PROBLEMS AND PERSPECTIVES IN THE HIGH RESOLUTION DATA FUSION

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ABSTRACT

In this work, our attention has been focused on the prospects held by the introduction of high resolution. We have particularly tried to point out the difficulties and the advantages met in the fusion of high resolution and multispectral data through a simple application carried out in two phases. The first was aimed at the fusion of the data by means of a standard merging method based on the transformation RGB-IHS and the second was aimed at edge detection on the merged data by means of an algorithm based on fuzzy theory.

INTRODUCTION

In the field of remote sensing the rapid development of technology and the opening of the image market have made high spatial resolution data available.
Information availability opens new prospects of research on the possible applications and on the methods to be adopted, particularly in the data fusion field.
"Data fusion is a formal framework in which are expressed means and tools for the alliance of data originating from different sources" in order to attain "information of greater quality" [1].
In the last decade, in this field, the scientific community has worked out new methods for the joint processing of data of different nature, testing and investigating a number of techniques [2]. These techniques can be classified under the traditional distinction of data fusion into three categories [3]:

1) data level fusion, implying techniques that aim at the simple combination of the raw data from all the sensors taken into consideration;
2) feature level fusion, implying techniques for the extraction, combination and classification of feature vectors from all the considered sensors;
3) decision level fusion, implying techniques which aim at the combination of the outputs of the classifications achieved on each single source.

Within this context, the introduction of high resolution, and particularly of high spatial resolution, poses questions which, though apparently obvious, may have implications of remarkable interest in the field of research. In particular, we wonder about the problems which may arise when using these data jointly with others, what advantages may result from their use and, finally, what the most suitable techniques may be for the interpretation and the analysis of the integrated data. Urged by these questions and having two sets of data from two different sources available, we performed a simple application aimed at edge detection by means of merged information in order to point out both difficulties and advantages in high spatial resolution data fusion.

METHODOLOGY

The analysis was performed on the town of Reggio Calabria, Southern Italy (figure 1) by using two sets of data: an aerial photograph and a high resolution image.

Figure 1 – The considered area

The aerial photograph is a false colour slide (5712 columns per

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5640 rows) acquired in 1992 on a scale of 1:75.000, whose pixel size is equal to 4,7 about meters.

The high resolution panchromatic image (0.49-0.59 μM, 14626 columns per 15940 rows), acquired in 1994 by a KVR-1000 camera aboard a Cosmos series satellite, has a spatial resolution equal to 2x2 meters.

Before moving on to processing, two windows have been cut out from the images, equal to 4801 columns per 5332 rows for the aerial slide and 8292 columns per 9900 rows for the high resolution image, with the aim of bypassing those areas which are not contained in both images and reduce their dimensions in terms of megabytes. In order to attain the fusion of the images, the first step of processing has concerned the superimposition of two kinds of data.

The aerial slide was registered by means of ground control points and then resampled in comparison with the high resolution image.

Registration definitely is an extremely delicate stage and getting optimum results is not always easy. In our case, because of the morphological and orographic configuration of the ground taken into consideration, the superimposing of pictures that we attained along the coastline was extremely accurate (error below one pixel), unlike the inland mountainous area for which we were not able to achieve the same results.

Then, for the merging of the images we used a technique which is usually applied in these cases. The multispectral aerial slide was converted into IHS (intensity, hue, saturation) channels, which means coding the RGB display of the image in spherical or cylindrical co-ordinates in the IHS space.

The merging was realized by using the high spatial resolution image as a substitute for the computed intensity. The intensity channel was replaced by the high spatial resolution image and a reverse transform to RGB colour space was performed.

In this way, the lower resolution image was enhanced and the final image preserves the overall contrast and colours of the aerial slide and the resolution of the high spatial resolution image.

The step that followed the merging of the two sets of data consisted in the application of an edge detection algorithm by means of fuzzy membership functions, as proposed by Solaiman et al. [4]. The method, described in [4], is divided into two stages and aims at attributing an edge membership value to each processed pixel by means of the fuzzy masks.

The first stage aims at improving the quality of the images in question, by means of the Modified Nagao Filter (MNF). MNF is a modified version of the Nagao edge preserving smoothing filter, which yields better results than the original filter in terms of homogeneous regions smoothing.

