EDITORS

AMALIA MARTÍNEZ GARCÍA · JOSUÉ ÁLVAREZ BORREGO · EDUARDO TEPICHÍN RODRÍGUEZ

RIAO-OPTILAS-MOPM 2019

· PROCEEDINGS ·

X IBEROAMERICAN OPTICS MEETING

XIII LATINAMERICAN MEETING ON OPTICS, LASERS AND APPLICATIONS

MEXICAN OPTICS AND PHOTONICS MEETING

CANCÚN · MÉXICO

RIAO

ACADEMIA MEXICANA
DE ÓPTICA, A.C.

CORRELATION BY ONE-DIMENSIONAL SIGNATURES INVARIANT TO ROTATION, POSITION, AND SCALE USING RADIAL HILBERT TRANSFORM OPTIMIZED

Alfredo Castro-Valdez[1], Josué Álvarez-Borrego[1], Selene Solorza-Calderón[2]
[1]Physics Division,Optics Department, CICESE,Carretera Ensenada-Tijuana No. 3918, Fraccionamiento Zona Playitas, Ensenada, Mexico, C. P. 22860
[2]Facultad de Ciencias, Matemáticas Aplicadas, UABC, Ensenada, Mexico.

jvcastro@cicese.edu.mx/ tel: +526469475815

Introduction

Object recognition can be easily made by people. Since we are born, we began to identify patterns like toys, does not matters if the toys are rotated or in perspective. The computers cannot identify patterns easily with the before distortions mentioned. To fix these troubles, the area of optics has produced multiple applications in pattern recognition. Several methods have been developed to find invariances to rotation, scale, and displacement [1]. Integrals transforms produce different invariances. The modulus of the Fourier transform has displacement invariance [2], the modulus of the Mellin transform has scale invariance [3] and, with binary masks of circumferences or rings the rotation invariance is achieved. [4, 5]. The Radial Hilbert transform has been used to detect borders in rotated images and, have rotation invariance [6], these qualities do the Radial Hilbert transform a good candidate to apply it. Different methodologies with different invariances can be created. However, the confidence to detect objects could change, some methodologies are more efficient to detect or discriminate objects. The improvement in the performance in object recognition led to the new study of a methodology with scale, rotation and, displacement invariances.

Methodology

To have different invariances is needed to apply different integrals transforms, the Mellin transform is applied to generate scale invariance. Mellin transform is defined as [7]:

$$F_M\left(s\right)=\int_0^{\infty} f(x)x^{i\omega-1}dx\,, \tag{1}$$

the principal property of the Mellin transform is that the scale changes only affects to the phase.

Another integral transform is 2D Radial Hilbert transform $\left(\mathrm{H}_R\right)$ presented as,

$$\mathrm{F}\left[\mathrm{H}_R\left[g\left(x_1,x_2\right)\right]\right]=H\left(\mu_1,\mu_2\right)G\left(\mu_1,\mu_2\right), \tag{2}$$

where $H\left(\mu_1,\mu_2\right)=\Phi\left(\phi\right)$ is an arbitrary radial function.

In the particular case where $\Phi\left(\theta\right)=e^{ir\theta}$, we obtain [7]:

$$g_H\left(x_1,x_2\right)=\mathrm{H}_R\left[g\left(x_1,x_2\right)\right]=\mathrm{F}^{-1}\left[e^{ir\theta}G\left(\mu_1,\mu_2\right)\right]. \tag{3}$$

The radial Hilbert transform optimized (RHTO) appears when a parameter α is added, as is proposed,

$$\Phi\left(\theta\right)=e^{ir^{\alpha}\theta}, \tag{4}$$

the α value has an optimal range, to find that range, different values of α were evaluated from 0 to 1.5. This change is related with the rings number produced by the radial Hilbert transform and, the rings number is related to the signature length and the autocorrelation value of the signature.

The signatures were created from the input images applying the Mellin transform, then the Fourier transform and, the RHTO, finally the values in the concentric rings were summed and associated to the signatures.

To correlate the signatures, a linear-nonlinear correlation was proposed in this work to produce superior performance in comparison with the classical filter techniques regarding discrimination capability. Where, if the factor Rz is one, it is a linear correlation, and it is non-linear for values of Rz different from one. To recognize the target into a problem image, the signature of the problem image (S_{PI}) is compared with the signature of the target image (S_{TI}) using the adaptive linear-nonlinear correlation (C_{ANL}), that is

$$C_{ANL}=\mathrm{F}^{-1}\left\{\left|F\left(S_{PI}\right)\right|^{Rz}\cdot\exp\left(i\phi_{S_{PI}}\right)\times\left|F\left(S_{TI}\right)\right|\cdot\exp\left(-i\phi_{S_{TI}}\right)\right\}, \tag{5}$$

where

$$Rz = \begin{cases} \dfrac{\sigma_{PI}}{\sigma_{TI}}, & \sigma_{PI} \le \sigma_{TI} \\ \dfrac{\sigma_{TI}}{\sigma_{PI}}, & \sigma_{PI} > \sigma_{TI} \end{cases}, \tag{6}$$

σ_{PI} and, σ_{TI} are the standard deviation of S_{PI} , S_{TI} and, $\phi_{S_{PI}}$, $\phi_{S_{TI}}$ are the phase of S_{PI} , S_{TI} .

