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Adaptive contourlet-wavelet iterative shrinkage/thresholding for remote sensing image restoration

Key words: Image restoration, Adaptive, Cartoon-texture decomposition, Linear search, Iterative shrinkage/thresholding

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Motivation

- Disadvantages of existing methods:
  - ✓ Poor signal-to-noise ratio
  - ✓ Large computation cost

- We propose an adaptive two-step contourlet-wavelet iterative shrinkage/thresholding (TcwIST) algorithm for remote sensing image restoration, to achieve a signal-to-noise ratio improvement (ISNR) for image restoration and high convergence speed.

Features of our method

- The split Bregman Rudin-Osher-Fatemi (ROF) model is used
- It is an adaptive method
- A linear search method is used
- It accelerates convergence.

Framework of our method (I)

The algorithms of auto-phase correction can be divided into two parts.

1. Image decomposition model

By using this kind of decomposition method, we can deal with the different image parts to achieve good image restoration results.

Algorithm 2 Image decomposition model represented by curvelet and DCT

Initialization: $\boldsymbol{u}=\boldsymbol{v}=\boldsymbol{0}$, $\boldsymbol{\theta}_u=\boldsymbol{\theta}_v=\boldsymbol{0}$

while 'not converged' **do**

Update $\boldsymbol{u}$ by $\boldsymbol{u}^{n+1} = P_{\text{ROF}}(\boldsymbol{x} - \boldsymbol{T}_v\boldsymbol{\theta}_v^n, \lambda)$

Update $\boldsymbol{v}$ by

$$\boldsymbol{v}^{n+1} = \boldsymbol{x} - \boldsymbol{T}_u\boldsymbol{\theta}_u^n - P_{\text{ROF}}(\boldsymbol{x} - \boldsymbol{T}_u\boldsymbol{\theta}_u^n, 1/\mu)$$

end while

Framework of our method (II)

2. Gradient-based shrinkage/thresholding algorithm

2.1 Optimization problem

$$f(\boldsymbol{\theta}) = \frac{1}{2} \| \boldsymbol{y} - \boldsymbol{R}\boldsymbol{W}^{-1}\boldsymbol{\theta} \|_2^2 + \tau\phi(\boldsymbol{\theta}).$$

2.2 Existing gradient-based algorithm(s)

(1) IST
(2) TwIST
(3) FISTA

2.3 Threshold rule

(1) Hard Shrinkage Function
(2) Soft Shrinkage Function
(3) Compromise Shrinkage Function

Framework of our method (III)

3. Contourlet-wavelet iterative shrinage/thresholding algorithm

3.1 Description of the proposed algorithm

$$f(\boldsymbol{x}) = \frac{1}{2} \| \boldsymbol{y} - \boldsymbol{A}\boldsymbol{x} \|_2^2 + \tau_{\mathrm{c}} \boldsymbol{\Psi}_{\mathrm{c}}(\boldsymbol{x}) + \tau_{\mathrm{w}} \boldsymbol{\Psi}_{\mathrm{w}}(\boldsymbol{x})$$

3.2 Parameter selection

(1) Shrinkage Threshold
(2) Regularization Parameter
(3) Iterative Step-Length

3.3 Convergence of TcwIST and the stopping criterion

Major results (I)

Image restoration results (for a comprehensive analysis):

Table 2 Experimental results for the comparison of different methods

	Method	ISNR				Number of iterations			
		Exp 1	Exp 2	Exp 3	Exp 4	Exp 1	Exp 2	Exp 3	Exp 4
Vegetated surface	IST	12.0117	5.8891	2.5235	−1.9004	30	127	90	72
	FISTA	12.6477	5.4166	2.4206	−3.8022	10	97	77	69
	TwIST	11.6069	0.0631	2.2701	−16.3308	19	51	24	70
	TcwIST	12.6298	6.4389	2.8450	1.9142	7	29	21	19
Beijing airport	IST	12.2667	4.3813	3.2175	−2.7629	14	110	83	70
	FISTA	12.2489	4.0793	2.9580	−4.6344	10	87	71	68
	TwIST	12.0773	−1.1992	−4.8401	−17.2974	10	39	47	73
	TcwIST	12.2865	5.1783	4.1338	2.2261	8	15	42	10
Water body	IST	5.7042	1.7555	1.5322	−5.7278	13	86	58	68
	FISTA	5.6216	0.3155	0.2627	−7.9396	10	77	57	67
	TwIST	5.5557	−7.1274	−12.6817	−21.1395	9	44	53	80
	TcwIST	5.6931	4.0123	3.1182	3.6309	7	24	16	7

