Satellite Images features Extraction using Phase Congruency model

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Summary
In computer vision all of the existing researches are interested in synthetic images features extraction. Theses images contain many types of features. Indeed, the features are classified in 1D feature (step, roof…) and 2D features (corners). Nevertheless, some approaches interest in the study of real images. Moreover, the satellite images are one most complex real image. It presents a widespread real application (weather, military…). Accordingly, many researches are developed in this way. The satellite images present a great variety of features due to the trouble what returns their treatment is little delicate.
In this paper, we introduce a new application of phase congruency model for features extraction in satellite images. The aim of this paper is to exploit the advantages and the limitations of this model applied in satellite images features extraction. On the other hand, two smoothing algorithms are used to improve the features extraction procedure.

Key words:
Satellite images, phase congruency model, smoothing algorithm

1. Introduction

In computer vision features are important clues in image analysis. Several gradient-based edge detection methods are developed. These methods are sensitive to edge magnitude, smoothness and magnification. To overcome these drawbacks of these approaches, many researchers are interested to features detection in the frequency domain. In this paper, we interest in the works based on local energy model. It is a new model and a robust feature detector. It's detects not only step, ramp and line edges but also a broader set of features. Several approaches for features detection have been developed. This model is based on the information contained in the phase component of the image. Indeed, Oppenheim and Lim [1] prove that phase information is crucial to features perception. Morrone and Burr [6] postulated formally the local energy model. From this work the local energy model has been used for edge detection, edge classification, image fusion and key point's detection. Morrone and Owens deal the problem of feature detection by considering how features are built up in an image instead of the differential properties in the luminance function. Recently, Venkatesh and Owens [7] deal the scheme of the local energy model for features extraction. Phase congruency was further modified by Kovesi [2], [3] and extended to two dimensions over several orientations and combines this results in some way. An interesting suggestion of this model applied for corner detection is described in [5]. Many others algorithms have been reported [4], [5], [6], [7], [8], [9] and [14].
The phase congruency model is relatively new model. It's applied in several domain of image processing like: face alignment [10], noise removal for iris image [11], feature extraction of chromosomes [12] and ultrasonic liver characterization [13].
From the above, the phase congruency represents a robust and accurate model for features extraction in wide ranges of images. In the present work, the phase congruency model is applied to step and line extraction in satellite images.
The remainder of this paper is organized as follows: Section 2 introduce the concept of 2D phase congruency model. Section 3 deals the application of this model in satellite images. Results of applying the features extraction scheme on satellite images and are presented in Section 4. We close the paper with some concluding remarks.

2. The phase congruency model using log Gabor filtering

2.1. Multi-channel filtering

Multi-channel filtering is popular methodology in image analysis. It employs a bank of filters with each filter modeling a single channel. Several filtering functions such as Gabor functions have been used [14] to analyze the text image and log Gabor functions have been used [2] to detect edges.
Image analysis entails the detection and extraction of features in an image, which are local changes in image intensity such as lines and edges. An important category of feature extraction involves filtering a given image and measuring the filter response energy. There are many

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techniques proposed in the literature for analyzing satellite images. Here the multi-channel filtering technique to extract satellite images features is used. This approach is inspired by the work [2]. In the local energy model, a given image is filtered with a set of filters that have identical amplitude spectra but orthogonal phase spectra. The input satellite image is filtered with a bank of log Gabor filters at various orientation and frequency with each filter modelling a single channel.

2.2. The proposed approach

With the enormous amount of largely redundant data in images, the extraction of images features is a fundamental process of computer vision systems. In literature, several approaches are developed to extract 1D or 2D features.
The local energy model has been used in many applications of image processing. It's relatively a new model for features extraction. Moreover, this model presents many advantages with other features detection methods. In the literature Venkatesh and Owens [7] showed that the local energy is proportional to phase congruency, therefore local maxima of phase congruency correspond to local maxima in local energy. In practice, the local energy is used to detect features in images. According to Kovesi [3] the phase congruency is defined by

$$PC(x) = \frac{\sum_o \sum_n W_o(x) \lfloor A_{no}(x) \Delta\phi_{no}(x) - T_o \rfloor}{\sum_o \sum_n A_{no}(x) + \varepsilon} \quad (1)$$

