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Abstract **- This communication presents a method allowing the combination of high spatial and spectral resolution images to improve the mapping of urban area. It makes use of two mathematical tools, the wavelet transform and the multiresolution analysis which are shortly introduced. This method, called ARSIS is then described. A qualitative comparison between a classical merging technique and the ARSIS method is presented through an example, the merging of SPOT XS images and the russian sensor KVR-1000. Then, the process used for urban mapping is explained and a map of a district in Riyadh, enhancing the roads and the buildings is presented.**

I. INTRODUCTION

Urban mapping seems to be a promising market for the earth observation satellites in the next decade. For this application, on the one hand, the high spatial resolution images are necessary for an accurate geometrical description of the cities; on the other hand, the high spectral resolution images discriminate the different types of urban structures. Unfortunately, no civil satellite sensor is available to provide high spatial and spectral resolutions images at the same time. Airborne solutions are expensive and are often restricted by flight authorizations. However, mathematical solutions exist and sensor fusion techniques provide high spectral and spatial resolutions images. Furthermore, sensor fusion is the best solution to minimize the costs.

In section II, two mathematical tools are shortly introduced and the ARSIS method (from its french name "amélioration de la résolution spatiale par injection de structures") is presented. An example of application of this method to the merging of SPOT XS images (high spectral resolution; spatial resolution: 20 m) and to russian images KVR-1000 (panchromatic band; spatial resolution: 2 m) and a qualitative comparison between the resulting images and the images obtained by a Intensity Hue Saturation (IHS) method are presented in section III. The process used for urban mapping is described in section IV and an extract of a urban map showing the roads and buildings in a district of the town of Ryadh (Saudi Arabia) presented.

II. ARSIS METHOD

For the application of a sensor fusion technique, images need to represent the same area, to be superposable, and it is required that no major change has occured in the observed landscape. The set of images to merge is supposed to have different spatial and spectral resolutions. Many methods have been proposed to enhance the spatial resolution of images owing the presence of one or more images of the same scene of better spatial resolution (see for example Carper *et al.* 1990; Chavez *et al.* 1991). But, not a lot of them take care of the multispectral content when increasing the spatial resolution.

The ARSIS method was designed to synthetize in a set of images with different spatial and spectral resolutions, multispectral images with the best resolution available in the set of images and to preserve the radiometric content of original images. This method makes use of 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 with coarser and coarser spatial resolutions. Combined with the multiresolution analysis, the wavelet transform allows the description of the difference of information between two successive approximations of the same image. Figure 1 present the general scheme of the ARSIS method. The best resolution image A is decomposed by a multiresolution analysis using a wavelet transform. The differences of information provided by the wavelet transform are modelized by the wavelet coefficients. The second image B with a coarser spatial resolution than image A is also decomposed through the multiresolution analysis with the wavelet transform. A model describing the transformation of the wavelet coefficients of the image A to the wavelet coefficients of the image B is established. This model takes into account the physics of both images and the correlation or anti-correlation existing between both coefficients images. This model is used to computed the wavelet coefficients needed to synthetize the image B at the spatial resolution A.

