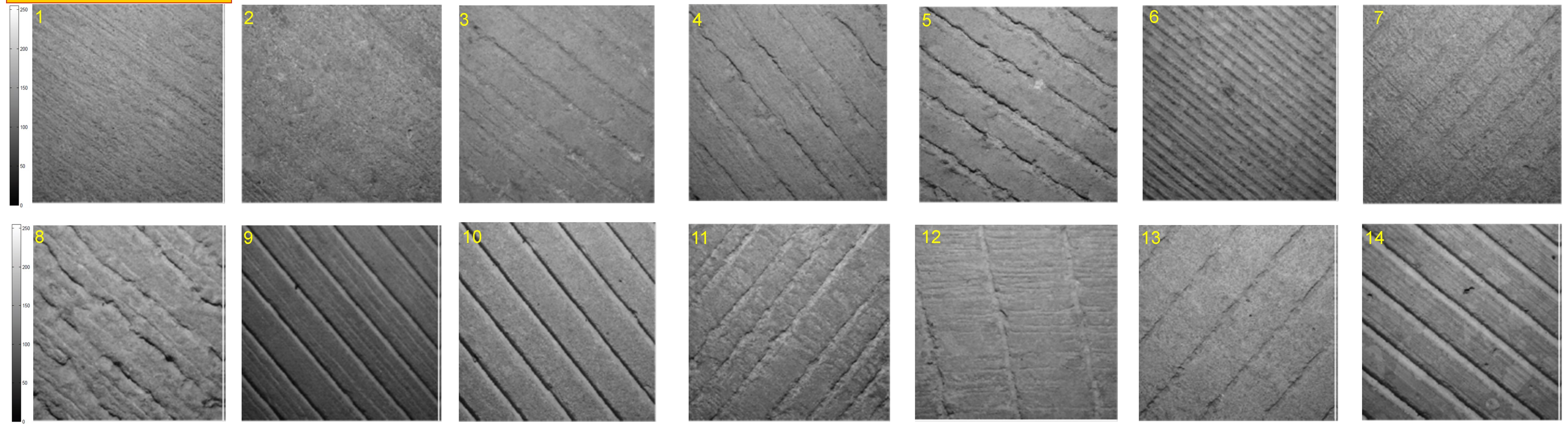
- PhotoTexture 2.0 was used to take images in October 2007 immediately before the road was opened for traffic. For each texturing type, one image was taken for each location.
- The pavement surface area of 100 mm ×100 mm within the image center is used for further analysis. Each of the images consists of 986×986 pixels. The resolution of the image DELAT=0.1014 mm/pixel (100 mm/986 pixel) in space domain.

4. Image Capturing

The variation in gray scale can be from the change in surface colour or from surface heights. Since the images of this research were taken from a new PCC pavement section right before the road was open for traffic, the effect of the change in surface colour is assumed not significant. The figure on the left illustrates the effect of surface heights upon the gray scale of the images.



5. Images of Various Texturing



6. Wavelet Transform

The wavelet transform is used to decompose a signal (pixel intensity of the pavement picture) into different frequency components and then present each component with a resolution matched to its scale. The Daubechies mother wavelet db3 was adopted for this research:

$$C(i,j) = \sum_{j=1}^{j=N} s(x)\Psi_{a,b}(x)$$
$$\Psi_{a,b}(x) = 2^{\frac{-j}{2}}\Psi(2^j x - i)$$

