The digital pattern recognition system by Fourier masks

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The digital systems to pattern recognition by Fourier masks which are invariant to position, rotation, noise and nonhomogeneous illumination are presented. Here, it is shown the manner to generate the mask filters and the one-dimensional signatures.

Introduction

The digital system by Fourier masks works with the modulus of the Fourier transform of the image $I$, that is $|FT(I)|$, because in this way the system is shift invariance in an easy manner. To obtain the rotational invariance, binary rings masks are build using the real and imaginary parts of the Fourier transform of the image, that is, $Re(FT(I))$ and $Im(FT(I))$.

Fourier masks

The $Re(FT(I))$ and $Im(FT(I))$ of a given image $I$ could be viewed as image too, hence both are processed by a disk filter of diameter $n$ and the results are called, $f_R$ and $f_I$. The digital system works with $n \times n$ gray-scale images which they centered-pixel are $(c_x, c_x)$; for $f_R$ and $f_I$ the 180 profiles of $n$-pixels length that passes for $(c_x, c_x)$ and separated by a $\Delta \theta = 1$ degrees were obtained. Next, the addition of the square of the intensity values in the profiles for $f_R$ and $f_I$ are computed. For each image, we will select the profile whose sum has the maximum value, named $T_R$ and $T_I$. Now, we can build the four binary functions

$$Z_{RP}(z) = \begin{cases} 1, & \text{if } T_R(z) > 0, \\ 0, & \text{if } T_R(z) \leq 0. \end{cases} \quad Z_{RN}(z) = \begin{cases} 0, & \text{if } T_R(z) > 0, \\ 1, & \text{if } T_R(z) \leq 0, \end{cases}$$

$$Z_{IP}(z) = \begin{cases} 1, & \text{if } T_I(z) > 0, \\ 0, & \text{if } T_I(z) \leq 0. \end{cases} \quad Z_{IN}(z) = \begin{cases} 0, & \text{if } T_I(z) > 0, \\ 1, & \text{if } T_I(z) \leq 0, \end{cases}$$

(1)

where $z = 1, \ldots, n$. Finally, taking the axis $z = c_x$ as the rotation axis, the graphs of $Z_{RP}$, $Z_{RN}$, $Z_{IP}$ and $Z_{IN}$ are rotated 360 degrees to obtain concentric cylinders of height one, different widths and centered in $(c_x, c_x)$ pixel [1]. Mapping those cylinders in the Cartesian-plane we built the binary rings masks associated to the given image. Fig. 1 shows an example of those Fourier masks.

The one-dimensional signatures

Once the masks are built, the next step is to obtain the one-dimensional signatures. First of all, $|FT(I)|$ is filtered by each of the four masks to generate the new four images $H_{RP}$, $H_{RN}$, $H_{IP}$ and $H_{IN}$. Then, the rings in each image are numbered from the center toward out-side and the addition of the intensity values in each ring are computed to generate the functions

$$S_j = \text{Index} \rightarrow A \subset \mathbb{R}$$

$$S_j(\text{ring}) = \sum H_j, \text{ if } H_j(x, y) \text{ belongs to the ring},$$

(2)
here \( \text{Index} \subset \mathbb{N} \), represents the set of the numbers of rings in the image \( H_j \) with \( j = RP, RN, IP, IN \). The \( S_j \) functions are called the one-dimensional signatures of the image. To obtain an efficient recognition pattern digital system each signature will be weighted by the magnitude of the maximum value of they non-linear autocorrelation [1].

**The recognition process**

In the recognition step, first of all, it is set the signatures for the target \( T \), here will named \( T_j \), where \( j = RP, RN, IP, IN \). Then, the four maximum values of the magnitude for the non-linear autocorrelations of \( T_j \) are computed [1]. Therefore, the average of those four values are obtained and assigned to \( T \). This average value will determine if a problem image \( PI \) is \( T \) or other image.

To determine the pattern in \( PI \), as a first step its signatures are obtained, lets called \( P_j \). The next step is compute the four maximum values of the magnitude for the non-linear correlations of \( T_j \) and \( P_j \) and then average them. If the average value of \( PI \) is similar to the average value of \( T \), hence the problem image contains the target, otherwise there is an object different to the target.

**Results**

The recognition pattern digital system was tested using 21 gray-scale diatom fossil digital images as target and 7560 problem images. The statistical analysis were done by box plots with mean, two standard errors \((\pm 2SE)\) and outliers. The digital system has shown a confidence level of 100% in the recognition of the diatom fossil images even with non-homogeneous illumination.

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**References**