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An improved method for image denoising based on fractional-order integration

Key words: Fractional-order integral; Cauchy integral; Image denoising; Fractional gradient; Texture protection

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Motivation

1. With the rapid development of computer technology, digital image filtering technology has been widely used. Image denoising is an important part of image filtering.

2. Several discretization methods of fractional calculus have been studied in detail and applied to image processing, and good numerical simulation results have been obtained.

3. The fractional-order integral operator has low-pass characteristic, and some details of the image will be damaged because of the multi-iteration process.

Main idea

1. In the denoising process, the proposed method sets a higher order of small integral to construct the denoising mask in the increasing stage of signal-to-noise ratio (SNR).

2. At the beginning of the decrease of SNR, a lower order of the micro-integral has been set to construct the denoising mask, and a compensation mechanism has been used to partially restore the edge and texture information of the image.

3. The corresponding image denoising mask can be constructed by setting the micro-integration order, and the local fine-tuning of the noisy image can be realized by combining large iteration numbers.

Method

1. The basic principle of the image denoising model based on fractional integration is to introduce two parameters, i.e., integral order *v* and iteration number *n*.

2. In the iterative denoising process, the fractional gradient modulus of the image is obtained by the fractional differential mask operator of eight pixel directions.

3. The intensity of image edge compensation is determined by the classical mathematical model using the fractional gradient modulus as the parameter.

Major results

1. Contrast images and horizontal lines by the Grünwald-Letnikov (G-L) method and the proposed method

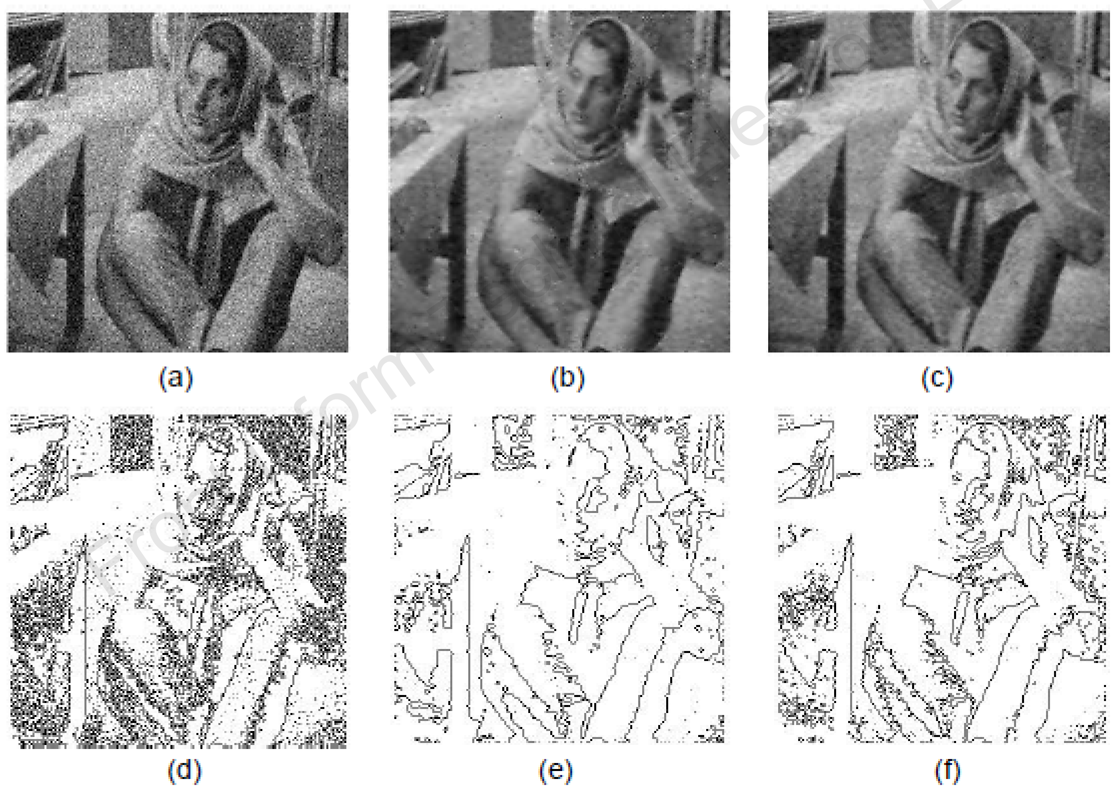

Fig. 1 Noise image (a), denoising effect of the Grünwald-Letnikov (G-L) method (b), denoising effect of the proposed method (c), horizontal line image of the noise image (d), horizontal line image of the G-L method (e), and horizontal line image of the proposed method (f)