Where

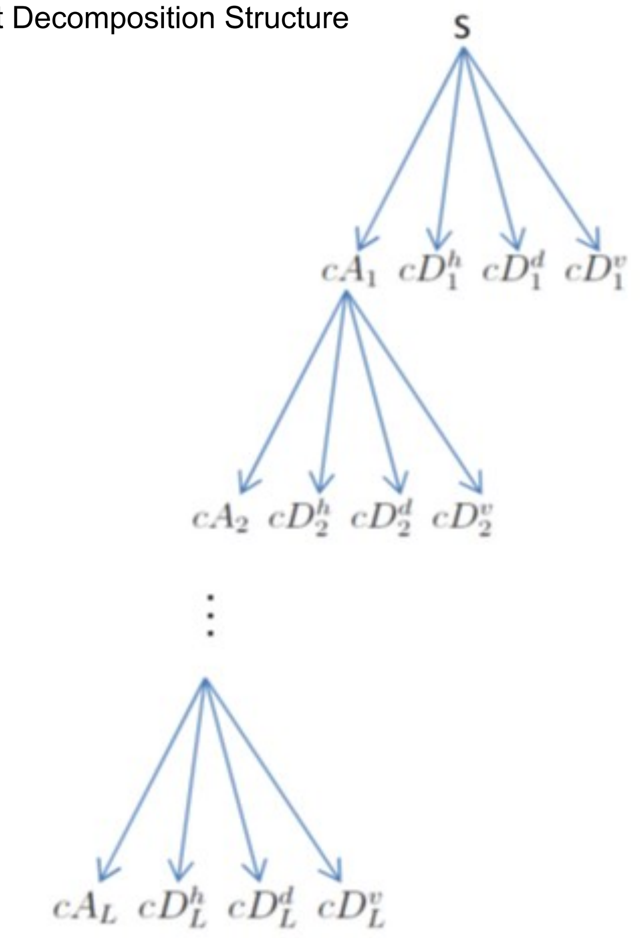
N = total number of data points,

$\Psi_{a,b}(x)$ = wavelet basis function with scaling parameter a and shifting variable b,

j = decomposition level.

Decomposition level	Frequency (circle/mm)	Wavelength (mm)	Texture classification
1	7.89	0.13	Micro-texture
2	3.94	0.25	
3	1.97	0.51	Macro-texture
4	0.99	1.01	
5	0.49	2.03	
6	0.25	4.06	
7	0.12	8.11	

Wavelet Decomposition Structure



Where

cA_j = approximation coefficients,

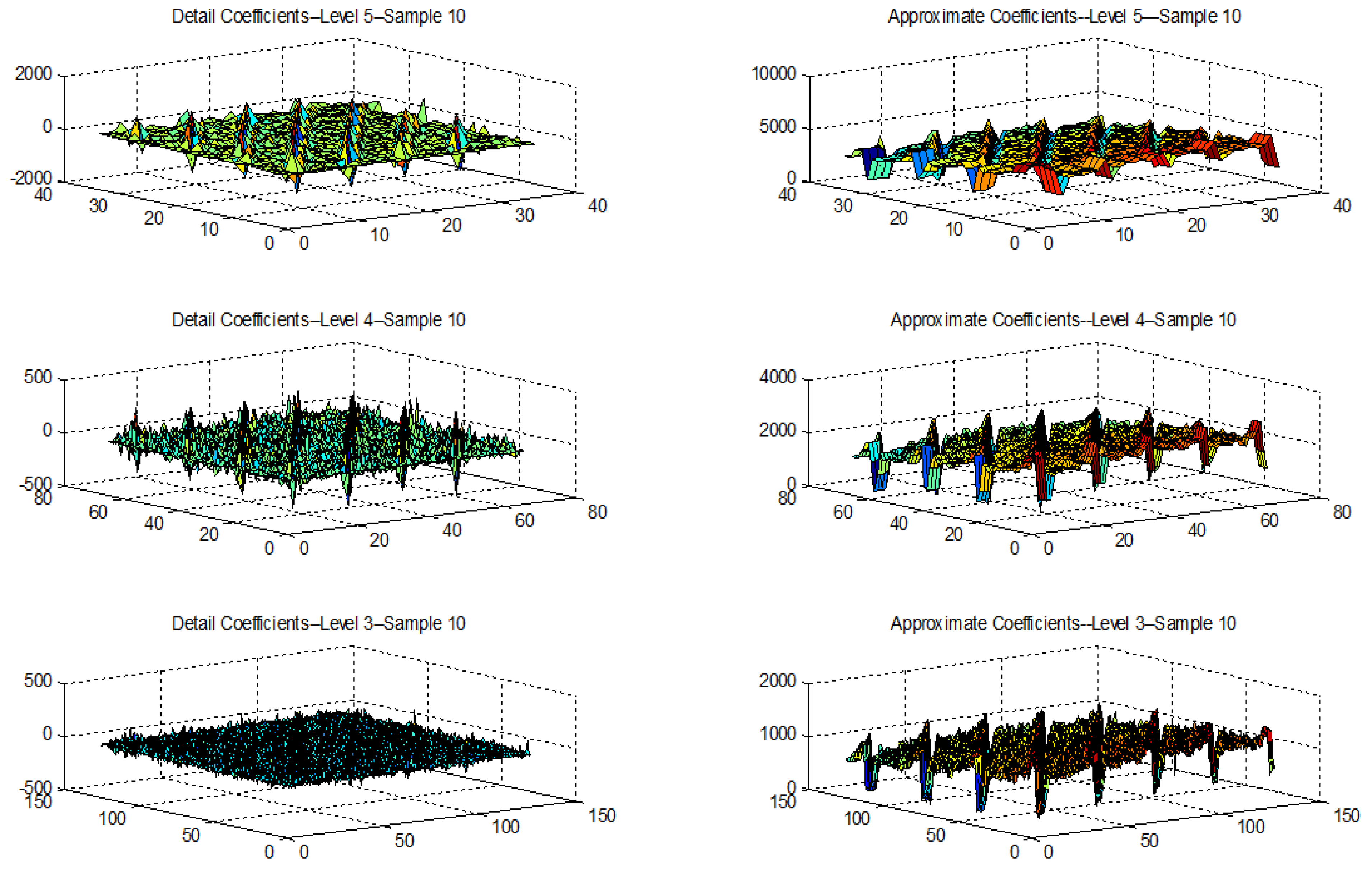
cD_j^h = horizontal detail coefficients,

