NEW QUALITY REPRESENTATION FOR HYPERSPECTRAL IMAGES

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ABSTRACT:

Assessing the quality of a hyperspectral image is a difficult task. However, this assessment is required at different levels of the instrument design: evaluation of the signal to noise ratio necessary for a particular application, determining the acceptable level of losses from compression algorithms for example. It has been shown previously that a combination of five quality criteria can provide a good evaluation of the impact of some degradation on applications, such as classification algorithms for example. This paper refines this concept, providing a representation of the degradation which allows predicting the impact on applications.

1 INTRODUCTION

Quality criteria should be easily applicable to measure the loss of information caused by compression or by any other forms of processing. In the case of ordinary 2D images, a quality criterion has often to reflect the visual perception of a human observer. This is not the case for hyperspectral images, which are first aimed to be used through classification or detection algorithms. Therefore, quality criteria have to be relevant to these corresponding applications. For example, some papers ([Ryan and Arnold, 1997], [Hu et al., 2004], [Qian, 2004]) address the problem of evaluating compression impact on specific hyperspectral applications. However, quality evaluations within the context of specific applications are heavy to conduct as they require in-depth knowledge of these applications.

In a previous work [Christophe et al., 2005], different degradations were applied to hyperspectral images: additive white noise, smoothing (spectral and/or spatial) with a lowpass filtering of the data, Gibbs effect (ringing around sharp changes) and JPEG 2000 compression [Taubman and Marcellin, 2002] using a multicomponent transform. Different images from the NASA/JPL AVIRIS hyperspectral airborne sensor were used for the experiments (Fig. 1). Finally, five quality criteria have been selected to give a valuable representation of the degradations affecting the hyperspectral data and their impacts on three different classification algorithms. These five quality criteria were found to be a good combination to discriminate between data degradation and appear to be almost orthogonal to each other. One advantage of this combination is the mix between local and global criteria for both spatial and spectral dimensions, thus enabling the detection of local and global degradations.

However, the way to use these measures was not detailed. The present paper proposes in the following section a graphic representation of the chosen quality criteria. A numerical method is then derived in section 3 from this representation to provide a way to identify the degradation nature if unknown and to predict its impact on a specific application. The interest of the proposed representation is finally illustrated and compared with traditional SNR-based measure.

(a) Moffett4 (b) Moffett3 (c) Harvard1

Figure 1: Different hyperspectral images used during the experiments. (a) and (b) are different parts from the f970620t01p02_r03 run from AVIRIS sensor on Moffett Field site. (a) presents uniform spatial area with strong spectral features. (b) is mixed area with city (strong spatial frequency features). (c) is from the f010903t01p01_r03 AVIRIS run over Harvard Forest, it contains mostly vegetation whose spectrum contrasts with man-made objects.

2 QUALITY REPRESENTATION

2.1 Efficient representation for five criteria

The five quality criteria retained in [Christophe et al., 2005] were the MAD, MAE, RRMSE, F_λ and $Q_{(x,y)}$. Denoting $I(x,y,\lambda)$ the original image, $\widetilde{I}(x,y,\lambda)$ the degraded image and $e_{\widetilde{I}} = I - \widetilde{I}$ (x, y being spatial dimensions and λ the spectral one), these five quality criteria are defined as

- Maximum Absolute Difference

$$\text{MAD} = \mathcal{L}_\infty(I - \widetilde{I}) = \max_{(x,y,\lambda)} \left\{ \left| e_{\widetilde{I}}(x,y,\lambda) \right| \right\}. \quad (1)$$

- Mean Absolute Error

$$\text{MAE} = \frac{\mathcal{L}_1(I - \widetilde{I})}{n_x n_y n_\lambda} = \frac{1}{n_x n_y n_\lambda} \sum_{x,y,\lambda} \left| e_{\widetilde{I}}(x,y,\lambda) \right|. \quad (2)$$

  where n_x, n_y and n_λ are the number of pixels for each dimension.