Major results (Cont'd)

2. Denoising performance comparisons between the proposed method and G-L method

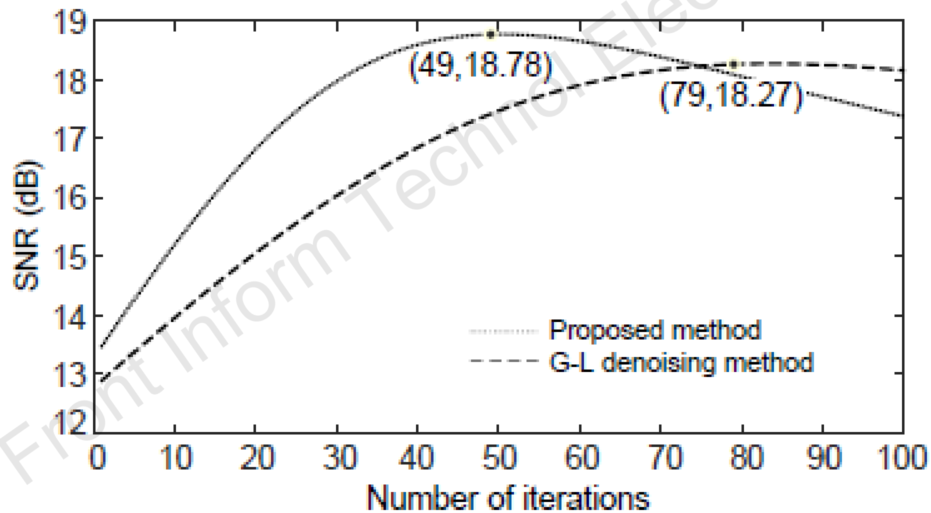

Fig. 2 Denoising performance comparison between the proposed method and the G-L method

Major results (Cont’d)

3. Denoising effects of different image denoising methods

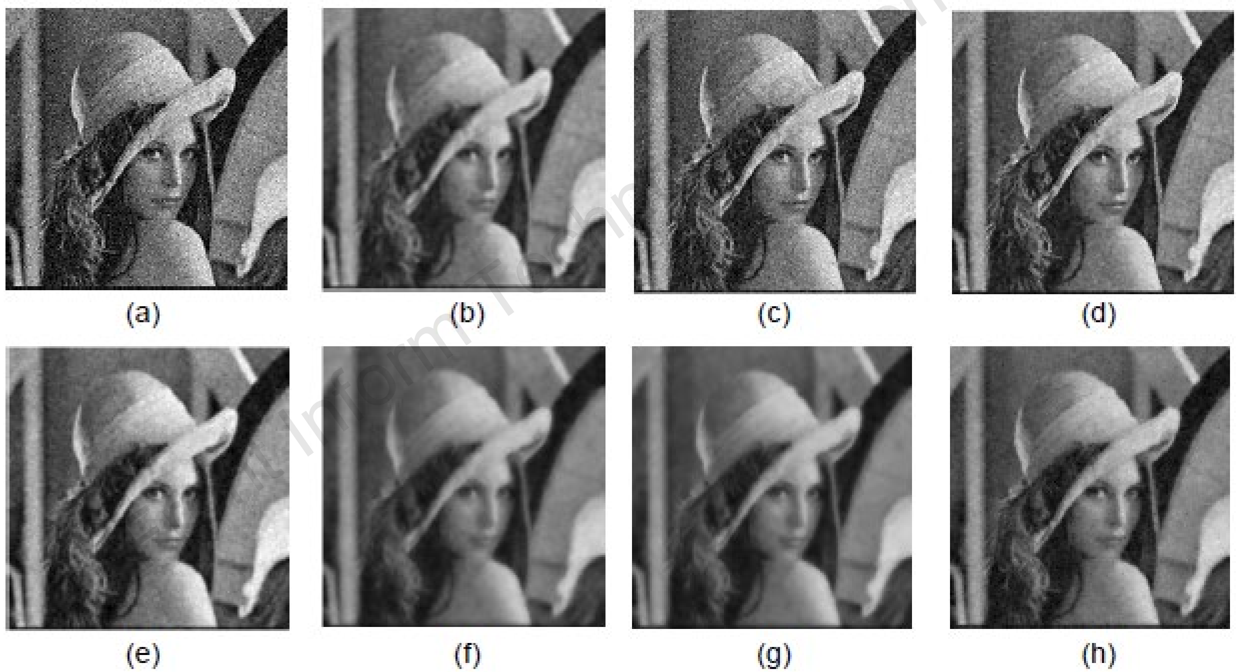

Fig. 3 Noise image (a) and the denoising effect obtained by the mean denoising method (b), Gaussian method (c), Wiener method (d), G-L method (e), PDE method (f), NLM method (g), and the proposed method (h)

