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Invariant Optical Color Correlation for Recognition of *Vibrio cholerae* O1

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Abstract

The goal of this work is evaluate the utility of coherent optical systems with invariant color correlation for the recognition of Vibrio cholerae O1 in culturable and non-culturable stage stained with direct inmunofluorescence in laboratory and environmental samples. Images of scenes was recorded with a CCD camera and decomposed in three RGB channels . The position, scale and rotation invariant image recognition was made through the scale transform. In all cases the bacteria was identified. The correlation peaks position that appear in green channel output are dependent of differences of bacteria's angle (along y-axis) and size (along x-axis) in problem images with filter image.

1. Introduction

The results reliability of ecological studies about microscopic organisms greatly depends on the correct identification and quantification of the organism under study in natural environments. For instance, *Vibrio cholerae* O1 is responsible of cholera disease and there are many unsolved questions about its ecology that could be answered through the observation of a large number of seawater samples world-wide in order to figure it out[1-2].

The different human-driven techniques to recognize bacteria have some troubles in the reliability. The automated methods like the optical systems represent a new possibility to make better measurements about the presence and quantity of this microorganism in its natural environment. Automatic systems eliminate observer bias and reduce analysis time and relieve researchers of tedious activity of organism identification and counting and provides major effectiveness.

Nevertheless, bacteria's recognition of particular specie is a complex issue. Bacteria shape does not provide enough information to identify them, because there are many species that share the same shape. *Vibrio cholerae* O1 has a transparent curve rod the same as all kind of Vibrionaceae family among others[3]. To solve this problem, we can mark Vibrio cholerae O1 with monoclonal antibodies and give them a specific green color[4]. We use optical color correlation systems in order to increases the discriminability capacity of pattern recognition filters, taking in account color and shape information[5-8]. Bacteria's color and shape depends on the illuminating wavelength, that is, color introduces additional information for recognition effectiveness. The logical or arithmetical sum of polychromatic object decomposition in three simple monochromatic channels (Red, Green and Blue RGB) produces a high level of recognition of targets. Bacteria's morphology, orientation and size changes are other problems that we have to address. Besides shape and color, we need an optical system invariant to position, scale and rotation. We use the digital scale transform, a particular case of the Mellin transform[9] in order to implement an optimal process that guarantees a high discrimination capability of invariant pattern recognition through color correlators. This approach have never been used in color systems. Our goal is to evaluate the efectiveness of color correlation sistems for *Vibrio cholerae* O1 recognition, and also develop invariant filters comparing the performance of Matched Filters with Phase-Only filters.

2. Invariant color object recognition

A numerical simulation was performed in order to correlate *Vibrio cholerae* O1 with Phase-only filters (POF). All steps were developed digitally. The Scale transform was used in this correlation process due its invariance to size changes[10]. If we call c the scale variable then scale transform and its inverse is given by

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$$D(c) = \frac{1}{\sqrt{2\pi}} \int_0^\infty f(x) \frac{e^{-jc\ln x}}{\sqrt{x}} dx \ , \qquad (1)$$

$$f(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^\infty D(c) \frac{e^{jc\ln x}}{\sqrt{x}} dc; \ x \geq 0 \ . \qquad (2)$$

The scale transform can be written as

$$D(c) = \frac{1}{\sqrt{2\pi}} \int_0^\infty f(x) x^{-jc-1/2} dx, \qquad (3)$$

which shows that it is the Mellin transform with the complex argument –jc+1/2. The Fourier-Mellin transform was introduced by Casasent[11] for rotation and scale invariant pattern recognition and also Altes has used it to study mammallian hearing[12]. A practical realization of the Mellin transform is given by a logarithmic mapping of the input scene followed by a Fourier transform. Since we are dealing with the Mellin transform of a complex argument, there exists a direct relationship with the Fourier transform. In particular if we define a signal $f_l(x) = \frac{1}{\sqrt{x}} f(\ln x)$ then by substituting in Eq. 1 we have

$$D_l(c) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^\infty f(x) e^{-jcx} dx, \qquad (4)$$

that is $F(c) = D_l(c)$. From this relation one can see the scale by resampling the uniformly distributed samples of x with a logarithmic function.

A non-separable direct 2D scale transform $D(c_r, c_\theta)$ is used in this correlation process because it is invariant to size changes, and is given by:

$$D(c_r, c_\theta) = \frac{1}{\sqrt{2\pi}} \int_0^\infty \int_0^{2\pi} f(r,\theta) r^{-jc_r-1/2} e^{-jc_\theta\theta} dr d\theta, \qquad (5)$$

and taking the log of the radial coordinate $\lambda = \ln(r)$ we get

$$D(c_\lambda, c_\theta) = \frac{1}{\sqrt{2\pi}} \int_0^\infty \int_0^{2\pi} e^{\lambda/2} f(\lambda,\theta) e^{-j(\lambda c_r + \theta c_\theta)} d\lambda d\theta. \qquad (6)$$

As it was mentioned before, bacteria's recognition of particular species is a complex issue. Bacteria shape does not provide enough information to identify them, because there are many species that share the same shape. In specific case of Vibrio cholerae O1, color information is so important and color becomes an important variable, which we need to add it to this mathematical process of identification.

