

Two-Dimensional Variational Mode Decomposition and Its Application in the Field of Road Surface Images Denoising

1st Zhongbin Wei *
*Mechanical and electrical technology department
Xijing University
Xi'an, China
358825406@qq.com*

2nd Song Zhao
*Mechanical and electrical technology department
Xijing University
Xi'an, China
610633400@qq.com*

3rd Kun Wu
*Mechanical and electrical technology department
Xijing University
Xi'an, China
342752260@qq.com*

Abstract—In order to extract road surface features and discriminate the condition of road surface, it is necessary to remove noises and maintain marginal information, based on this, a new non-recursive Two-Dimensional Variational Mode Decomposition (2D-VMD) algorithm is introduced. The algorithm uses non-recursive sifting method to analyse signals in frequency domain, which can inhibit the mode and frequency mixing better, compared to previous some mode decomposition algorithms, such as Bidimensional Empirical Mode Decomposition (BEMD) and Bidimensional ensemble Empirical Mode Decomposition (BEEMD). Thus, it can separate the noises and preserve the original information of images at the greatest extent. By means of contrast experiments, the results indicate that 2D-VMD can remove noises and maintain marginal information effectively with lower Error Rate (2.2%) and higher Power Signal-to-Noise Ratio (29.3012dB). It is feasible to adopt the algorithm in the field of road surface image denoising of road engineering.

Keywords—road engineering, road surface image denoising, marginal information, Two-Dimensional Variational Mode Decomposition, Bidimensional Empirical Mode Decomposition(BEMD), Bidimensional ensemble Empirical Mode Decomposition(BEEMD)

I. INTRODUCTION

The use of pavement quality on traffic safety and road cycle has important influence. With the development of image processing technology, image processing technology was applied to test pavement diseases became the focus of the study [1]. Therefore, the image quality for pavement diseases has very big effect. But inevitable in the process of image in the intake or transmission by the interference of random signal, causing the image contains noise, the noise is not only the serious influence people to accept the information, but also each link of image processing in the late and the final output results will produce great influence, so to deal with the noise of image has become the field of image processing and the important one link.

Empirical Mode Decomposition (EMD) [2] and its improved versions integrated Ensemble Empirical Mode Decomposition (EEMD) [3] after ten years of development, has been widely used in many scientific research, Bidimensional Empirical Mode Decomposition (BEMD) [4] and Bidimensional Ensemble Empirical Mode Decomposition (BEEMD) [5] in the field of image processing, especially in the denoising aspect got the extensive concern of many scholars, such as literature [6]、[7]、[8] which has been applied to hyperspectral image denoising, medical image and SAR image denoising, but lack of BEMD and BEEMD alike, is the recursive screening characteristics which is modal aliasing phenomenon, especially in the background noise is stronger and more complex cases, lead to decompose the effect is not ideal, the consequences of denoising is not complete. Based on this, this paper adopts a new adaptive signal Mode decomposition method, Variational Mode Decomposition (VMD) [9], the method put forward by Dragomiretskiy in 2014, its biggest characteristic is to abandon the BEMD and BEEMD recursive screening of thought, the algorithm estimate of the modal shift for the Variational problem solving, and in the frequency domain constantly updating the modal and its center frequency, finally the modal by Fourier inverse transformation to the time domain, and VMD algorithm combined with Wiener Filter Banks (WFB), make its can effectively deal with background noise, greatly enhance the robustness of the algorithm. The method of one dimensional form has been applied in the fields of the medical signal [10], mechanical fault signal processing [11], the seismic signal processing [12], but the type of 2 D- VMD application is less, now its application in road image denoising, aimed at to pavement image processing field introduced a new method and train of thought.

II. 2D-VMD ALGORITHM

2D-VMD and VMD algorithm principle, the same goal is $f_{AS}(x)$ will be an image signal is decomposed into several unrelated sparse temperament signal, namely modal component, assuming that each 2 d modal component signal $u_{AS,k}$ has the center frequency and bandwidth limited, the constraint conditions for each mode is equal to the sum of the input signal $f_{AS}(x)$, and minimizing the sum of each modal estimate bandwidth, the algorithm flow chart is shown in figure 1.