Major results (Cont'd)

4. Horizontal lines of the denoised image obtained by different image denoising methods

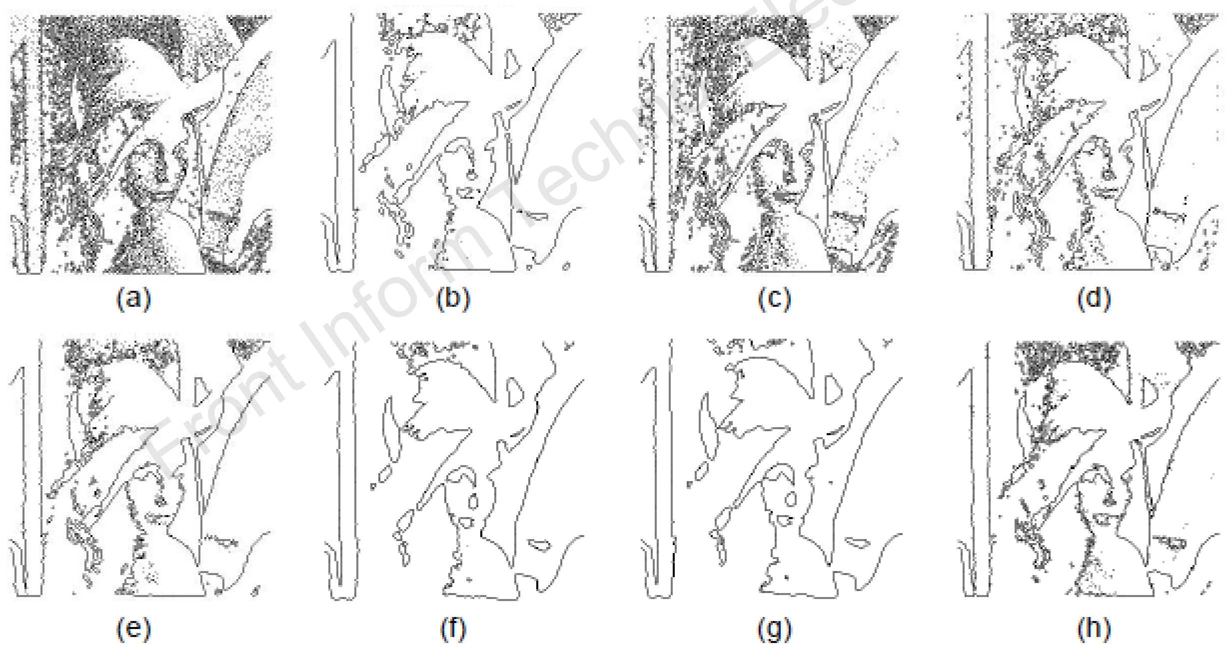

Fig. 4 Noise image (a) and horizontal line images obtained by the mean denoising method (b), Gaussian method (c), Wiener method (d), G-L method (e), PDE method (f), NLM method (g), and the proposed method (h)

Major results (Cont'd)

5. Performance comparison of the Lena image processed by different image denoising models

Table 1 Performance comparison of Lena image processed by different image denoising models

Method	MSE	SNR (dB)	AG	EPI
Mean denoising	0.0049	14.6732	10.5327	2.3962
Gaussian	0.0042	15.6993	11.2498	2.8953
Wiener	0.0041	16.5922	11.3890	3.0242
G-L	0.0039	17.1527	12.0012	3.2189
PDE	0.0038	17.2315	11.8965	3.1682
NLM	0.0036	17.9212	13.6793	3.7639
Proposed method	0.0034	18.2165	13.5985	3.7038

Conclusions

1. A new fractional-order integral denoising method has been proposed which uses the fractional gradient modulus to control the intensity of edge compensation.

2. Simulation results showed that the proposed image denoising method can protect the edge texture information of the image while removing the noise.

3. This method can obtain higher image feature values and better image vision after denoising than the existing denoising methods, because a texture protection mechanism is adopted during the iterative processing.

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