A methodology for data fusion evaluation based on synthetic images

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Abstract

This paper presents a methodology to produce synthetic images that reproduce real multi-spectral satellite images, which are suitable for the evaluation of image data fusion techniques.

1. Introduction

The number of satellite sensors acquiring high resolution images of the Earth is steady increasing in recent years. Most of these sensors use two complementary image modes – a multi-spectral image (M) and a higher spatial resolution panchromatic image (P). Some examples include the following sensors: IKONOS (multi-spectral image with 4m pixel and panchromatic image with 1m pixel), QuickBird (2.4m / 0.6m) or SPOT (5m / 10m, or 10m / 20m). The two images are often combined, resulting in a high spatial resolution multi-spectral image. This process is called image data fusion.

There are several methods used for image data fusion. The most widely used are the Intensity Hue Saturation (IHS), Brovey, Principal Components Analysis (PCA) and Wavelet Transform [1]. The quality of the fused image depends on the method used and on the data itself. The evaluation is usually based on visual analysis, or sometimes on statistics that analyze the similarity or the discrepancies between the fused and original products on a pixel by pixel and band by band basis [2]. However, for many remote sensing applications the objective is to extract information based on a combination of bands for areas with several pixels. An example is the production of average Normalized Difference Vegetation Index (NDVI) values for land parcels [3]. The impact of the data fusion process in these cases is not yet clearly understood.

The purpose of this work is to present a methodology, based on synthetic images, for evaluation of image data fusion techniques on a parcel basis.

2. Image data fusion using the IHS method

The IHS data fusion method is simple and quite effective. Its main limitation is the fact that the input multi-spectral image can only have 3 bands, each one of them considered as a color component in the Red, Green and Blue (RGB) model. Initially the RGB image is converted to the IHS color space. The intensity component is then replaced by the panchromatic image, after histogram normalization. The idea behind the process is the fact that the color component in the IHS model is decoupled from the image intensity. The final step is to convert the new IHS image back to the RGB color space [2], resulting in the fused image.

3. Synthetic test image generation

A methodology to produce synthetic test images was developed. The objective is to simulate land parcels of various sizes with different cover types. Initially the number of land cover types (c), the size of the smallest unit (u), the range of sizes (s) and a repetition parameter (r) are used to produce a base image. As an example, figure 1 shows the base image for c=5, u=4, s=4, r=2. The smallest squares on the top left section of this example have 4 by 4 pixels, while the largest ones on the lower right have 16 by 16 pixels (s=4). In this case r=2 means that there are 4 parcels for each size. The whole image is 80 by 80 pixels, with a total of 64 parcels. There are 4 single unit parcels (4 by 4 pixels), and generally 4 parcels of i * j units, with i,j=1,2,3,4. It is worth noting that two neighboring parcels always belong to different classes.

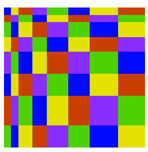

Fig. 1 – Synthetic base image (c=5, u=4, s=4, r=2)

3.1. Multi-spectral synthetic images

The base image and a reference satellite image are used to produce multi-spectral synthetic images. Reference areas need to be previously established in the multi-spectral satellite image, one for each land cover class considered (1, …, c). The multi-spectral synthetic image produced will have the same number of bands as the reference satellite image, with the pixel values of each class in the base image replaced by random vectors from the reference areas. A lower resolution version of this multi-spectral image is also produced (reduced by a factor of 2), as well as a full resolution panchromatic image.

3.2. Example

A SPOT satellite image was used as reference. The RGB color composite of bands 3, 2, 1 (near infrared, red, green) is presented in figure 2 (top), as well as a grayscale version with the 5 reference areas marked (bottom). The 5 land cover classes used were: irrigated and non-irrigated permanent semi-natural mountain meadows, evergreen forest, communitarian pastures and annual crops. Two multi-spectral synthetic images were created with u=3, s=8 and r=3: image I with c=4 and image II with c=5. The results are presented in figure 3, with a histogram linear enhancement.

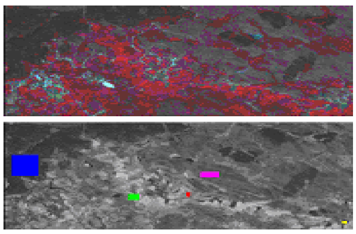

Fig. 2 – SPOT satellite image used as reference.

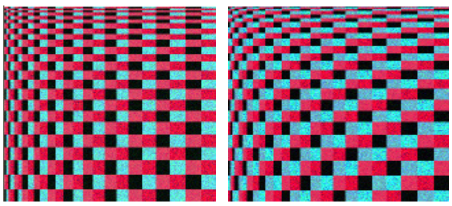

Fig. 3 – Multi-spectral synthetic images I (left) and II

4. Preliminary results and discussion

Each multi-spectral synthetic image was used to produce two NDVI images: one using the original multi-spectral data and another using the result of the IHS fusion of the reduced resolution multi-spectral image and the full resolution panchromatic image. The NDVI average values were computed for all 576 parcels in both images. A graphical representation of these NDVI values is presented in figure 4 for test image II. These results suggest that the average NDVI values based on the fused image tend to be slightly higher that the NDVIs computed from the original image for classes with low NDVI values, and the opposite occurs in the presence of high NDVI values. A similar result was obtained for test image I. The use of fused data to compute NDVI seems to result in a reduction of extreme values.

The linear correlation coefficient (r) between the original and fused NDVI was computed for each square shaped parcel. The results are presented in figure 5, as a function of the square size (in units, where 1 unit =3x3 pixels). As expected, the values of r increase with the size of the parcel. Further work need to be done to properly understand the impact of scale in derived products from satellite images, such as NDVI. Other fusion methods will also be investigated in the future.

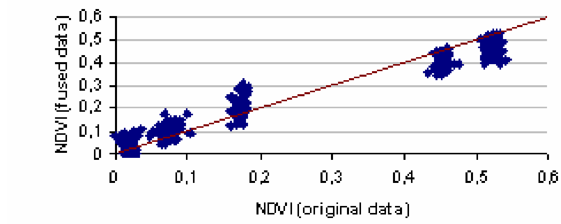

Fig. 4 - Average NDVI per plot for test image II

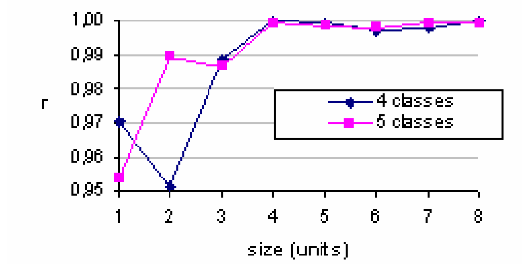

Fig. 5 - Linear correlation coefficient per parcel

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References

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