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Merging SPOT-P and KVR-1000 images for updating urban maps

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Abstract - **This communication presents a method allowing the combination of images acquired on the same area with different dates for updating urban maps. This method makes use of two mathematical tools, the wavelet transform and the multiresolution analysis which are shortly introduced. An example is provided in Jeddah (Saudi Aradia) for the updating of a KVR-1000 image by a SPOT panchromatic image acquired at a more recent date. Due to the difficulty to obtain KVR-1000 images at recent dates, this method allows the combination of the high spatial resolution of this kind of images and the regular acquisition of images by the different Earth observation satellites.**

I. INTRODUCTION

High spatial resolution images are necessary to urban mapping, due to the great accuracy needed for this type of application. Till the end of 1992, it is possible to acquire images from the russian sensor KVR-1000. These images are provided in the panchromatic band with a spatial resolution of 2 m. Before the end of the century, new civil missions with high spatial resolutions close to 1 or 2 m are planned and will answer to the need of accuracy for urban mapping. Unfortunately, these missions have a limited life time (KVR-1000) or may be limited in access because of cloud cover, repetitivity, site access, data access, operational constraints, ... These limitations may prevent the update of information content of the area of interest. This communication proposes to benefit from the operational SPOT missions to provide an update of urban area by the means of sensor fusion techniques. The merging process is based on the multiresolution analysis and the wavelet transform presented in section II. The merging process itself is presented in section III. An example of the merging of a KVR-1000 image with a more recent panchromatic image acquired by the SPOT satellite is explained in section IV. A comparison of the two dates of acquisition is provided, enhancing the necessity of the updating process. The benefits of using such a fusion approach are discussed.

II. WAVELET TRANSFORM AND MULTIRESOLUTION ANALYSIS

The merging process proposed is based on the wavelet transform and the multiresolution analysis. The multiresolution analysis was introduced by Mallat (1989). It allows the computation of successive approximations of the same image at coarser and coarser spatial resolutions. This can be represent by a pyramid, where the basis is the original image and the different approximations of the original image, the floors of the pyramid. The theoretical limit of this multiresolution analysis is a pixel that will represent the mean of the original image. In this representation, the difference of information existing between two successive approximations is represented by the wavelet coefficients computed from a wavelet transform. The wavelet basis is computed by dilatation and translation of an unique function called the mother wavelet. The image is decomposed on this basis, and a space-scale representation is obtained. The multiresolution analysis using the wavelet transform is an inversible operation and provided an exact reconstruction of the original image. Hence, from one approximation of the image and the different wavelet coefficients representing the differences of information between the original image and this approximation, it is possible to reconstruct exactly the original image.
Ranchin and Wald (1993) have presented some possibilities of use of these tools for the field of remote sensing. For a more mathematical introduction, one can refer for example to Mallat (1989), Rioul and Vetterli (1991), Daubechies (1992) and Meyer (1993).

III. MERGING METHOD

The data available for the urban mapping are:

- a high spatial resolution image A acquired at the first date,
- a most recent image B acquired with a spatial resolution lower than the first image one.

The two images are supposed to represent the same area and to be superposable.
If we considered that the image B contains the most update information, we need to give more importance to this image. But for urban mapping, the high spatial resolution is of great

importance due to the scales needed to well represented the different kind of structures in the area. So it is needed to preserve the fine details provided by the image A and to introduce them in the most recent representation, the image B. As explained in the previous section, the wavelet transform and the multiresolution analysis are two mathematicals tools very well-adapted to represent an image at different spatial resolutions and to modelize the difference of information between these resolutions.

The merging process will be the following. A multiresolution analysis using the wavelet transform is first applied to the image A, providing an approximation of the original image at a spatial resolution close to the image B resolution. The wavelet coefficients represent the difference of information between the spatial resolution of the image A and the one of the approximation computed. The differences represented by the wavelet coefficients and the image B, are used to reconstruct an image with the spatial resolution of the image A, the finest structures available in this image and the information content of the image B. In this approach, the geometrical information is privileged. The aim is not to preserve the spectral content of the original image as proposed in the ARSIS method (Ranchin *et al.* 1993), but to represent the most complete geometrical information.