Major results (II)

ISNR and the objective function along iterations:

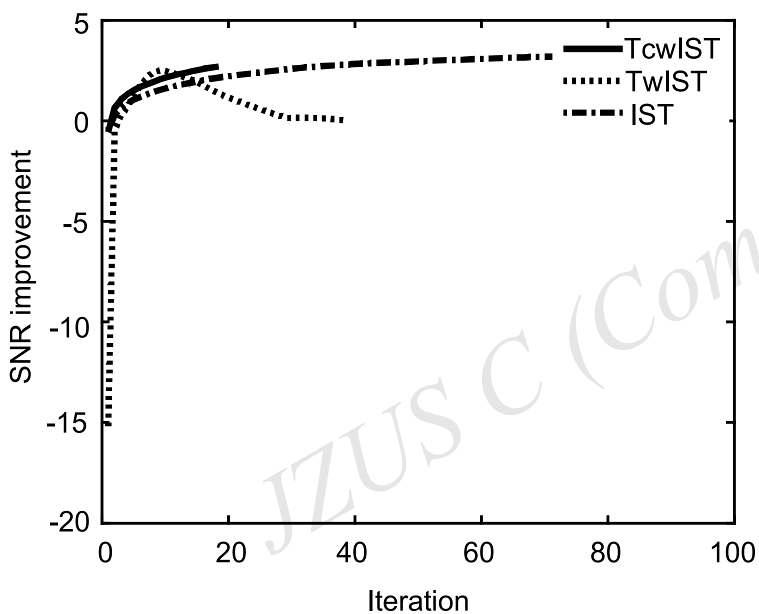

Fig. 7 Image deconvolution of cameraman image in Experiment 3: evolution of the SNR improvement produced by TcwIST, TwIST, and IST for the first 100 iterations

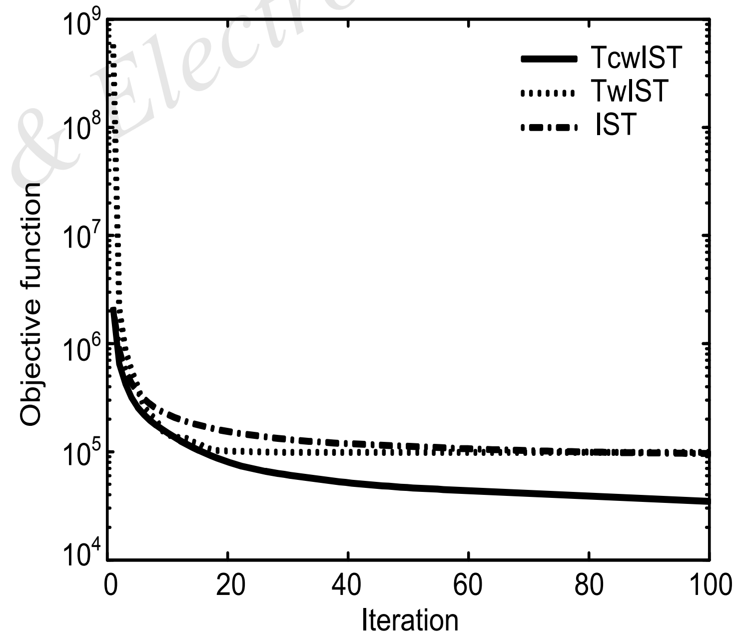

Fig. 8 Convergence speed comparison of cameraman image in Experiment 2. Objective function values of TcwIST, TwIST, and IST for the first 100 iterations