JOINT POWER SPECTRUM ADDITION TECHNIQUE FOR OPTICAL COLOR PATTERN RECOGNITION

Tanwir Zubayer Islam, Md. Waliullah Khan Nomani, Syed Mustafa Khelat Bari, Md. Rafiqul Haider, and Mohammed Nazrul Islam

Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology
Dhaka-1000, Bangladesh
phone: +880 11 877122, fax: +880 2 8613046, email: jumon@agnionline.com, zubayer@hotmail.com

ABSTRACT

An improved fringe-adjusted joint transform correlator based technique for optical color pattern recognition is proposed. In this proposed technique, a joint color image is processed through three channels. The joint power spectrum (JPS) of each channel-component is obtained by Fourier transform operation. The JPS of the individual channels are then added to obtain the overall JPS. After applying the Fourier plane subtraction to the overall JPS, it is passed through a color fringe-adjusted filter to produce excellent correlation discrimination. The implementation complexity is reduced as the filtering and the inverse Fourier transform processed through only one channel. Opto-electronic implementation of the proposed technique is presented that can be applied in real time color pattern recognition for practical applications.

1. INTRODUCTION

Optical pattern recognition is usually carried out on the basis of correlation, which can be performed easily by the ability of a lens to perform a Fourier transform in parallel and in real time. Matched spatial filter correlators and joint transform correlators [1] (JTC) are the two widely used correlators. Between these, the JTC has become an imperative and impervious method in optical processing [2] because of its superior performance and absence of complex filter fabrication. However, the classical JTC suffers [3] strong zero-order diffraction terms. Fourier plane subtraction [4], correlation plane subtraction and phase-shift power spectrum subtraction all can yield a better correlation output but they all need multi-steps to achieve it, which limits their applications to the highly required real-time recognition tasks. Fringe-adjusted JTC [5] (FJTC) using the power spectrum of the reference image, can solve the real–time problem.

All of the above mentioned processes requires monochrome lasers to illuminate the images to perform various optical operations. Therefore, color pattern recognition using FJTC technique requires extra arrangements and special measures. Several works [6-8] have been proposed for classical JTC based color pattern recognition technique. Most of the works involve the separation of the color image into three components - red, green and blue. The multi-channel fringe adjusted JTC [9] for color pattern recognition technique produces a pair of correlation peaks for each of the red, green and blue channel, thus producing three pairs of correlation peaks for each target. This technique requires additional circuit components. The multi-channel single output FJTC [9] produces only one pair of correlation peaks for each target, but it requires special spatial arrangements for the red, green and blue components of the reference and input images. Both the techniques suffer from strong zero-order terms. The multi-channel single output FJTC produces fourteen other small delta-like peaks for each target, which may produce complicity for multiple target detection. Again, both the techniques involve monochrome lasers for illumination and therefore, require the color components (red, green and blue) to be converted into gray level. This requires off-line processing and thus reduces the processing speed. In this work, we propose a unique Fourier plane JPS addition technique, which involves three separate lasers (red, green and blue) for the three color channels to perform Fourier transform. In this technique, the joint power spectrums of the red, green and blue components of the joint image are individually Fourier transformed and then added to obtain the overall JPS of the joint color image. This technique does not require any off-line gray level conversion, does not produce any zero-order terms and above all, produces only one pair of sharp delta-like peaks for each target.

2. FRINGE-ADJUSTED JTC

In joint transform correlator (JTC), let the reference image and the input scene images are given by $r(x, y+y_0)$ and $t_1(x-x_1, y-y_1)$, $t_2(x-x_2, y-y_2)$……………… $t_n(x-x_n, y-y_n)$ respectively, then the joint image can be expressed as :

$$f(x,y) = r(x, y+y_o) + \sum_{i=1}^{n} t_i(x-x_i, y-y_o) \qquad (1)$$

The joint power spectrum (JPS) of equation (1) is

$$\begin{aligned}|F(u,v)|^2 &= |R(u,v)|^2 + \sum_{i=1}^{n} |T_i(u,v)|^2 \\ &+ 2\sum_{i=1}^{n} |T_i(u,v)||R(u,v)| \times \cos[\Phi_{ti}(u,v) - \Phi_r(u,v) - ux_i - vy_i - 2vy_o] \\ &+ 2\sum_{i=1}^{n}\sum_{\substack{k=1\\k\neq i}}^{n} |T_i(u,v)||T_k(u,v)| \times \cos[\Phi_{ti}(u,v) - \Phi_{tk}(u,v) - ux_i + ux_k - vy_i + vy_k]\end{aligned} \qquad (2)$$