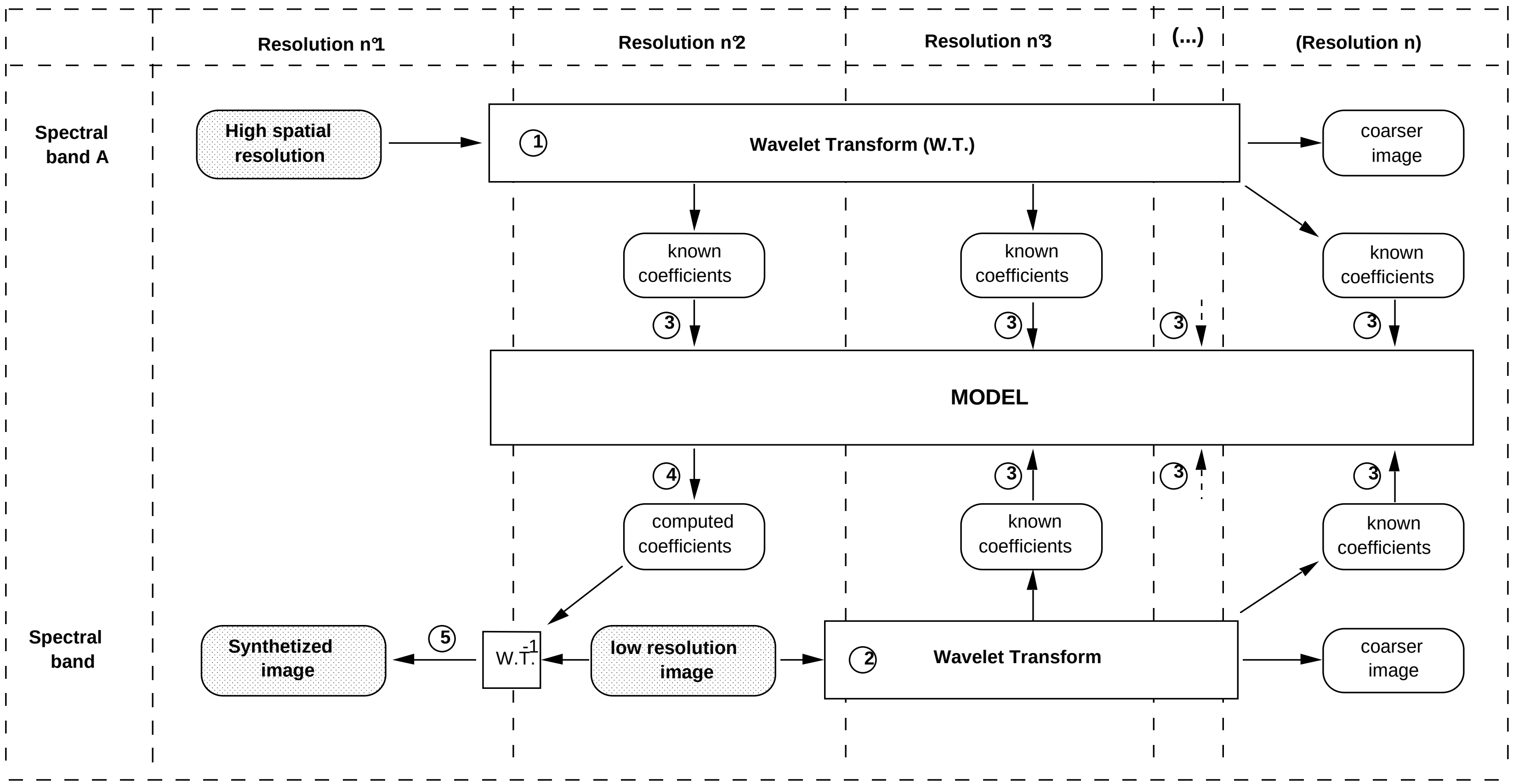


Fig. 1. General scheme of the ARSIS method

This synthesis is made by a reconstruction, WT^{-1} in the general scheme which is the inverse operation of the multiresolution analysis. ARSIS allows the preservation of the spectral content of each image and an improvement of the spatial resolution of each images up to the best one available in the original set. A more complete description of the ARSIS method can be found in Ranchin (1993). In the case of SPOT imagery, ARSIS was shown to give the best achievable results in terms of preservation of the original content (Mangolini *et al.* 1995).

III. EXAMPLE AND COMPARISON

An application of the ARSIS method is presented in this section. The set of images is composed by a SPOT XS scene of the town of Riyadh (Saudi Arabia) acquired the 16th of May 1993 and a russian image KVR-1000 of the same area acquired the 7th of September 1992. The three XS images have a spatial resolution of 20 m and a spectral range of 0.5 - 0.59 µm for XS1 band, of 0.61 - 0.68 µm for XS2 band and of 0.79 - 0.89 µm for XS3 band. The KVR-1000 image has a spatial resolution of 2 m and a spectral range of 0.51 - 0.71 µm equivalent to a panchromatic band. Two merging processes are applied to this set of images. The ARSIS method described in the previous section, and the Intensity-Hue-Saturation (IHS) method (Carper *et al.* 1990). To allow a comparison of the two methods and the benefits provided by the sensor fusion, three extracts of the same scene are presented. Figure 2 shows a composition of the XS images, Figure 3 the result of the IHS method and Figure 4 the result of the ARSIS method.

The big crossroads at the upper left corner of image is of interest. One can see that the resulting image provided by the ARSIS method is close to the XS original composition than the resulting image of the IHS method. Due to the gap of resolution between the XS and the KVR images, it is difficult to propose a method to quantitatively estimated the resulting images. Even if the geometrical quality of both images seems to be very close, the images resulting from the ARSIS method allows to see all the roads on the crossroads even the lower left loop which exists and is also represented in the original images. Hence the images resulting provided by ARSIS where prefered for the urban mapping.