Where o and n denotes the index over orientations and scales respectively, the symbols $\lfloor \ \rfloor$ denote the enclosed quantity is equal to itself when its value is positive, and zero otherwise. $A_{no}(x)$ is the amplitude of the filter pair at position x. ε is a very small positive real number, used to prevent division of zero, and its value is set to be 0.001. The noise compensation T_o is performed in each orientation independently and is estimated empirically. For an extensive discussion of the underlying theory, readers are referred to reference [3].
Satellite images present several false features due to external contributions (atmospheric noise). Indeed, in the weather domain many parameters like: rain, cloud and wind decrease the quality of the satellite images. Unfortunately, in the literature, all the existing approaches of features extraction suffer some drawbacks in the real images. So, the analysis of the satellite images requires a pre-processing like smoothing and the application of some techniques of thresholding.
Although the phase congruency model of images features makes no a priori assumption about the shape of image features, points of maximal phase congruency correspond to a wide range of features profiles. In this work, the features can be extracted are the step and the line edges which are local changes in image intensity. For these features: lines or edges, the Fourier phase spectrum is constant what returns their detection easy compared with other features. In addition, many other features can be identified in satellite images.
An important category of feature extraction involves filtering a given image and measuring the filter response energy. There are many techniques proposed in the literature for analysing texture. Here we use the multi-channel log Gabor filtering technique to extract features in satellite images. Then, two smoothing algorithm are used to improve the quality of the satellite images.
The proposed scheme for phase congruency computing is given by this diagram.

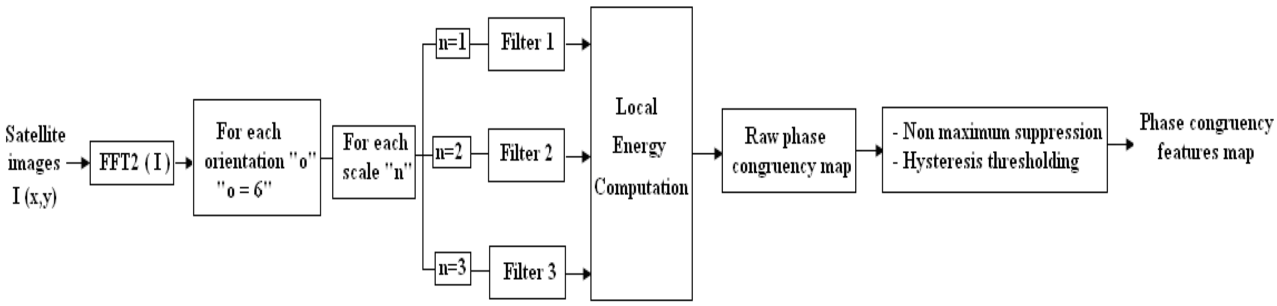


Fig. 1 The phase congruency computation scheme

3. Experimental results

In the new application of local energy model in satellite images, the 2D log Gabor filter is used. The same parameters used by Kovesi [2] have been employed in this manuscript.

According to [2] the raw phase congruency images were obtained by applying equation (1) to the images with the following parameters: Local frequency information was obtained using two-octave bandwidth filters over three scales and six orientations. The wavelength of the smallest scale filters was 3 pixels; the scaling between successive filters was 2. The 2D log Gabor filters were constructed directly in the frequency domain. A logarithmic Gaussian functions in the radial direction and a Gaussian in the angular direction. In the angular direction, the ratio between the angular spacing of the filters and angular standard deviation of the Gaussians was 1.2. A noise compensation *k* value of 2.0 was used.

The phase congruency feature maps were obtained by performing nonmaximal suppression on the raw phase congruency images followed by hysteresis thresholding with upper and lower hysteresis threshold values fixed at phase congruency values.

The hysteresis threshold values was set to [0.6-0.3] for satellite image 1 and [0.4-0.2] for the second and the third satellite images. The line and step features are detected and classified using the mean weight phase angle [4].

Moreover, we present the detected features in the smoothed images using two techniques of smoothing. The first method is presented in [15] by Liu for synthetic images boundary detection. The second method [16] preserves the phase of the image and consequently preserves the features present in the satellite images.

