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Research on Vehicle Bottom Image Enhancement Method Based on Fourier Transform Domain

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Abstract:

In order to recover the missing information of underbody image, improve the contrast of underbody image and improve the definition of local detail features of underbody image, an image enhancement method based on Fourier transform domain is proposed in this paper. Through the construction of the new Fourier transform equation, the approximate solution method is designed, and the approximate solution of the missing part of the Fourier coefficient is obtained. When the number of iterations is 80, the enhancement experiments are carried out for three groups of different underbody images. The experimental results show that the algorithm has better enhancement effect, the enhanced image contrast is significantly enhanced, the local detail features are clearer, and the enhanced image also has higher peak signal-to-noise ratio.

***Keywords**: Underbody image, image enhancement, Fourier transform, peak signal-to-noise ratio*

I. INTRODUCTION

Vehicle bottom image processing is of great significance for safety detection [1]. However, the underbody image is large and occupies a large transmission bandwidth. It needs compression coding before it can be transmitted back to the upper computer. At the same time, in the imaging process, due to limited lighting conditions, fast vehicle speed, short imaging distance and short exposure time, there will also be large noise in the image and low overall brightness of the underbody image [2-3].

The loss of underbody image in the transmission process and the ambiguity in the imaging process will have a great impact on the subsequent safety detection work. Therefore, the enhancement of vehicle bottom image is an urgent technical problem in the field.

Kinoshita adopts the coding method of rainbow code and hot metal code to realize the pseudo color enhancement of the collected gray image, and applies it to the CT image of log cross section. The enhanced CT gray image can provide more detailed physical information, and can more clearly divide the structural distribution of different densities inside the wood [4].

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Parkjunhee proposes an algorithm for low illumination image enhancement based on HSI color space. The visual effect of low illumination color image can be significantly improved by enhancing component s by piecewise exponential transform and orthogonal multiwavelet v-transform of component I [5].

Wu proposed a variational based fusion method. In this method, the global contrast of the H component is retained for adaptive enhancement to generate the local enhanced image, and then the local enhanced image is generated by retaining the local contrast of the H component. Finally, the variational based method is used to fuse the image, correct the color and optimize the contrast, This method maintains the color balance of global enhancement and local enhancement, and has a good enhancement effect on images with non-uniform illumination [6].

Yidan proposed a low illuminance image enhancement algorithm based on HSI spatial fusion. By decomposing the HSI color space component of the image, the obtained I brightness component is homomorphic filtered. The obtained result is curvelet transformed with the original illuminance component, and the transformed component is processed by local contrast enhancement. Finally, the transformed i illumination component is fused with H and s. The algorithm has good performance in eliminating uneven illumination, contrast enhancement and noise elimination [7].

Zhang proposed an underwater image enhancement algorithm based on natural color. The algorithm neutralizes the underwater color deviation by introducing the mean processing of I component, and then improves the naturalness of the input image through the mean equalization algorithm based on cluster intelligence. The algorithm effectively improves the color restoration quality of underwater image [8].

Arturo proposes a multi-scale significance detection method based on improved HSV. Image sequences of three scales are obtained by Gaussian pyramid decomposition, and then the feature map of each image sequence is extracted by improved S-R algorithm. Finally, the feature map is processed by linear fusion. The advantages of this method are mainly reflected in high detection efficiency and good robustness [9].

Hassan proposed a trilateral filtering Retinex image enhancement algorithm based on HSV. Firstly, the trilateral filtering technology is used to extract the brightness component of the image, reduce the impulse noise and Gaussian noise of the image, then the binary function is used to smooth the image edge, and finally the multi-scale Retinex algorithm is used to recover the image information, The algorithm has a good retention effect on the details and edge information of the image [10].

Kinoshita proposed a machine vision image defogging algorithm based on dark primary color a priori. After the fogged image is transformed into gray image, it is enhanced by histogram equalization, which provides a better input image for the subsequent guidance filtering processing of gray image as guide image and reduces the running time. The algorithm can obtain good defogging effect and high operation efficiency [11].

