QUADRATURE BANDPASS ISOTROPIC FILTERS FOR URBAN ZONES SEGMENTATION IN SATELLITE IMAGERY.

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ABSTRACT:

This article introduces a new and effective method for urban zone segmentation in satellite imagery. The proposed method consists in filtering a band of the multi-spectral image (from the SPOT satellite) with a quadrature bandpass isotropic filter. The filter bandwith and tuning frequency are determined from the source images by a simple experimental analysis. The final image can be obtained by low-pass filtering the quadrature filter's output, or by a Bayesian method using a Hidden Markov Measure Field Model. Our experiments in SPOT imagery at 10 meters resolution, report classification errors of around 5%. Sea zones containing similar features to those found in urban areas are removed by a neural network.

1. INTRODUCTION

In the last few years, urban zones detection in satellite imagery has become important to study the urban growth in the world over time. A spatio-temporal analysis of growth patterns is essential in order to develop sufficient infrastructure to support the growth (Orun, 2004). Sometimes it may be difficult to distinguish between natural and poorly structured residential areas. Variance operators have been used by several authors as an important feature for that task (Gluch, 2002; Orun, 2004).

In recent works, the urban zones segmentation problem has been studied by several authors by using satellite imagery at high resolution. Orun (2004) uses IRS-1 satellite imagery at 5 meters panchromatic resolution, by employing different texture analysis measures (with different variance measures) and by choosing the best operators to distinguish between natural and man-made areas. Gluch (2002) merges Landsat TM (at 30 meter resolution) and SPOT (at 10 meter resolution data). The purpose in that work is to analyze urban growth over time. In order to classify urban zones, Gluch combines high and low-pass filters with the variance operator in a 3 by 3 window.

In this work, a new and effective method for urban zones segmentation is proposed. This method is based on quadrature bandpass isotropic filters, and it consists in filtering a band of the multi-spectral image (provenient from SPOT satellite) with one of these filters. The desired classification may then be obtained by smoothing and thresholding the filter's output.

2. TECHNIQUES USED

2.1 Quadrature Bandpass Isotropic Filters

The multi-dimentional generalization of the analytic signal, which is called the *monogenic signal*, (Felsberg, et.al., 2000) is given by

$$F_M = (F, FH_1, FH_2) \qquad (1)$$

where F is a bandpass filter
H_1, H_2 are given by

$$H_1(u_1,u_2) = i\frac{u_1}{\sqrt{u_1^2+u_2^2}}$$
$$H_2(u_1,u_2) = i\frac{u_2}{\sqrt{u_1^2+u_2^2}} \qquad (2)$$

where $i=\sqrt{-1}$.

A good choice for the bandpass filter is a Gaussian filter defined with the transfer function

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$$G_{(r_0,s)}(u_1,u_2) = \frac{1}{\sqrt{2p}\,s}\,\mathrm{e}^{-\frac{\left(\sqrt{u_1^2+u_2^2}-r_0\right)^2}{2s^2}} \qquad (3)$$

where s indicates bandwith and
r_0 indicates tuning frequency.

So, for an image I, the filter's output is given by the norm of the vectorial image:

$$I * f_M = \left(I * h_{BP}, I * h_{BP} * h_1, I * h_{BP} * h_2\right) \quad (4)$$

where $h_{BP} = \mathrm{F}^{-1}\left[G_s\left(u_1,u_2\right)\right]$,
$h_1 = \mathrm{F}^{-1}\left[H_1\right]$,
$h_2 = \mathrm{F}^{-1}\left[H_2\right]$.

Figure (1) shows the filters conforming the *monogenic signal* for bandpass filter defined above.

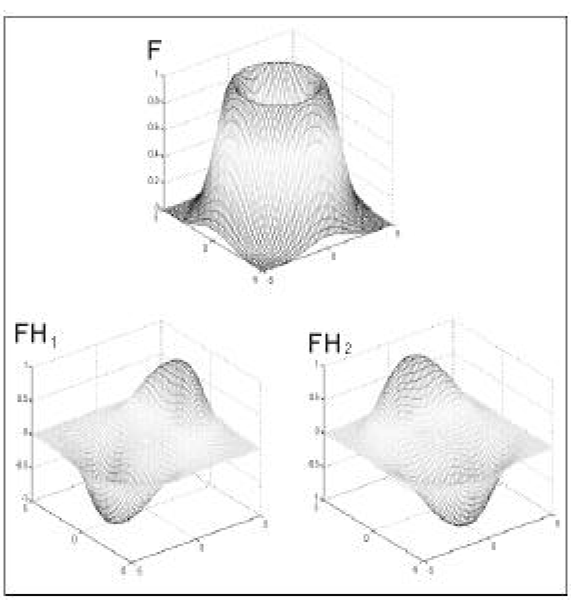

Figure 1. Monogenic signal.