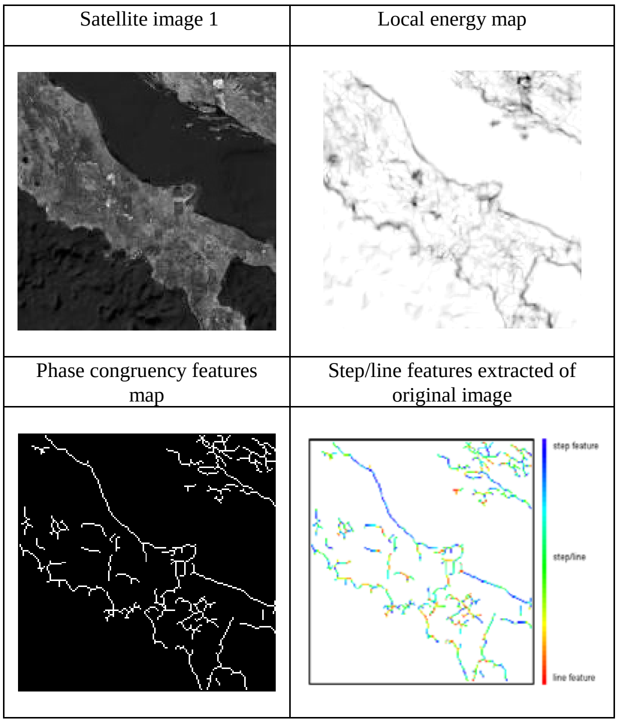


Fig. 2 Features on satellite image 1

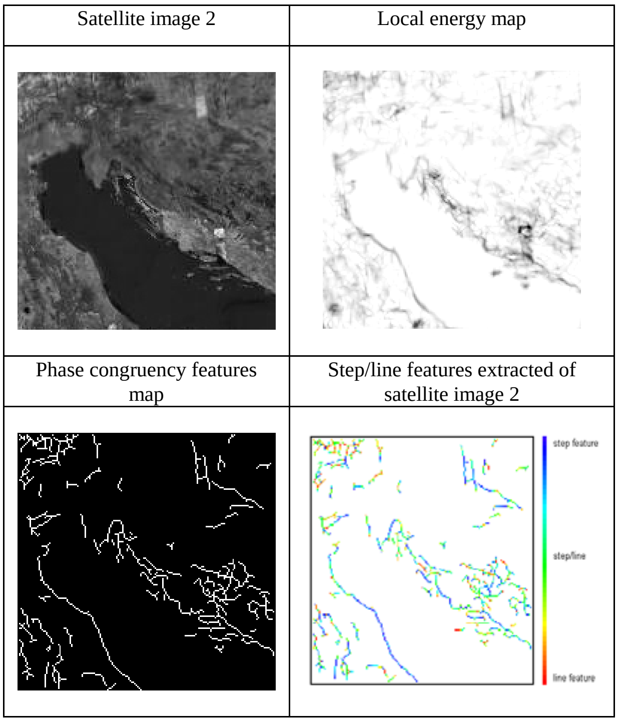


Fig. 3 Features on satellite image 2.

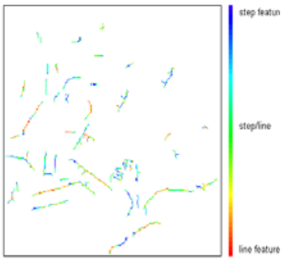
Satellite image 3	Local energy map
	
Phase congruency features map	Step/line features extracted of satellite image 3
	

Fig. 4 Features on satellite image 3.

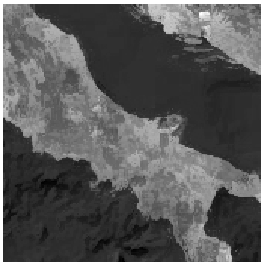
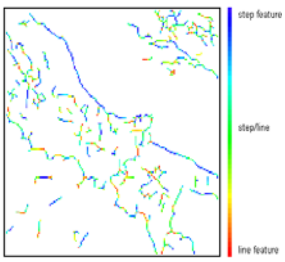
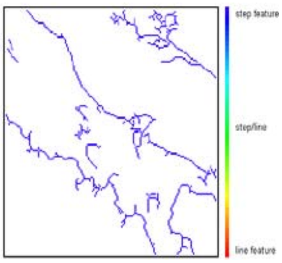
Smoothed satellite image 1 Using phase preserving denoising algorithm [16]	Smoothed satellite image 1 Using non linear contextual smoothing algorithm [15]
	
Features extracted of smoothed image 1	Features extracted of smoothed image 1
	

Fig. 5 Features on smoothed satellite image 1.