The filter suggested makes use of 9 cliques surrounding each pixel. The grey level assigned to each pixel is given by the sum of the product of the mean value computed on each clique by the weight of the contribution of each clique. The weight of the contribution of each clique is equal to:

$$p_{\mathrm{i}} = \frac{1/\sigma_{\mathrm{i}}^2}{\sum_{\mathrm{j}=0}^{8} 1/\sigma_{\mathrm{j}}^2}$$

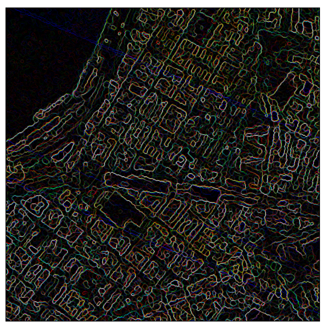
where $\sigma_{i,\, i\in\{0,\ldots,8\}}$ is the standard deviation value of the i$^{\mathrm{th}}$ clique.

The second phase of the analysis is concerned with singling out the edges by using the fuzzy masks. Let us take into consideration a 3x3 window centred over the considered pixel. It is possible to define 36 elementary 2D edge structures making up 36 fuzzy masks and representing 36 fuzzy sets. Each fuzzy mask is divided into two subregions: a homogeneous bright and a homogeneous dark region.

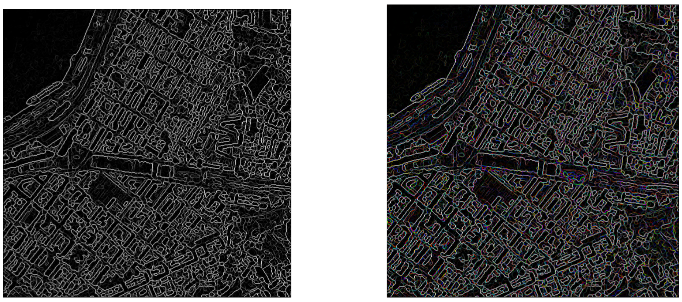
A membership value is computed for each fuzzy mask in the two subregions of the pixel at issue. The value ascribed to the pixel is the lower of the two computed membership values.

Once the calculations for the whole of the 36 fuzzy masks have been carried out, the final membership value of a pixel to the fuzzy set "Edge" is equal to the maximum membership of this pixel computed on the 36 fuzzy masks. The figure 2 shows the results attained by applying this algorithm onto the aerial slide, the high resolution image and the merged image.

a) official mapping (1:10.000)



b) aerial slide



c) high resolution image *d) merged image*

Figure 2 – Comparison of results

CONCLUSION

The most salient aspects emerged in the course of the analysis can be briefly summed up as follows.

In the first place, we have detected a practical difficulty in relation to processing time. In fact, the treatment of "extra-large" images was very expensive in terms of processing time. The huge size (hundreds of megabytes) of each image has greatly slowed down both the processing phases and the ordinary phases of data loading and storage, giving way to some difficulties.

Another difficulty to be taken into due account is connected with geometric correction proceedings. In our case, a major role as concerns this feature was played by the morphological nature of the considered area. But though the images at issue were not too dissimilar from the point of view of their spatial features, registration was not at all easy. Which makes us ponder over the problems which may arise when dealing with images whose spatial resolution differs too widely.

Among the advantages we have detected is an evident increase in the discrimination power. The joint employment of multispectral and high spatial resolution data improves beyond any possible doubt the capability of discriminating ground targets, also allowing easier map-making updating on a more detailed scale than in the past.

Heath contribution, achieved through data fusion, can both make visual interpretation considerably easier for the analyst and facilitate the computer-based interpretation processes.

This simple application has led us to ponder over the problems implied in high spatial resolution data fusion and the many themes that this particular research field may offer. The subjects we reckon are most likely to yield interesting results are those connected with:

- techniques of data compression, to get round some of the practical difficulties mentioned above. If on the one hand, rapid technological advancement provides us with more and more powerful hardware and software instruments, on the other, the "control" of image dimensions does allow an easier and rational use.
- algorithms aimed at improving the automatized processes of geometric "feature" extraction, taking into account the information concerning multispectral data and, therefore, "colour";
- classification methods, particularly those concerning imprecision and uncertainty, such as, for example, those based on Dempster-Shafer evidence theory, on consensus theory or on fuzzy logic;
- accuracy assessment of integrated data;
- definition of product quality standards.

A final consideration. We believe that it rests with the scientific community not only to open new research prospects, but also and more than anything else, to convey the potential which may result form the employment of these new data and foster their circulation among the final users, even through the performance of simple applications.

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