III. THE REAL IMAGE PROCESSING

In order to verify the 2D-VMD in real road image denoising of practicability, this experiment adopts real photograph of a pavement crack image is 128 x 128 pixel size, as shown in figure 2, can see the road in the image in figure not only has a

crack, pavement image at the same time also by the influence of impurities and sand, they can be considered as isolated noise [13].

This experiment to arrange two or three groups of experiments to compare three kinds of algorithm of denoising ability, the first group on the basis of the original image noise and gaussian noise noise level sigma = 0.06;The second group on the basis of the original image noise and noise level of sigma = 0.06 salt and pepper noise.

Figure 3 for three algorithms under the influence of gaussian noise decomposition denoising after heavy composition, can be seen from the graph 2D-VMD denoising ability is obviously better than the other two algorithms, not only to in addition to the original impurities in image noise, and gaussian noise better. Figure 4 for the crack under the binary figure, edge information can be seen from the diagram of BEMD binary figure still have a lot of noise, BEEMD while get rid of the noise removing a lot of noise but also removed a lot of crack edge information, and 2D-VMD in denoising and maximum keep the edge information of cracks.

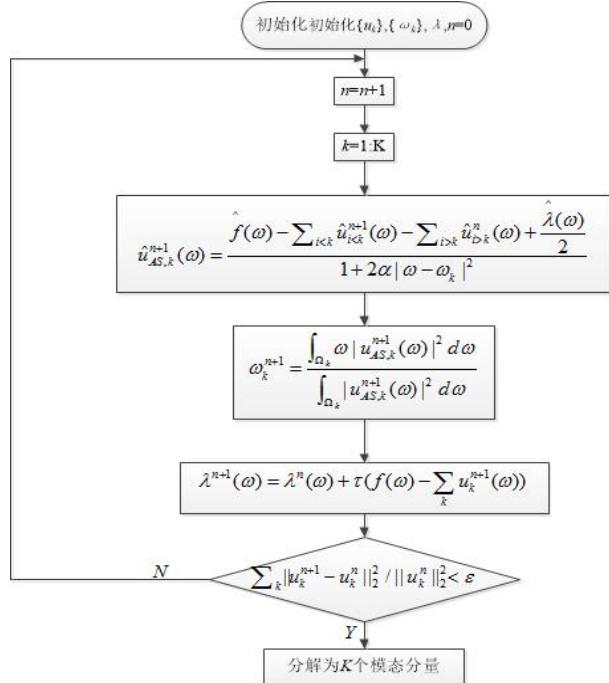
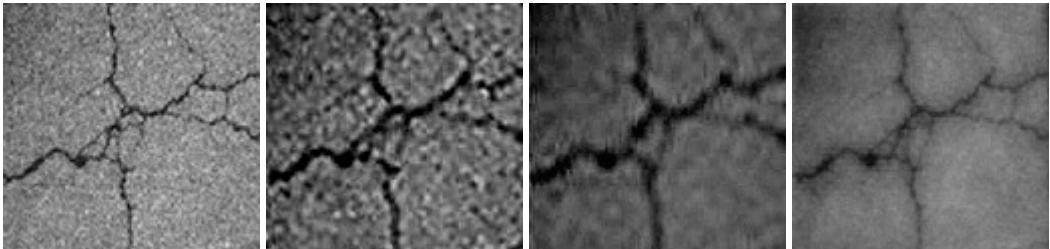


Fig 1. Flowchart of 2D-VMD

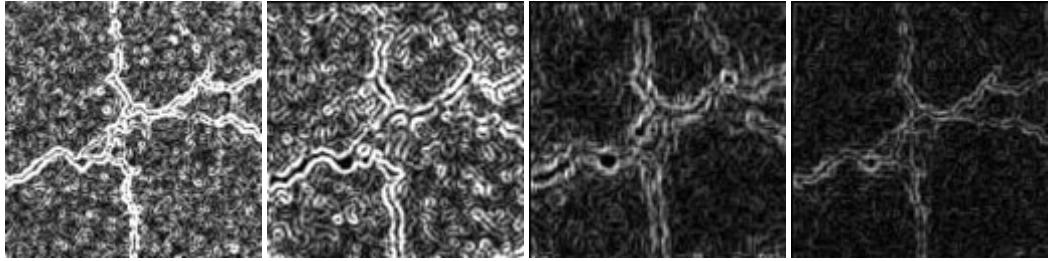


Fig 2. Cracked road surface



(a)after add noise image (b) BEMD decomposition reconstruction images (c) BEEMD decomposition reconstruction images (d) 2D-VMD decomposition reconstruction images