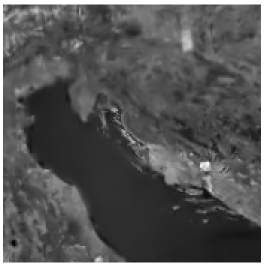
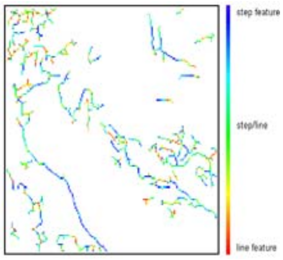
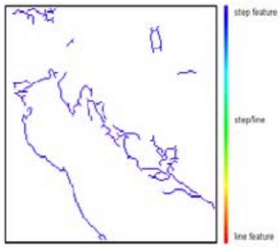
Smoothed satellite image 2 Using phase preserving denoising algorithm [16]	Smoothed satellite image 2 Using non linear contextual smoothing algorithm [15]
	
Features extracted of smoothed image 2	Features extracted of smoothed image 2
	

Fig. 6 Features on smoothed satellite image 2.

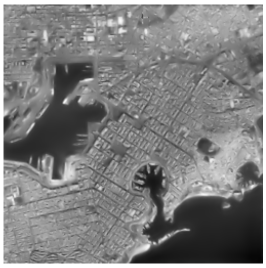
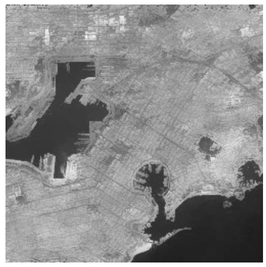
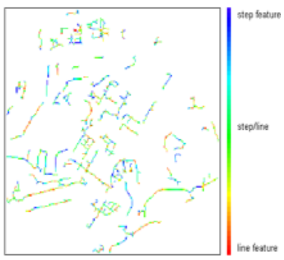
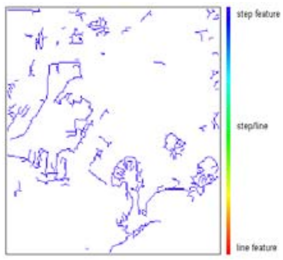
Smoothed satellite image 2 Using phase preserving denoising algorithm [16]	Smoothed satellite image 2 Using non linear contextual smoothing algorithm [15]
	
Features extracted of smoothed image 3	Features extracted of smoothed image 3
	

Fig. 7 Features on smoothed satellite image 3.

4. Discussion

Satellite images contain many features (step, line and many others). These features are important clues for satellite image boundary detection. A great deal of works demonstrates the richness of information containing in phase congruency map. Moreover, this model is used in many wide ranges of images. Unfortunately, the present application show that the phase congruency features detector suffers some drawbacks. Indeed, it include many false features due to the atmospheric noise what makes difficult the analysis of these images.

Fig 2, Fig 3 and Fig 4 shows the phase congruency features map, the local energy map, the features images, features extracted, and histogram of feature type occurrence. These figures show that the satellite images have many false features.

Fig 5, fig 6 and fig 7 show that the phase preserving denoising algorithm preserves all of the features in the images. But, for the non linear contextual smoothing algorithm all of non significant features are moved. Indeed, single the step edges constituting the boundary of satellite images are detected.

5. Conclusion

Satellite images are a most complex images containing several types of features for that it analysis entails a preprocessing like smoothing, denoising…. With this method, the features extracted are the step and the line edges. Thus, the satellite images contain mainly these two linear features. We conclude that the phase congruency model can be employed in satellite images. We finish that the non linear contextual smoothing algorithms is better than the phase preserving because the first one preserves only the features form the boundary of the remarkable region in the three satellite images. Finally, straightforward application of the local energy model detects features accurately and robustly.

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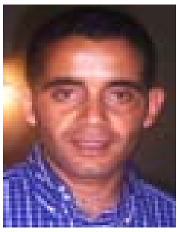

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