cD_j^d = diagonal detail coefficients,

cD_j^v = vertical detail coefficients,

j = decomposition level, $j = 1...L$,

L = maximum decomposition level.



Plot of Wavelet Transform Coefficients at Various Decomposition Levels

7. Power Spectrum Energy (PSE)

The energy (E_j) for decomposition level j is defined as its sum of the squares of diagonal detail coefficients as follows:

$$E_j = \sum_{j=1}^{j=N} cD_j^d$$

Where E_j = energy at decomposition level j, other variables are as defined previously.

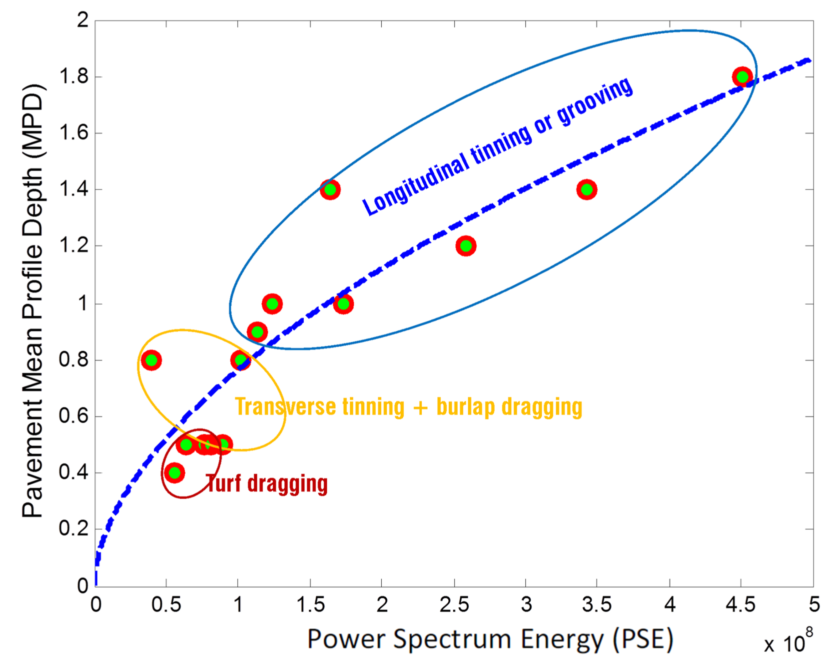
Power Spectrum Energy (PSE) is defined as the sum of the detail energy for all decomposition levels as shown on the right