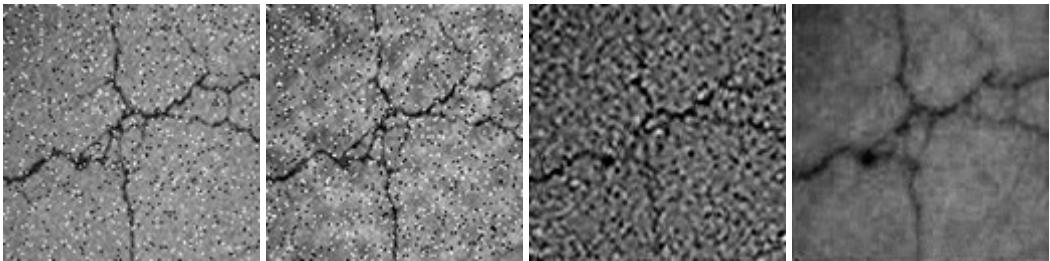
Fig 3. Restriction image comparison after denoising



(a) after add noise binary map (b) BEMD reconstructing binary map (c) BEEMD reconstructing binary map (d) 2D-VMD reconstructing binary map

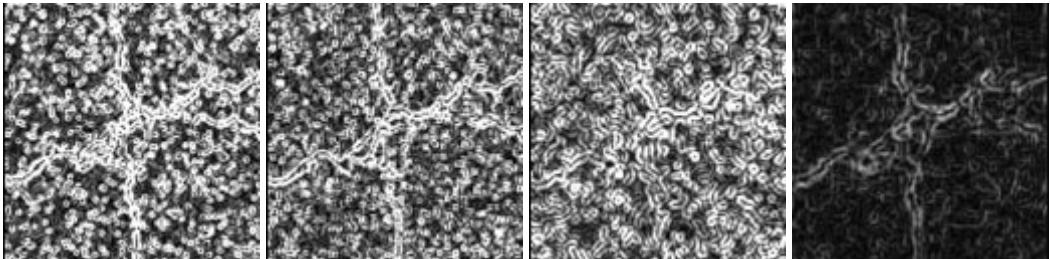
Fig 4. Binary image comparison after denoising

Figure 5 and figure 6 for three kinds of algorithms in the salt and pepper noise under the influence of heavy composition and decomposition denoising after binary figure, compared with the first set of experiments, found that the effects of three kinds of algorithms in the salt and pepper noise, salt and pepper noise removal is BEMD failure, although BEEMD removed part of the salt and pepper noise, but the second graph edge crack information completely disappeared, and salt and pepper noise on 2 d - VMD is relatively small, the influence of crack edge information is less than the first group, but still can recognize.



(a)after add noise image (b) BEMD decomposition reconstruction images (c) BEEMD decomposition reconstruction images (d) 2D-VMD decomposition reconstruction images

Fig 5. Reconstruction image comparison after denoising



(a) after add noise binary map (b) BEMD reconstructing binary map (c) BEEMD reconstructing binary map (d) 2D-VMD reconstructing binary map

Fig 6. Binary image comparison after denoising

IV. CONCLUSION

(1) The VMD algorithm with the EMD algorithm has essentially different, the EMD is analyzed from the time domain and using a sieve recursively, and VMD is analyzed from the frequency domain using the screening recursively.

(2) Through the real road image denoising experiment, which was found that in gaussian noise, salt and pepper noise and superposition of two kinds of noise under the influence, the 2D - VMD can better remove noise, and can better keep the edge information, in the face of complex background noise show that the algorithm has good robustness, therefore is feasible for the actual road image processing field.

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