MULTIRESOLUTION FUSION IN REMOTELY SENSED IMAGES USING AN IGMRF PRIOR AND MAP ESTIMATION

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1. ABSTRACT

In this paper we propose a model based approach for multi-resolution fusion of satellite images. Given the high spatial resolution panchromatic (Pan) image and a low spatial and high spectral resolution multi-spectral (MS) image acquired over the same geographical area, the problem is to generate a high spatial and high spectral resolution multi-spectral image. This is clearly an ill-posed problem, which requires a proper regularization. We model each of the low spatial resolution MS images as the aliased and noisy versions of their corresponding high spatial resolution images. A decimation (aliasing) matrix is estimated for each of the MS bands by using the available Pan and the MS image. The high spatial resolution MS images to be estimated are then modeled as separate Inhomogeneous Gaussian Markov Random Fields (IGMRFs) and the Maximum A Posteriori (MAP) estimation is used to obtain the fused images. The required IGMRF parameters representing the spatial correlation among high resolution MS pixels are estimated from the available high resolution Pan image and are used in the prior model during the regularization. Since the method does not directly operate on the Pan pixel values as most of the other methods do, the spectral distortion is minimum and the spatial properties are better preserved in the fused image as the IGMRF parameters are learnt at every pixel. We demonstrate the effectiveness of our approach by conducting experiments on synthetic data as well as on real images captured by the Quickbird satellite.

2. INTRODUCTION AND PROBLEM STATEMENT

Multiresolution fusion is the process of combining a high spatial resolution panchromatic (Pan) image and a low spatial but high spectral resolution multispectral (MS) image to produce a high spatial and spectral resolution MS image. The area of multiresolution fusion is quite matured with many researchers attempting to solve the fusion problem for remote sensing applications [4, 2, 3, 1]. However, most multiresolution fusion methods operate directly on Pan pixel values in order to obtain the fused MS image. This may be a practical constraint affecting the fusion results when fusing the Pan and MS images acquired by different satellites. Here the Pan data may differ significantly from the MS images due to the change in sensor, but the spatial correlation does not get affected since the images are acquired over the same region. Also the upsampling of the MS image in these methods is achieved via standard interpolation techniques, which does not consider the aliasing present in the low resolution observation and causes the fused image to suffer from aliasing and hence introduces distortion in the final result.

In this paper we solve the multiresolution fusion problem based on a different concept called super-resolution. Towards this end, recently, in [5] we proposed an autoregressive (AR) prior model based multi-resolution fusion technique in which a fixed decimation matrix was used and few homogeneous AR parameters estimated globally from the Pan image were used for regularizing the solution. In the proposed method we choose to use an inhomogeneous IGMRF prior model to capture the spatial correlation among pixels in the high resolution MS image. This enables us to capture the smooth regions as well as the strong spatial variations due to edges. We estimate these inhomogeneous parameters directly from the available high resolution Pan image as both the MS and Pan images cover the same geographical area, and relate to the same underlying scene. We also infer the decimation matrix by considering the Pan and MS image pair. The advantage of our approach is that it is less influenced by the spectral properties of the high spatial resolution Pan image when compared to other standard methods, thus enhancing the spatial information of the fused MS images while keeping the spectral properties intact. Thanks to the estimated decimation matrix, the high frequency details are better preserved and the distortion due to aliasing is minimized.

3. BLOCK DIAGRAM DESCRIPTION OF THE PROPOSED METHOD AND EXPERIMENTS

The block diagram in Figure 1 illustrates the proposed fusion process for the \( n^{th} \) low resolution image and the Pan image with the result corresponding to the fused MS image. A low resolution MS image is modeled as an aliased and noisy version
Fig. 1. Illustration of the Multiresolution fusion process for a MS and a Pan image. Here LR and HR indicate low resolution and high resolution, respectively.

Fig. 2. Results for a synthetically generated and degraded checkerboard image. (a) 256 × 256 pixels high resolution checkerboard image. (b) Decimated and noisy version of (a) using a noise variance of 0.0004. (c) Estimated high resolution image using the proposed approach. (d) Bicubically interpolated image of (b).

of the corresponding high spatial and spectral resolution fused image. An initial estimate such as bicubic interpolation of the corresponding MS image could be used for optimization, but this is not mandatory. The decimation matrix is estimated from the high resolution Pan and the low resolution MS images, since it is part of the data term (likelihood term). The IGMRF parameters estimated from the Pan image are used in the prior term. A suitable optimization technique is used to minimize the global cost function, which is the sum of the data and prior terms, in order to estimate the unknown high resolution MS image. The optimization is carried out separately for each of the MS images thus obtaining a fused image for each of the MS bands. In Figure 2 we demonstrate the validity of our model with the experimentation on a simulated observation by considering a spatial resolution difference of 2. It can be clearly seen that the noise in the reconstructed image using the proposed approach is very much reduced and the edges appear sharper.

4. CONCLUSIONS

We propose a method for the multiresolution fusion of remotely sensed images that does not directly use the Pan image pixel values, but exploits the spatial correlation among pixels in the form of IGMRF parameters estimated from the Pan image. The advantage of the proposed approach is the better performance in terms of both the spectral and the spatial fidelity when compared to other standard approaches.

5. REFERENCES