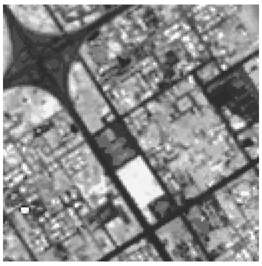


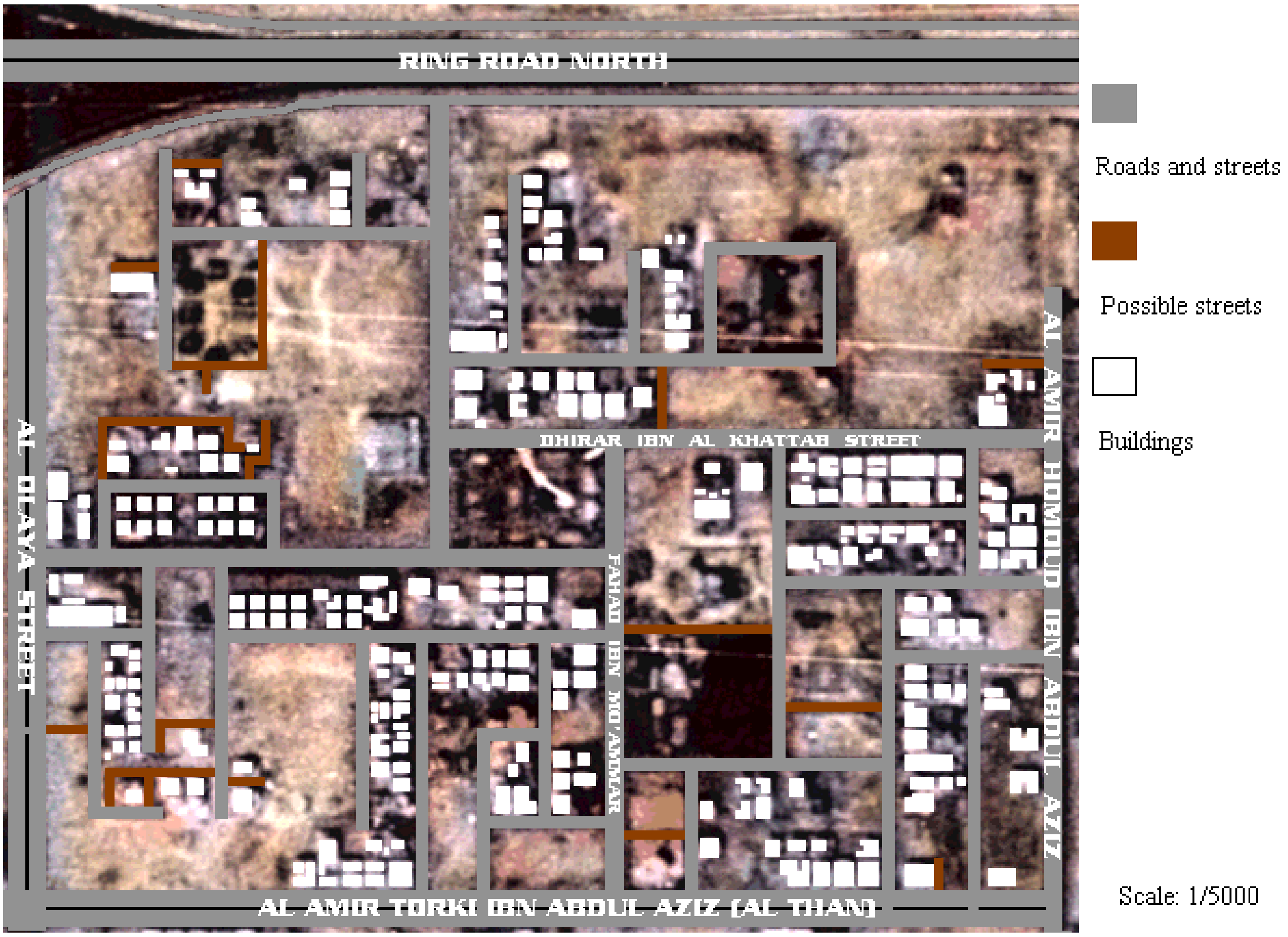
Fig. 2. XS original composition

Fig. 3. Resulting image obtained from the IHS method

Fig. 4. Resulting image obtained from the ARSIS method

IV. METHOD FOR URBAN MAPPING

The following process was applied to draw the urban map presented Figure 5. This map is corresponding to the upper right part of the area shown Figure 4. First, a non supervised classification, based on the maximum of likelihood, is computed on the color composition obtained from the images synthetized by the ARSIS method.



This classification allows to discriminate two classes: the roads and the buildings. This result is used to help for the manual photo-interpretation of the area, and the urban map is derived.

V. CONCLUSION

In this communication, we have shown the benefits of sensor fusion for urban mapping. The possibility of having multispectral images at high spatial resolution with a preservation of their spectral content by the use of the ARSIS method, enables the application of classification algorithms. This allows to save time of manual photo-interpretation and to improve the quality of the results. The ground-truth performed in this area as shown that all the roads where well classified and that close to all buildings also. The differences observed are principally due to the differnce of date between the ground-truth and the images.

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