where, (u, v) are the frequency co-ordinates. $R(u, v)$ and $T_i(u, v)$ are the amplitude spectrum of the reference image and the input object image, respectively. $\Phi_r(u, v)$ and $\Phi_{ti}(u, v)$ are the phase spectrum distributions. Inverse Fourier transform of the JPS in equation (2) produces the correlation output. In equation (2) the first two terms corresponds to zero order peak, the third term corresponds to the correlation between the reference image and the input scene objects and the last term represents the correlation between the different input scene objects.

In classical JTC the JPS expressed by equation (2) is directly fed into a second SLM, which is illuminated by a second laser. By taking the inverse Fourier transform of the JPS, correlation output is obtained. The correlation output contains broad zero order peak and false alarms between similar target and non-target objects. False alarms can be generated when multiple targets are present in the input scene. These false alarms can be avoided by eliminating the cross correlation terms between the different input scenes objects with the help of Fourier plane image subtraction technique. To eliminate the false alarms and other extraneous signals, Fourier plane image subtraction method is employed and the corresponding modified JPS is expressed as

$$P(u,v) = |F(u,v)|^2 - |R(u,v)|^2 - |T(u,v)|^2$$
$$= 2\sum_{i=1}^{n} |T_i(u,v)||R(u,v)|\cos[\Phi_{ti}(u,v) - \Phi_r(u,v) - ux_i - vy_i - 2vy_o] \quad (3)$$

where, $|R(u, v)|^2$ and $|T(u, v)|^2$ are the reference only power spectrum and the input only power spectrum respectively. The modified JPS as found in equation (3) is then multiplied by the fringe adjusted filter (FAF) transfer function. The FAF can be expressed as

$$H_{FAF}(u,v) = \frac{C(u,v)}{D(u,v) + |R(u,v)|^2} \quad (4)$$

where, $C(u, v)$ is used to control the gain of FAF and $D(u, v)$ to eliminate the problem related to poles and to suppress noise or to band limit the signal.

After multiplying the JPS with the FAF as found in equation (4), the fringe adjusted JPS can be expressed as

$$G(u,v) = H_{FAF}(u,v) \times P(u,v) \quad (5)$$

Inverse Fourier transform of equation (5) produces a pair of sharp delta-like correlation peaks for each target object.

3. FOURIER PLANE JPS ADDITION TECHNIQUE

Any color pattern can be fully represented through its three components, red, green and blue. For color patterns, the joint image shown in equation (1) can be realized through these three components. Therefore, the joint image becomes,

$$f_C(x,y) = \sum_{i=1}^{3} f_i(x,y)$$
$$= \sum_{i=1}^{3} \left(r_i(x, y + y_o) + \sum_{j=1}^{n} t_{ij}(x - x_j, y - y_o)\right)$$

where, $f_1(x, y)$, $f_2(x, y)$ and $f_3(x, y)$ are the red, green and blue components of the joint image respectively. The JPS, shown in equation (2) is therefore, the summation of the joint power spectrums of these three components of the joint image. The overall JPS for the joint color image can be represented as,

$$|F_C(u,v)|^2 = \sum_{i=1}^{3} |F_i(u,v)|^2 \quad (6)$$

where, $F_i(u, v)$ is the Fourier transform of $f_i(x, y)$ and $|F_1(u, v)|^2$, $|F_2(u, v)|^2$ and $|F_3(u, v)|^2$ are the individual joint power spectrums of the red, green and blue components of the joint image, found by the equation (2). In the proposed Fourier plane JPS addition technique, the red, green and blue components of the joint image are individually Fourier transformed to get the joint power spectrums for each channel. These three joint power spectrums are then added to obtain the overall JPS of the joint color image.