IV. EXAMPLE

To illustrate this sensor fusion technique, an example is provided on a district of the town of Jeddah (Saudi Arabia). Figure 1 presents the KVR-1000 image acquired in March 16, 1991. This image has a spatial resolution of 2 m and a spectral range in the panchromatic band and represents an area of 1024 m by 1024 m. This district of the town is in a very modern part with perpendicular roads and square blocks of buildings. One can notice the very fine details in this image giving the possibility to photo-interpret this area to construct urban map.

Figure 2 presents the SPOT panchromatic image acquired in September 5, 1993. To allow a comparison of the two images, this image was processed using a nearest-neighbour interpolation to obtain the same spatial resolution. The effective spatial resolution of the image is 10 m but the pixels have a resolution of 2 m. The big lower right square is of interest. In the middle of this square, major changes can be noticed between the image of 1991 and the image of 1993. It seems that new buildings were constructed even if it is sometime difficult to evaluate how many.

On the upper right part, the same phenomenon is visible. One building has been constructed in a block where nothing exists in the KVR-1000 image. Figure 1 illustrates the necessity to have a good geometrical description of the area, allowing to distinguish the different buildings.

Fig.1. original KVR-1000 image acquired in March 1991

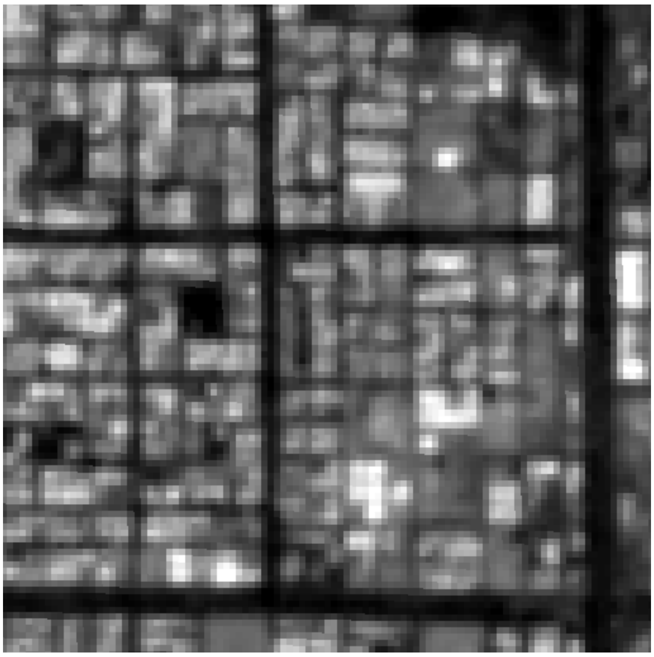

Fig. 2. original SPOT panchromatic image acquired in September 1993

Even if the SPOT panchromatic image has a lower spatial resolution, the regular acquisition of images allows to update the information on a given area.

Hence it is necessary to perform an updating of the information, to work on the most complete image.

To obtain the merged image, a multiresolution analysis using the wavelet transform was applied to the KVR-1000 image. The wavelet coefficients represent the fine structures missing to the SPOT panchromatic image.

Fig. 3. Image resulting of the merging process.

Hence, these differences are introduced in the panchromatic pyramid and the merged image is constructed. The multiresolution analysis algorithm used in this merging process is called the "à trous" algorithm and was proposed by Dutilleux (1987).

Figure 3 presents the result of the merging process. The different structures missing in the original KVR-1000 image are now available on this image. The different buildings constructed between March 1991 and September 1993 are visible in this image and the photo-interpretation can be realized only from this image which contains all the structures existing in both images.

This image allows to build the urban map, enhancing the areas where a survey is needed or describing the differences between the two dates. Figure 4 shows the urban map realized on the lower part of the image. The photo-interpreter has chosen to propose a survey for the area where changes have occured.

V. CONCLUSION

In this communication, a merging process was proposed to allow an updating of an image by a more recent one. It was shown that the merging process preserves the best of the two images, in one hand the high spatial resolution of the KVR-1000 image and in the other hand the most update information provided by the SPOT panchromatic image. This merging process can be used for a periodical updating of urban maps, allowing the reduction of the time necessary for the survey and the cost of this survey. It allows also the construction of a single representation of an area with all the informations available from different images.

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Al Salamah

Scale: 1/5000

Fig. 4. Urban map derived from Fig. 3. The blocks where changes have occured are designed by areas to survey.