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RIAO-OPTILAS-MOPM 2019

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DE ÓPTICA, A.C.

Fractional Fourier-radial transform for digital image recognition

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INTRODUCTION

In last decades, the pattern recognition has become a fundamental part of the industrial and health sectors, which make it one of the main fields in image processing research with the purpose of identify objects in digital images. For this, different techniques have been developed to get Translation, Rotation and Scale (TRS) invariance vectorial signatures, but there still some complications, such as the TRS invariant recognition of objects using a single target image (not composite filters) and increase the scale range with high effectiveness.

This work takes advantage of some integral transforms (mentioned below) to design a new methodology that generates four TRS signatures for each image and then compare these signatures against the signatures of other image.

One of the most used methods for comparing data is the correlation, due to its easy implementation in the plane of frequencies.

The size of the images in the dataset are 320 × 320, but when generating translation, scale and rotation invariance of an image, four vector of length 26 are calculated, called signatures, with the characteristic information of the original image and now the signatures of the images are compared, only. In this way 26 elements are used instead of 102400, which means a great advantage about computing time.

METHODOLOGY

Taking an image and calculating the module of the Fourier-Mellin transform, a new representative image of the original image is generated with the advantage that this new image is invariant to the position and scale of the original image.

The two dimensional Fourier transform is defined by [1]

$$F(u,v)=\mathcal{F}\left\{f(x,y)\right\}=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)e^{-i2\pi(ux+vy)}\,dx\,dy, \tag{1}$$

and the two dimensional Mellin transform [2] is defined by

$$F_M(s,t)=M\left\{f(x,y)\right\}=\int_{0}^{\infty}\int_{0}^{\infty} f(x,y)x^{s-1}y^{t-1}\,dx\,dy. \tag{2}$$

Then is calculated the fractional Fourier transform of order (α,β) (in this work $a=\beta$ to reduce computing time and test the effectiveness of this methodology) and it is separated in its real and imaginary part.

The expression for the two dimensional fractional Fourier transform [3] is

$$F_{\alpha,\beta}(u,v)=\mathcal{F}^{\alpha,\beta}\left\{f(x,y)\right\}=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)K_{\alpha,\beta}(x,y,u,v)\,dx\,dy, \tag{3}$$

where the kernel is defined by

$$K_{\alpha,\beta}(x,y,u,v)=\sqrt{1-i\cot\phi_\alpha}\exp\left[i\pi\left(x^2+u^2\right)\cot\phi_\alpha-i2\pi ux\csc\phi_\alpha\right]\times\sqrt{1-i\cot\phi_\beta}\exp\left[i\pi\left(y^2+v^2\right)\cot\phi_\beta-i2\pi vy\csc\phi_\beta\right] \tag{4}$$

where ϕ_α and ϕ_β are the rotation in the plane space-spatial frequency for each coordinate and are given by

$$\phi_\alpha=\alpha\frac{\pi}{2},\ \phi_\beta=\beta\frac{\pi}{2}, \tag{5}$$

Then the real and imaginary part of the fractional Fourier transform are multiplied independently by each one of the masks H_R and H_I proposed by Alcaraz-Ubach [4], the pixel values of each resulting ring is added, then a value is obtained for each ring, such that they can be ordered in a vector of dimension equal to the number of rings to generate the signatures. These signatures will be normalized by its maximum value. Figure 1 shows a diagram of the methodology explained above. The optimal order of the fractional Fourier transform will be the order that maximize the autocorrelation value, so each signature of each image will have each own optimal order. Once the optimal order of each signature is known, cross-Pearson correlation [5] is performed to compare images.

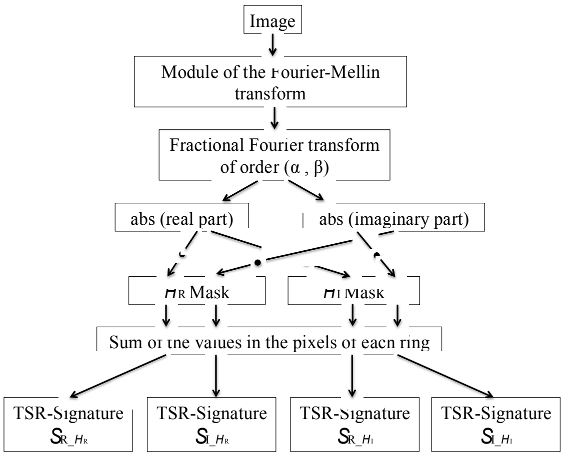

Figure 1. Methodology for the generation of the RTS invariant signatures.

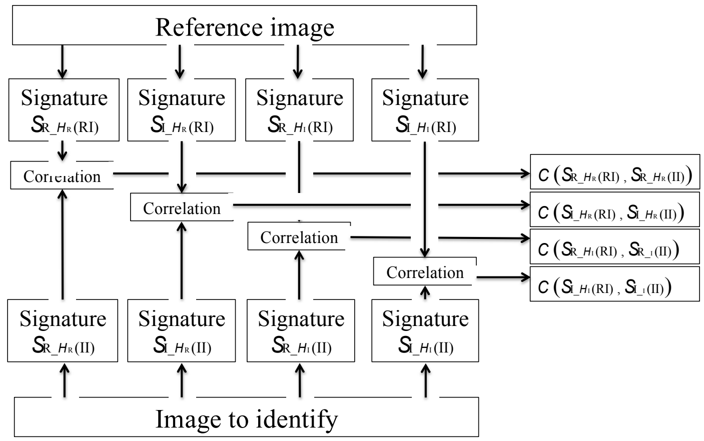

Figure 2. Signatures correlation methodology. RI: Reference image. II: Image to identify.

RESULTS AND CONCLUSIONS

30 images of different phytoplankton species were selected for the test of the algorithm. These images were selected due to the similarity and complexity between some of them, in order to test the effectiveness of this methodology.

Rotating each image in 5 degrees intervals, 72 images are obtained for each image, by scaling these 72 images from 80% to 120% in 5% intervals, a total of 19440 images are generated.

It is possible to identify objects in digital images using the fractional Fourier-radial transform proposed in this work. In fact, all the images reach at least the 92.68% of confidence in all correlations. The mean of the highest confidence values for the scale variation correlations is 98.47%, for the rotation variation correlations is 100% and for the rotation and scale variation correlations is 98.15%. This tells us about the high effectiveness of this new methodology.

Using the methodology presented in this work you obtain a level of confidence at least 92.68% invariant to position, scale and rotation, supporting scale variations of ±20% and performing a very simple correlation, Pearson correlation.

In the case of obtain a useless signature of an image, there still three more signatures to use and select the best one. Which reduce the probability of getting four useless signatures of an image.

Keywords: Fractional Fourier-radial transform; fractional Fourier transform; Mellin transform; Hilbert radial transform; Pearson correlation; pattern recognition.

Topic Code: Image processing, vision and artificial intelligence.

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