In general, a polychromatic object presents different shape and amplitude distribution $A_{\lambda i}(x,y)$ when illuminated with different wavelength λ. However, two different objects may present similar amplitude distribution when they are illuminated with determined wavelength λ_0. So, in an optical pattern recognition process using a correlator illuminated with a wavelength λ_0, these objects will give very similar amplitude correlation distributions, and some false alarms will appear. To avoid this problem, it is necessary to use the information about the dependence of the object amplitude distributions on wavelength[13].

Most of the natural colors can be obtained as a combination of three colours (called primaries) if they are well selected. Each of them has to be on red (R), green (G), and Blue (B) regions of visible spectrum respectively. When the object is a transparency, the amplitude transmittance obtained with illumination of one of these primaries will be called red, green and blue components of the object.

The recognition of an object in a scene is achieved by decomposing the information in three monochromatic channels and by identifying the object independently in each channel. In another words, the correlation $C_{\lambda i}(x,y)$ between the scene to be analyzed $F_{\lambda i}(x,y)$ and the bacteria to be detected $B_{\lambda i}(x,y)$, in this case, are obtained by illuminating an optical set up with three wavelengths λ_i=R,G,B which cover visible spectrum

$$C_{\lambda i}(x,y) = F_{\lambda i}(x,y) \otimes B_{\lambda i}(x,y) \qquad (7)$$

Thus, the invariant correlation will be repeated for each channel (R,G, and B). In each channel, the filter to be used is matched to the corresponding component of the target. In general, objects which have a determined component $A_{\lambda i}(x,y)$ similar to component of the target $B_{\lambda i}(x,y)$ will give a maximum of correlation in this channel (λ_i). But only the target will simultaneously give a correlation maximum in each channel. So, an object is detected as the target if it simultaneously produces a correlation peak in the three channels. But, in this particular case of *Vibrio cholerae* O1, we could mark it with a specific green color with monoclonal antibodies. So, the correct identification for these bacteria will be in the green channel, the presence of correlation peaks in the other two channels is a discriminate criterion. Therefore it is possible, with this methodology mentioned above, to

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recognize Vibrio cholerae O1 in a digital correlator invariant to rotation, position and scale.

3. Results and discussions

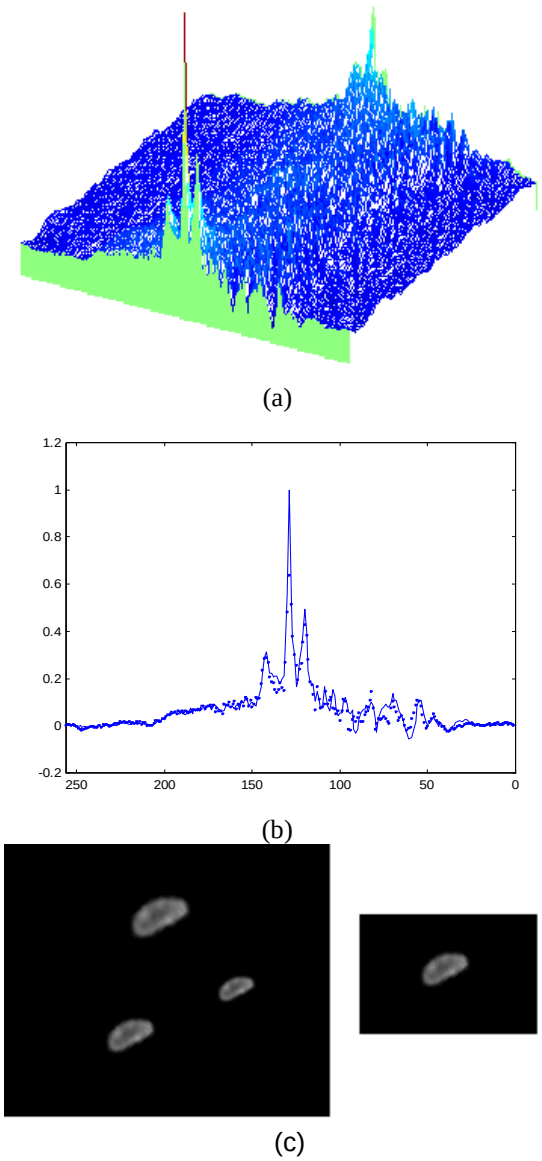

Figure 1. Correlation of three *Vibrio cholera* 01 with different scale.