Results

The α optimum value was $\alpha = 1.09$. Using the linear-no linear correlation and a group of 30 phytoplankton species scaled from 85% to 115% and rotated around 360° the correlation value was obtained. Then using the Z-Fisher transform [8] with 99.9% of confidence level to transform each correlation value, in each species the maximum and minimum ρ value were graphed. The results for each species shown that the RHTO methodology could recognize all species, the correlation values using species 20 as filter are shown in fig. 1. The results are similar to the other 29 species correlated with RHTO signatures and adaptive linear-nonlinear correlation. To each species, the filter values are upper than the other values and this allow identified the target species.

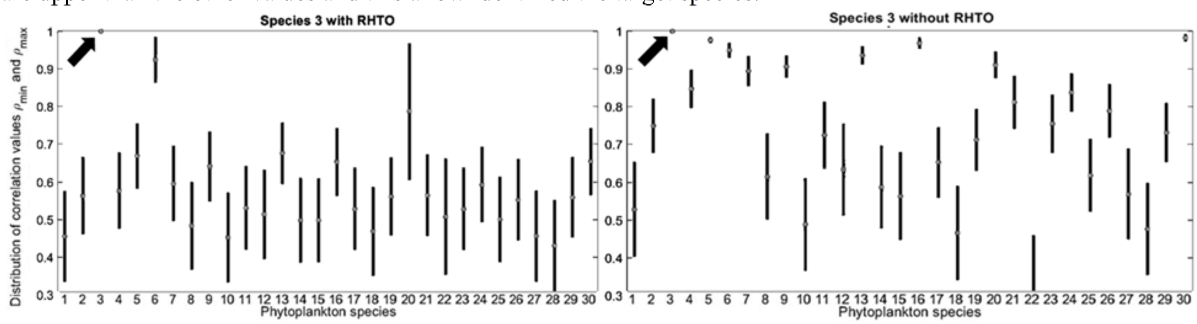

Fig. 1 ρ values between different phytoplankton images using the Z-Fisher transform and adaptive linear-nonlinear filter and its comparison with the conventional signature cases.

Conclusions

The RHTO produces an optimized signature which is longer, it discriminates between other representative signatures and it has a higher confidence level. In this work the optimal value of α was 1.09 to provide longer signatures, this α value is the same for auto-correlation value and maximum signature length.

Longer signatures had more information to correlate; this produces a better confidence level than the signatures created with conventional radial Hilbert transform. The correlation values were evaluated with the Z-Fisher transform, found a confidence level up to 99.9% in the 30 species and a confidence level of 100% using alphabetic letters. This methodology can be used to obtain more information from an image transformed into a signature. The proposed methodology produces a good discrimination capability for the target signature.

Keywords: Optimized Hilbert transform; linear-nonlinear correlation; Fourier optics; pattern recognition.

Topic Code: Image processing, vision and artificial intelligence.

References

[1] Guerrero-Moreno, R. E., & Álvarez-Borrego, J., *Optical Engineering*, Vol. 48, No. 6, 067201-067201 (2009).
[2] Bracewell, R., Fourier Analysis and Imaging. 3rd. ed. *Springer,* New York, (2000).
[3] Casasent, D., & Psaltis, D., *Applied Optics*, Vol. **15**, No. **7**, 1795-1799 (1976).
[4] Selene Solorza and Josué Álvarez-Borrego. *Optics Communications*, **283**, pp. 3613-3630 (2010).
[5] Barajas-García, C., Solorza-Calderón, S., and Álvarez-Borrego, J. *Optics Communications*. **367**, 335-345 (2016).
[6] Pei, Soo-Chang., Tseng, Chien-Cheng. (ICASSP'03). IEEE International Conference, **3**, 357-360 (2003).
[7] Andrews, L. C., & Shivamoggi, B. K. *Integral Transforms for Engineers*, **66**, SPIE Press, (1988).
[8] Sánchez-Bruno, A. and del Rosal, A. B. *Psicothema,* Vol. **17** No. **1**, 148–153 (2005).