3. METHODOLOGY

One of the issues with the use of variance operators is that in some cases, it is confused to distinguish between urban areas and natural non-homogenous areas, since the variance response in last case is high.

The use of Quadrature Bandpass Isotropic Filters (QBIF) helps to make that distinction because it is possible to estimate the characteristic frequency in urban areas and eliminate other frequencies.

The proposed method consists in filtering the band 1 (green) of the multi-spectral image with a QBIF. Imagery comes from the SPOT satellite at 10 meters resolution. The filter bandwith and tuning frequency are determined from the source images by a simple experimental analysis, by getting $r_0 = 0.28274$ and $s = 0.5$ as the best parameters.

The final can be obtained by thresholding and thresholding a smoothed version of the quadrature filter's output, or by a Bayesian method using a Hidden Markov Measure Field Model (Marroquín, 2003).

There may be sea zones containing similar features to those found in urban areas due to swell. These zones are removed by a neural network (Rojas, 1996). Figure (2) show the diagram for the proposed method.

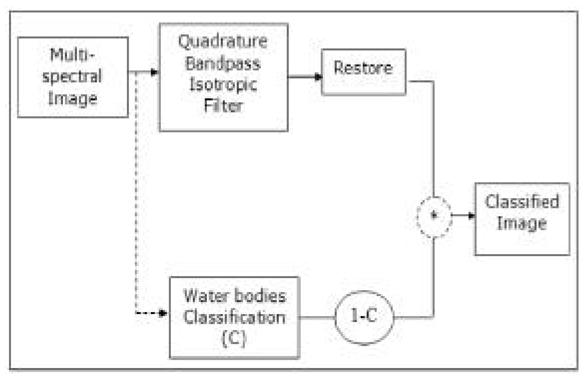

Figure 2. Diagram for the proposed method.

4. RESULTS

The proposed method was compared with Gluch (2002) method adapted to SPOT image (without merging data), which consists in performing a high-pass filter followed by a variance operator in a window for each pixel, thresholding this image for urban zones segmentation (Gluch, 2002).

Figure (3) shows results for both methods. In the first column, band 1 of multi-spectral image for different test areas is shown; in the second column, urban zones classification by visual interpretation is shown for each test area. In the last two columns urban zones classification by proposed and Gluch method are shown.

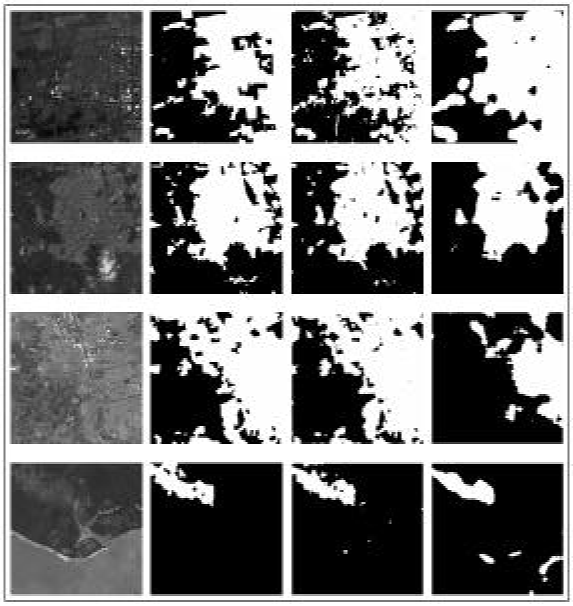

Figure 3. Results for urban zones segmentation.

Error is defined as the rate of wrongly classified pixels with respect to classification by visual interpretation. Errors for each test area and for each method are presented in table (4).

	Proposed method	Gluch method
Image 1	0.034093	0.069396
Image 2	0.061349	0.126941
Image 3	0.060558	0.327766
Image 4	0.018116	0.042615
Average	0.043529	0.141679

Table 4. Segmentation errors.

As can be seen, the reported errors are around 5% for the proposed method, while reported errors for variance based method are around 14%.

5. CONCLUSIONS

A new method for classifying urban zones in imagery satellite from SPOT satellite was proposed. In this method quadrature bandpass isotropic filters and neural networks are combined. The method consists of filtering a band of the multi-spectral image with a QBIF, with filter bandwith and frequency determined by experimental analysis. Finally, the classified image is obtained by low-pass filtering and thresholding the quadrature filter's output, or by a Bayesian method using a Hidden Markov Random Field Model.

When similar features to those found in urban areas are contained in sea zones, it is necessary to remove those zones by a simple neural network.

There are no parameters to adjust, because all of them were previously found by experimental analysis, and those work well for several kinds of images. The reported errors are around 5%. The method works better than variance based methods in poorly structured residential areas.

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