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Kaur proposed a salient image extraction algorithm based on improved histogram equalization. By improving the cumulative probability density function, the image distortion is effectively avoided. The local equalization method is introduced to preserve the details. Compared with the traditional histogram equalization algorithm, the enhanced image target of the algorithm is more prominent and the histogram distribution is more uniform [12].

Jawad processes the illuminance component of the underwater image through segmented histogram equalization, and multiplies the result with the original detail layer image, which can enhance the contrast of the underwater image and retain its detail information [13].

It can be seen that in order to solve the problem of quality degradation in the process of image transmission, it is a widely used idea to transform the image to different domains or channels for interception. Inspired by this, this paper introduces the semi supervised algorithm in Fourier transform domain and proposes a new image enhancement strategy to solve the problem of vehicle bottom image enhancement.

II. PROPOSED METHOD

2.1 Semi Supervised Fourier Enhancement Method

From the correspondence between image spatial domain and Fourier transform domain, it can be seen that the decrease of contrast caused by image loss in compression coding is closely related to the loss proportion of Fourier coefficients, and shows a positive correlation. Therefore, if the lost Fourier coefficients can be found in the Fourier transform domain, it is possible to recover the lost image information, improve the image contrast and achieve the purpose of image enhancement.

For the image f with resolution size $M \times N$, Fourier transform is performed as follows:

$$F(u,v) = F^{H}(M-u, N-v), (u,v) \in X \tag{1}$$

If image information $F(u,v)$ of and $F(M-u,N-v)$ disappeared, set the following sets:

$$\begin{gathered} K = \{(u,v) \in X \mid F(u,v) \text{Exist}\} \\ L = \{(u,v) \in X \mid F(u,v) \text{missing}, uv \neq 0\} \\ L' = \{(u,v) \in X \mid F(u,v) \text{missing}, uv = 0\} \\ \Gamma = \{(x,y) \in X \mid (x,y) \text{is } anauxiliarypo\text{int}\} \end{gathered} \tag{2}$$

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For any pixel position, the result of inverse transformation is as follows:

$$f(x,y)=\frac{1}{MN}\left(\sum_{(u,v)\in K}F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}+\sum_{(u,v)\in L\cup L'}F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}\right) \tag{3}$$

Further define the following sets:

$$\begin{aligned}
L_1 &= L\bigcap(\{1,2,\cdots,\lfloor M/2\rfloor\}\times\{1,2,\cdots,\lfloor N/2\rfloor\}) \\
L_2 &= L\bigcap(\{1,2,\cdots,\lfloor M/2\rfloor\}\times\{\lceil N/2\rceil,\cdots,N-1\}) \\
L_3 &= L\bigcap(\{\lceil M/2\rceil,\cdots,M-1\}\times\{1,2,\cdots,\lfloor N/2\rfloor\}) \\
L_4 &= L\bigcap(\{\lceil M/2\rceil,\cdots,M-1\}\times\{\lceil N/2\rceil,\cdots,N-1\})
\end{aligned} \tag{4}$$

In this way, the following relationship is obtained:

$$\sum_{(u,v)\in L_4}F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}=\sum_{(u,v)\in L_1}F^H(u,v)e^{-2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)} \tag{5}$$

$$\sum_{(u,v)\in L_3}F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}=\sum_{(u,v)\in L_2}F^H(u,v)e^{-2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)} \tag{6}$$

By further completing the expansion derivation, we can get:

$$\begin{aligned}
&\sum_{(u,v)\in L}F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)} \\
&=\sum_{(u,v)\in L_1}\left(F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}+F^H(u,v)e^{-2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}\right) \\
&+\sum_{(u,v)\in L_2}\left(F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}+F^H(u,v)e^{-2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}\right)
\end{aligned} \tag{7}$$

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$$= \sum_{(u,v)\in L_1} 2\left\{G(u,v)\cos\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right] - H(u,v)\sin\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right]\right\}$$

$$+ \sum_{(u,v)\in L_2} 2\left\{G(u,v)\cos\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right] - H(u,v)\sin\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right]\right\}$$

$$= \sum_{(u,v)\in L_1\cup L_2} 2\left\{G(u,v)\cos\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right] - H(u,v)\sin\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right]\right\}$$