$$PSE = \sum_{j=1}^{L} E_j$$

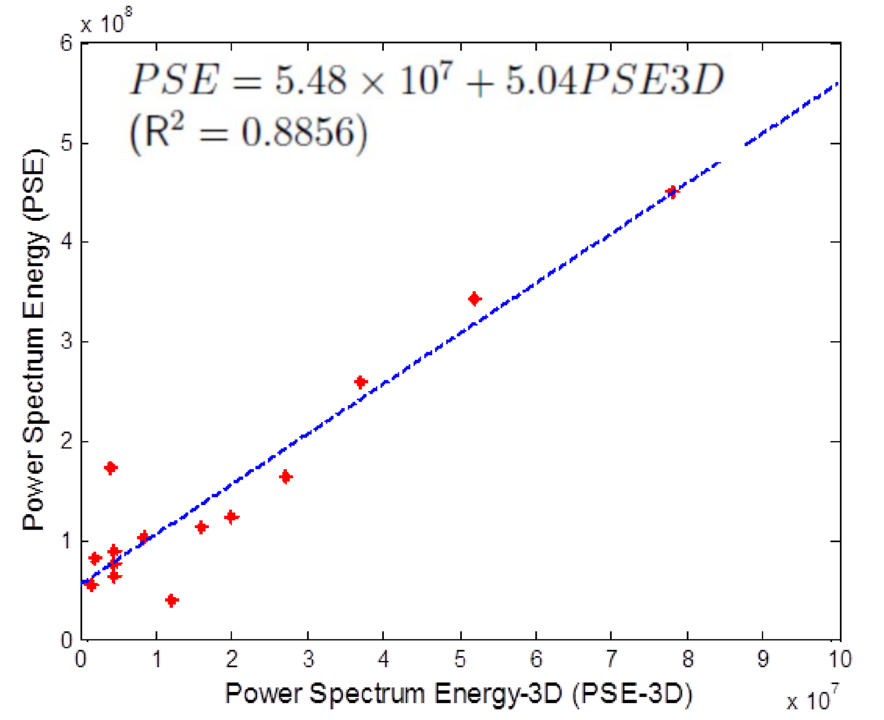
8. Correlation Analysis

The figure below shows the relationship between MPD and PSE

$$MPD = 2.71 \times 10^{-5} + PSE^{0.56} \qquad (R^2 = 0.7529)$$

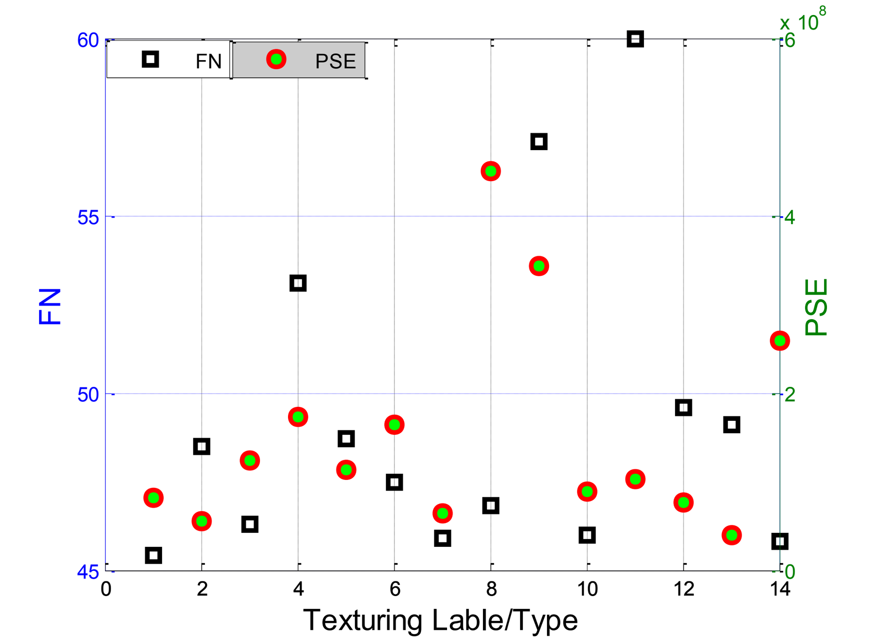


After recovering the pavement heights in 3D manner, A. El Gendy and A. Shalaby calculated the power spectrum energy (PSE3D) by using Fourier transform. A linear relationship exists between PSE and PSE3D as can been seen in the figure below.



The relationship between PSE and FN was also examined as shown in the figure on the left. No significant relationship was found between them.

PSE itself is insufficient to represent pavement texturing especially when friction is studied.



9. Conclusions

MPD of the pavement surface can be estimated from only one pavement image. This method might be one of the easiest ways to predict MPD with reasonable accuracy.

This method was verified by photometric stereo techniques. A linear relationship exists between PSE and PSE-3D. PSE might be a representative of PSE-3D with significant accuracy.

No significant relationship was found between PSE and FN.

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