A Bayesian Joint Decorrelation and Despeckling approach for speckle reduction of SAR Images

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Abstract

In this paper, we present a novel approach for joint decorrelation and despeckling of synthetic aperture radar (SAR) imagery. An iterative maximum a posterior estimation is performed to obtain the correlation and speckle-free SAR data, which incorporates a correlation model which realistically explores the physical correlated process of speckle noise on signal in SAR imaging. The correlation model is determined automatically via Bayesian estimation in the log-Fourier domain and patch-wise computation is used to account for spatial nonstationarities existing in SAR data. The proposed approach is compared to a state-of-the-art despeckling technique using both simulated and real SAR data. Experimental results illustrate its improvement in preserving the structural detail, especially the sharpness of the edges, when suppressing speckle noise.

1 Introduction

Synthetic Aperture Radar (SAR) has competitive advantages: complementary information to optical systems, penetration of radar waves, weather independent, day-and-night imaging capability and geometric resolution independent of the distance. It has good applications in numerous areas, such as sea-ice monitoring and land cover classification [1, 2]. However, SAR data is facing a challenge with speckle noise which is a granular 'noise', inherently exists in and degrades the quality of SAR data [2]. Speckle noise removal is a nontrivial task and can be regarded as an estimation problem. Most of the methods proposed ignore the fact that there exists the correlation between neighboring backscatter signals, which results in correlated speckle pattern [4].

In this paper, a Bayesian joint decorrelation and despeckling approach is studied for considering the underlying correlation among a small window size of SAR data when despeckling. The key contribution is to account for decorrelation and despeckling as a whole by constructing a posterior probability model with consideration of decorrelation in the likelihood model and despeckling in the prior model.

2 The correlation model

To explore the correlation occurring in the propagation and scattering stage of SAR imaging process, the received image f in a small region w, denoted by f_w, is modeled as the convolution

$$f_w(x,y) = h_w(x,y) * r_w(x,y) = \iint_W h_w(x,y,m,n) \cdot r_w(m,n)\, dm\, dn, \quad (1)$$

where h_w denotes the radar point spread function (PSF) h in w, assumed to be spatially invariant, r_w is the reflectance function when scattering, $*$ denotes the operation of convolution and the system noise is not considered here for having little effect on the system. Furthermore, the log-Fourier transform of (1) as an additive separation form is $F_w{}^l = H_w{}^l + R_w{}^l$ where $F_w{}^l = log\{|F_w(u,v)|\}$, $H_w{}^l = log\{|H_w(u,v)|\}$ and $R_w{}^l = log\{|R_w(u,v)|\}$, and F_w, H_w and R_w are the Fourier transforms of f_w, h_w and r_w, respectively. Then the analytical solution for the Bayesian least square estimation of $\hat{H}_w^l$ is

$$\hat{H}_w^l(u,v) = E[H_w{}^l(u,v) | F_w{}^l(u,v)]. \quad (2)$$

There is no information known for the prior of H_w^l, so uniform is usually assumed in this situation. The likelihood can use Fisher-Tippett distribution based on the common Gaussian scatter model for R_w [1].

3 The Bayesian joint decorrelation and despeckling approach

After the PSF function h is estimated, the Maximum a Posterior estimation of r is to estimate r given f, which is expressed as

$$\hat{r} = argmax_r p(r|f) = argmax_r p(f|r)p(r) \quad (3)$$

with the likelihood

$$p(f|r) = \Pi_w L(h_w * r_w) \quad (4)$$

and the prior $p(r) = \Pi_w e^{-\frac{(r_w - E(r_w))^2}{2\sigma^2}}$.

4 Experimental results

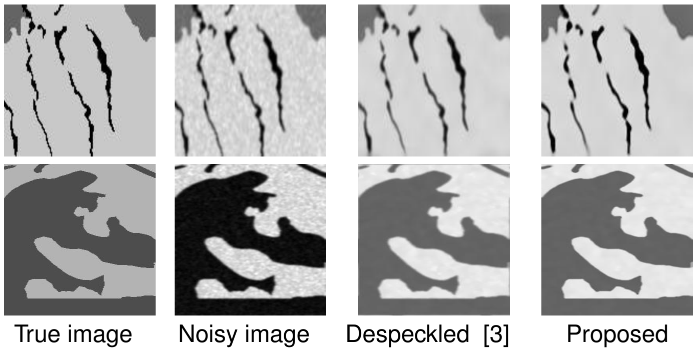

Fig. 1: Experimental results for simulated sea-ice SAR images.

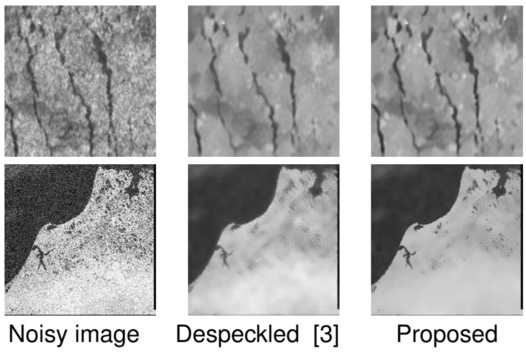

Fig. 2: Experimental results for real sea-ice SAR images.

To illustrate the efficacy of the proposed approach for improving structural detail while suppressing speckle noise, we applied the proposed approach as well as a state-of-the-art despeckling technique on both simulated (Fig. 1) and real (Fig. 2) SAR data. It can be observed in both cases that the proposed method provides noticeably improved detail preservation compared to the state-of-the-art method, while greatly reducing speckle noise compared to the original images. As such, the proposed joint decorrelation and despeckling method can have great potential for improving SAR image quality.

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