So far, the following results are obtained:

$$\begin{aligned} f(x,y) &= \frac{1}{MN}\sum_{(u,v)\in K} F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)} \\ &+ \sum_{(u,v)\in L_1\cup L_2} 2\left[G(u,v)\cos\left(2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right)\right] \\ &- \sum_{(u,v)\in L_1\cup L_2} 2\left[H(u,v)\sin\left(2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right)\right] \end{aligned} \tag{8}$$

If you can get$\tilde{F}$, you can find the lost image information, first consider the following relationship:

$$\hat{f}(x,y) = \frac{1}{MN}\left(\sum_{(u,v)\in K} F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)} + \sum_{(u,v)\in L\cup L'} \tilde{F}(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}\right) \tag{9}$$

$$\tilde{f}(x,y) := \hat{f}(x,y) - \frac{1}{MN}\sum_{(u,v)\in K} F(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)} \tag{10}$$

By combining the above two equations, we can further deduce that:

$$\tilde{f}(x,y) = \frac{1}{MN}\sum_{(u,v)\in K} \tilde{F}(u,v)e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)} \tag{11}$$

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$$+\sum_{(u,v)\in L_1\cup L_2} 2\left\{\tilde{G}(u,v)\cos\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right]\right\}$$

$$-\sum_{(u,v)\in L_1\cup L_2} 2\left\{\tilde{H}(u,v)\sin\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right]\right\}$$

The above formula can be expressed as a simplified matrix:

$$\tilde{f} = Sx \tag{12}$$

Here,

$$S = \frac{1}{MN}\left[\overbrace{P}^{(u,v)\in L'} \mid \overbrace{A}^{(u,v)\in L_1\cup L_2} \mid \overbrace{B}^{(u,v)\in L_1\cup L_2}\right]\}(x,y)\in\Gamma \tag{13}$$

$$\tilde{f} = \left(\tilde{f}(x,y)\right)_{(x,y)\in\Gamma}, x = \begin{bmatrix} p\}(u,v)\in L' \\ g\}(u,v)\in L_1\cup L_2 \\ h\}(u,v)\in L_1\cup L_2 \end{bmatrix} \tag{14}$$

$$\begin{cases} P_{r,p} = e^{2\pi j\left(\frac{ux}{M}+\frac{vy}{N}\right)}, r := (x,y)\in\Gamma, p := (u,v)\in L' \\ A_{r,s} = 2\cos\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right], r : (x,y)\in\Gamma, s := (u,v)\in L_1\cup L_2 \\ B_{r,t} = -2\sin\left[2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right], r : (x,y)\in\Gamma, t\in L_1\cup L_2 \end{cases} \tag{15}$$

So far, we have obtained the results we want:

$$\tilde{F}(u,v) = \begin{cases} p(u,v), (u,v)\in L' \\ g(u,v) + jh(u,v), (u,v)\in L_1\cup L_2 \end{cases} \tag{16}$$

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2.2 Solution of Fourier Enhancement Equation

In the previous section, the Fourier coefficient equation corresponding to image information restoration and enhancement is constructed, but it is very difficult to solve formula (12) and it is difficult to find an accurate solution.

Therefore, an approximate solution method capable of solving formula (12) is constructed in this section.

First, perform the following decomposition:

$$S = U \sum V^{H} \tag{17}$$

Here, U and V are unitary matrices. Use separately σ_1^2, $\sigma_2^2 \ldots \sigma_n^2$ express the singular value of formula (7), then:

$$\sigma_1^2 \le \sigma_2^2 \le \cdots \le \sigma_n^2 和 \begin{cases} \sigma_i^2 > 0, i = 1, \cdots, r \\ \sigma_i^2 = 0, i = r+1, \cdots, n \end{cases} \tag{18}$$

Further, the following matrix is defined according to singular values:

$$\sum = \begin{bmatrix} \sigma_1 & & & & & & \\ & \sigma_2 & & & & & \\ & & \ddots & & & & \\ & & & \sigma_r & & & \\ & & & & 0 & & \\ & & & & & \ddots & \\ & & & & & & 0 \end{bmatrix} \tag{19}$$