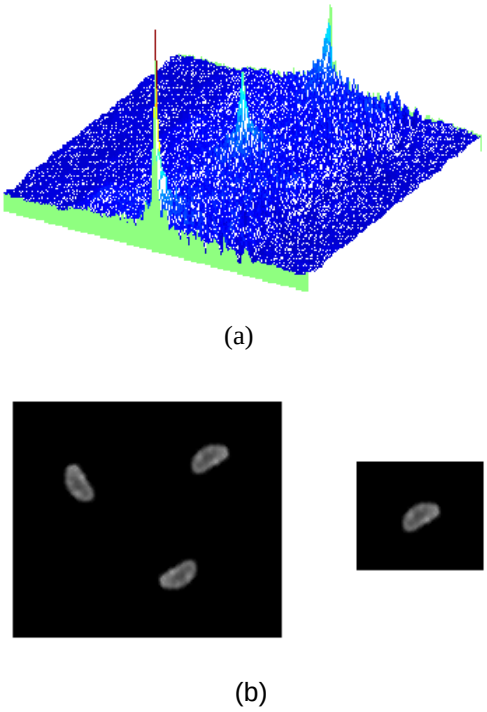

Figure 2. Correlation of three *Vibrio cholera* 01 with different rotation.

Figure 1 shows an invariant correlation, in the green channel, where it is possible to identify three *Vibrio cholerae* 01 with three different scales. Figure 1a shows a tridimensional perspective of the results where we can observe three peaks (in the scale direction). Each peak corresponds to one identification. Figure 1b shows a profile of the first line (filled line) and of the second line of the output matrix (dotted line). In this way we can observe better the peaks. Figure 1c shows the problem image and the filter to be recognized. Figure 2 shows the same filter but with different problem image. Now we can see three different rotations. The output plane, in the green channel, shows three peaks which corresponds to 0^o degrees, 90^o degrees and 180^o degrees of rotation with respect to the filter. In the red and blue channel we can not find any information.

4. Conclusions

Using the scale transform via Mellin transform is possible to identify *Vibrio cholerae* 01 to different scales and rotations. The ubications of the peaks depend of the scale and rotation of the images to be recognized. The output correlation is in the green channel only.

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5. References

[1] R. Colwell, "Global climate and infectious disease: The cholera paradigm", *Science*, 274:2025-2031, 1996.

[2] R. R. Mouriño-Pérez , "Oceanography and the seven cholera pandemic", *Epidemiology*, 9(3):355-357, 1998.

[3] K. Wachsmuth, G. K. Morris, J. C. Feeley, "Vibrio" In *Manual of Clinical Microbiology*, pages 226-234, Denver, CO, 1980.

[4] J. A. K. Hasan, D. Bernstein, A. Huq., L. Loomis, M. L. Tamplin, R. R. Colwell, "Cholera DFA: An improved direct fluorescent monoclonal antibody staining kit for rapid detection and enumeration of *Vibrio cholerae* 01", FEMS *Microbiol Letters*, 120:143-148, 1994.

[5] M. S. Millan, J. Campos, C. Ferreira, M J. Yzuel, "Matched filter and phase only filter performance in colour image recognition", *Optics communications*, 73(4):277-284, 1989.

[6] M. S. Millan, M. J. Yzuel, J. Campos, C. Ferreira, "Strategies for the color character recognition by optical multichannel correlation", In *SPIE*, volume 1507, pages 183-197, 1991.

[7] M. S. Millan, N. Vila, M. J. Yzuel, "Colour reversal films in multichannel optical correlators for polychromatic image recognition", *Pure Appl. Opt.* , 1:199-218, 1992.

[8] V. Kober, V. Lashn, I. Moreno, J. Campos, "Color component transformations for optical pattern recognition*", J. Opt. Soc. Am*., 14:2656-2669, 1997.

[9] J. L. Pech-Pacheco, J. Alvarez-Borrego, "Optical-digital system applied to the identification of five phytoplankton species", *Marine Biology*, 132:357-365, 1998.

[10] L. Cohen, "Time-frequency analysis", Prentice Hall Signal Processing Series, Upper Saddle River, New Jersey 07458, 1995.

[11]] D. Casasent and D. Psaltis. Position, rotation and scale invariant optical correlation. Appl. Opt., 15(7):1795-1799, 1976.

[12] R. Altes. The Fourier-Mellin transform and mammalian hearing. *J. Acous. Soc. Am.*, 63(1):174-183, 1978.

[13] J. Campos, M. S. Millan, M. J. Yzuel, C. Ferreira, "Colour invariant character recognition and character-background colour identification by multichannel matched filter", In *SPIE*, volume 1564, pages 189-198, 1991.