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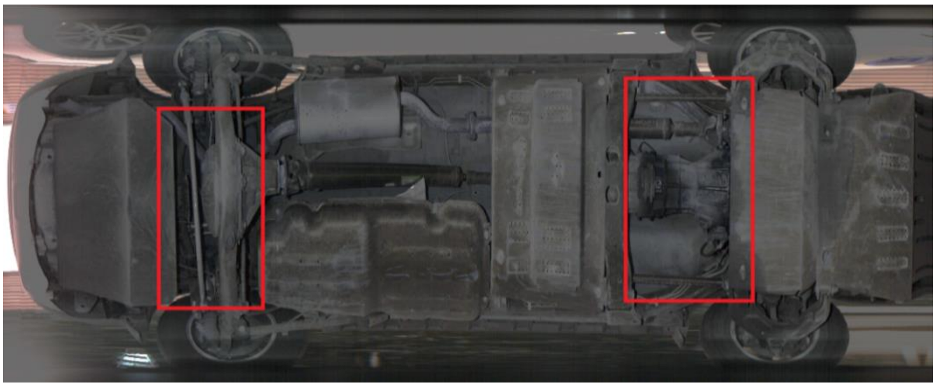
$$\Sigma^{+} = \begin{bmatrix} \sigma_1^{-1} & & & & & & \\ & \sigma_2^{-1} & & & & & \\ & & \ddots & & & & \\ & & & \sigma_r^{-1} & & & \\ & & & & 0 & & \\ & & & & & \ddots & \\ & & & & & & 0 \end{bmatrix} \tag{20}$$

At this time, the approximate solution of formula (2) can be obtained:

$$x = S^{+}\overline{f} \tag{21}$$

III. EXPERIMENTAL RESULTS AND ANALYSIS OF VEHICLE BOTTOM IMAGE ENHANCEMENT

Next, the practical effect of this algorithm is investigated by the specific underbody image enhancement results. As shown in Figure 1, it is the experimental result of thorough image enhancement using the algorithm in this paper. In the experiment, the algorithm performs 40 iterations and 80 iterations respectively.



(a) original vehicle bottom

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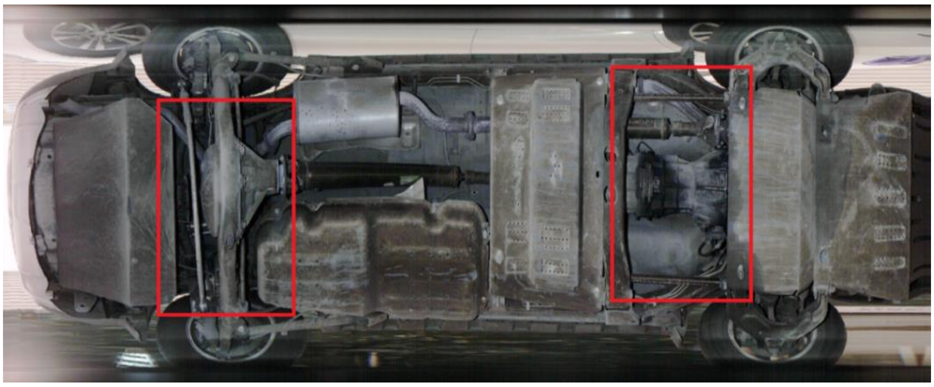
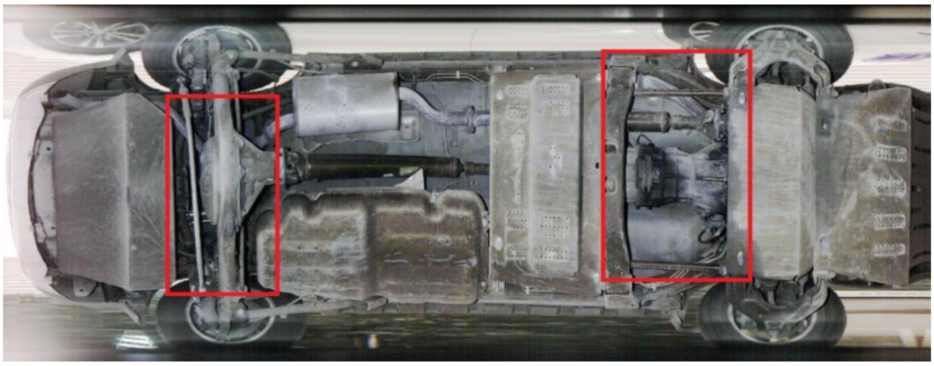


(b) enhancement effect after iteration 40



(c) enhancement effect after iteration 80

Fig 1: In this paper, the algorithm enhances the image of the vehicle bottom under different iterations

It can be seen from the results in Fig. 1 that the original underbody image shown in Fig. 1 (a) has low contrast and blurred detail features. After the enhancement processing of the algorithm in this paper, the visual effects of Fig. 1 (b) and Fig. 1 (c) have been greatly improved. In comparison, the enhancement effect of Fig. 1 (c) is better and ideal. After enhancement, the contrast of the resulting image has been significantly improved, and the detailed features of the underbody have become clearly visible.

In the following experiments, 80 iterations are taken as the standard iteration times of the method in this paper, and the truncated support vector machine enhancement method (TSVD) with better enhancement effect is selected as the comparison method to enhance and compare the three groups of underbody images. The results are shown in Figure 2.

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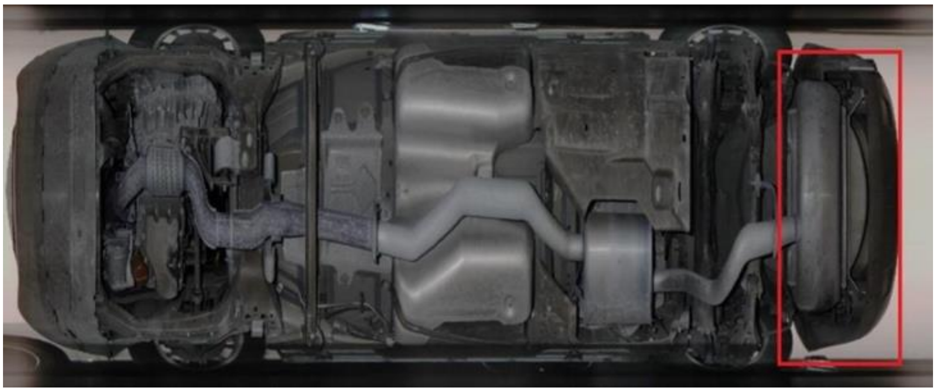
(a) original image of the first set of underbody images



(b) enhancement results of TSVD method

(c) enhancement results of our method

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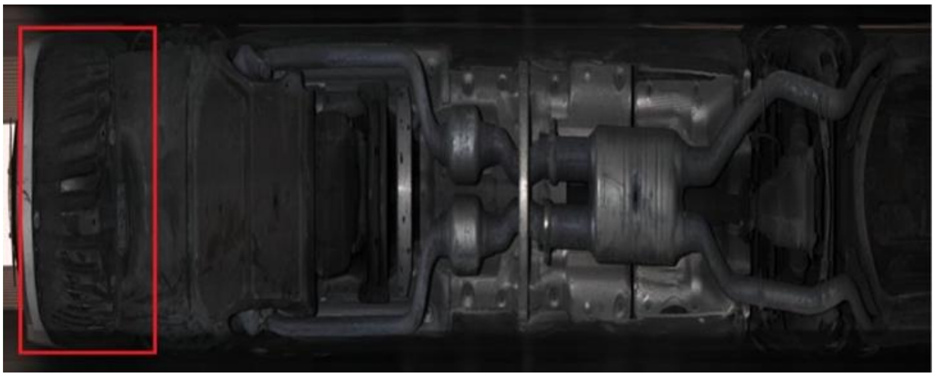
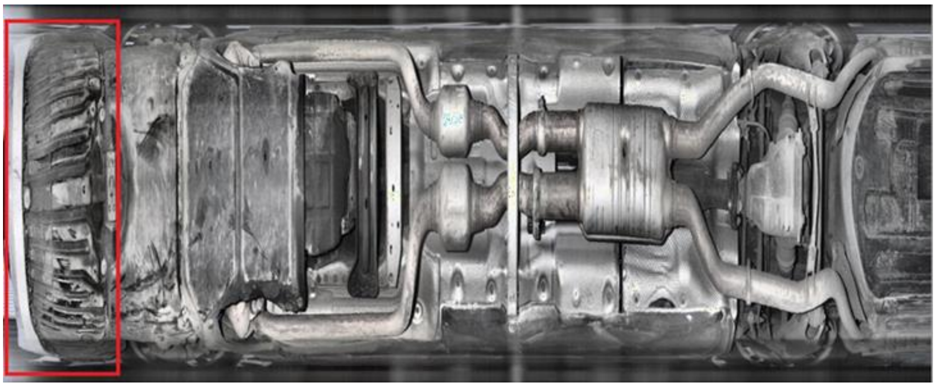
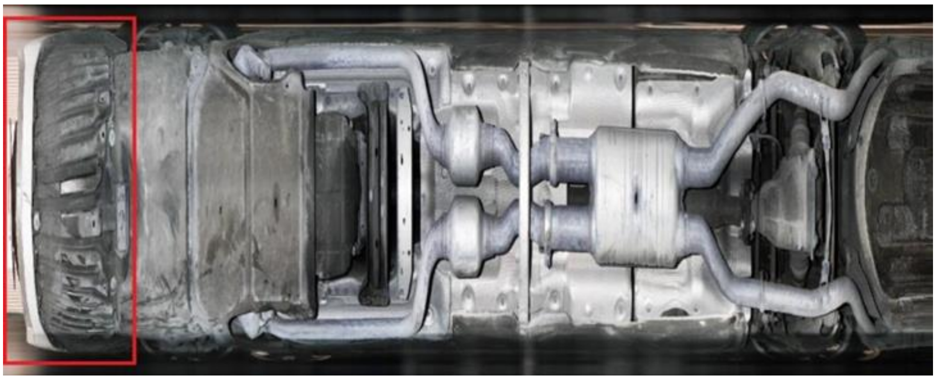


(d) original image of the second set of underbody images



(e) enhancement results of TSVD method



(f) enhancement results of our method

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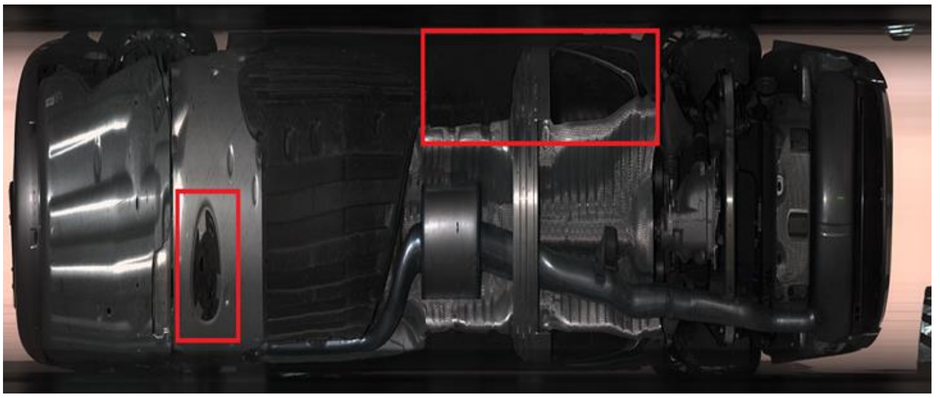
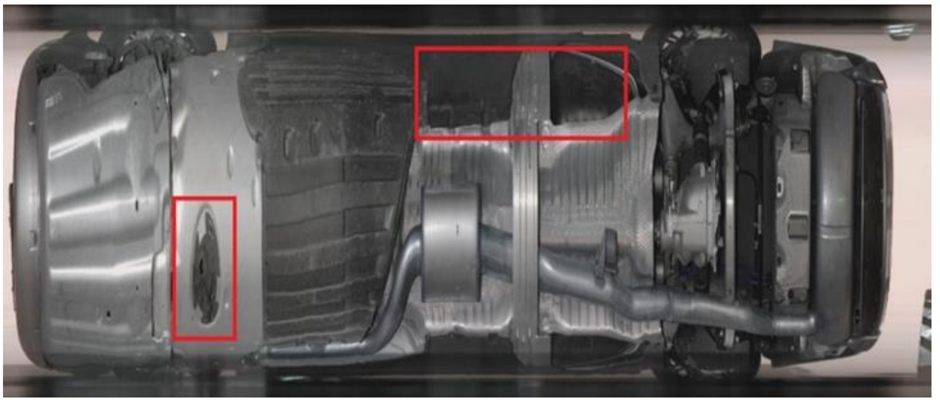
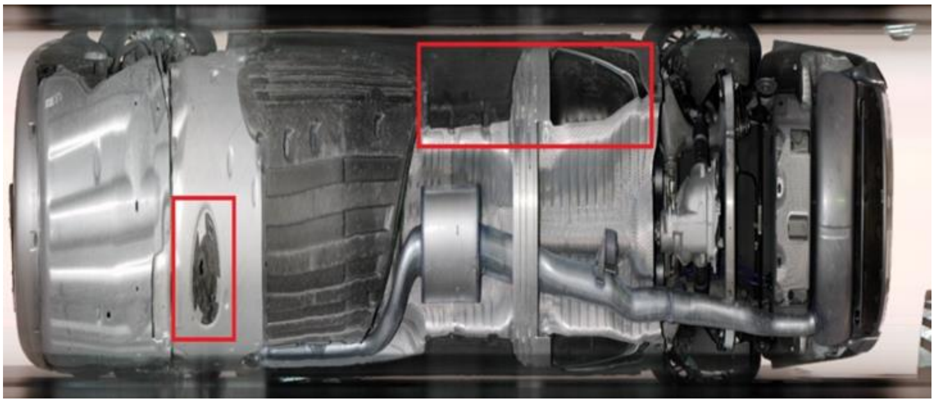


(g) original image of the third set of underbody images



(h) enhancement results of TSVD method



(i) enhancement results of our method

Fig 2: Comparison of enhancement effects of two methods

Figure 2 (a-i) shows three groups of original underbody images and the image enhancement effect obtained by TSVD algorithm and this algorithm. In the three images (a), (b) and (c), TSVD algorithm and

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this algorithm can effectively enhance the image. This algorithm has better edge contrast than TSVD algorithm in the rear of the vehicle where the edge such as the red area is located. In the three images (d), (e) and (f), the edge processing of the algorithm in this paper is better in the texture details of the front of the vehicle. In the three images (g), (h) and (i), the algorithm in this paper shows more transformation information in the dark area of black surface than TSVD algorithm, and can obtain better visual effect.

To sum up, compared with TSVD algorithm, this algorithm can better improve the contrast of underbody image, and it has good enhancement effect and good robustness under different underbody images.

In order to more objectively verify the effectiveness of the algorithm in the real underbody scanning image, the peak signal-to-noise ratio is used as the image objective evaluation standard. The peak signal-to-noise ratios of the two algorithms in the three groups of experiments in Figure 2 are shown in TABLE I.

TABLE I. Peak Signal-to-Noise Ratio Comparison Results of the Two Methods

Method	TSVD	Our Method
Vehicle Bottom 1	14.731	19.717
Vehicle Bottom 2	11.177	19.298
Vehicle Bottom 3	17.154	23.603

According to the data in TABLE I, compared with TSVD algorithm, the image enhancement algorithm proposed in this paper can fully improve the image quality of the underbody, and the enhanced image has a higher peak signal-to-noise ratio.

IV. CONCLUSION

Affected by the shooting environmental conditions, the contrast of the underbody image is low and the local detail features are not clear. Limited by transmission conditions, the underbody image needs to be compressed and encoded before transmission, resulting in the loss of some image information. To solve these two problems, this paper proposes a new image enhancement method in the Fourier transform domain. Through the construction of a new Fourier transform equation, an approximate solution method is designed to obtain the approximate solution of the missing part of the Fourier coefficient. This can not only restore the exact information of the image, but also improve the contrast of the image. The experimental results show that when the number of iterations is 80, for three different groups of underbody image enhancement, the algorithm in this paper obtains better enhancement effect. The enhanced image contrast is significantly enhanced, the local detail features are clearer, and the enhanced image also has higher peak signal-to-noise ratio.

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