Elimination of the false alarms and other erroneous signals are done bye Fourier plane image subtraction technique as shown in equation (3). Here, again, the reference only power spectrum $|R(u, v)|^2$ and the input only power spectrum $|T(u, v)|^2$ are the summation of the power spectrums of the three components. Therefore, the modified overall JPS of color joint image after image subtraction is given by,

$$P_C(u,v) = \sum_{i=1}^{3} |F_i(u,v)|^2 - \sum_{i=1}^{3} |R_i(u,v)|^2 - \sum_{i=1}^{3} |T_i(u,v)|^2$$

Here, $|R_1(u,v)|^2$, $|R_2(u,v)|^2$ and $|R_3(u,v)|^2$ are the reference only power spectrums for the red, green and blue components of the reference image and $|T_1(u,v)|^2$, $|T_2(u,v)|^2$ and $|T_3(u,v)|^2$ are the input only power spectrums for the red, green and blue components of the input image. The FAF defined by the equation (4) is changed as the reference only power spectrum is changed for color image. The color fringe adjusted filter (CFAF) for this technique is therefore defined as,

$$H_{CFAF}(u,v) = \frac{C(u,v)}{D(u,v) + |R_1(u,v)|^2 + |R_2(u,v)|^2 + |R_3(u,v)|^2} \quad (7)$$

After multiplying the overall modified JPS of the color joint image with the CFAF as found in equation (7), the fringe adjusted JPS can be expressed as

$$G_C(u,v) = H_{CFAF}(u,v) \times P_C(u,v) \quad (8)$$

Inverse Fourier transform of equation (8) produces a pair of sharp delta-like correlation peaks for each color target object.

4. OPTICAL IMPLEMENTATION AND SIMULATION RESULTS

The opto-electronic implementation setup for Fourier plane JPS addition technique is shown in Fig. 1. The three channels are shown by red, green and blue colors respectively. The input color image is recorded by the color CCD. The red, green and blue components of the input image are displayed in the left of SLM1, SLM2 and SLM3 respectively, via a switching circuit. The reference is downloaded from the computer and the red, green and blue components of the reference image are displayed in the right of SLM1, SLM2 and

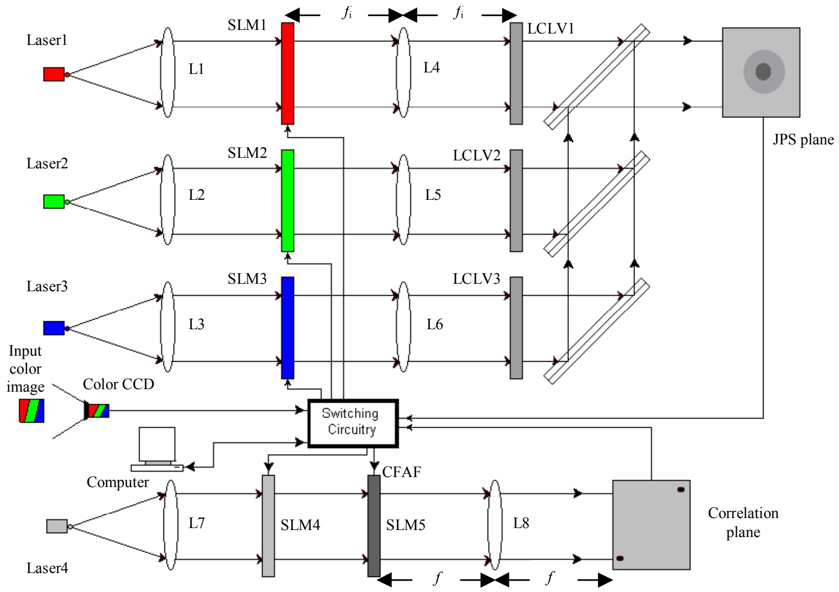

Figure 1: Opto-electronic implementation setup for Fourier plane JPS addition technique.

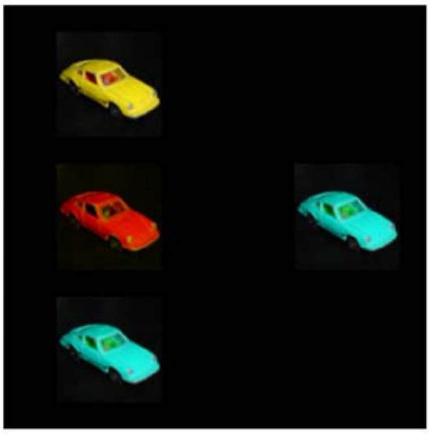

Figure 2(a): Joint image

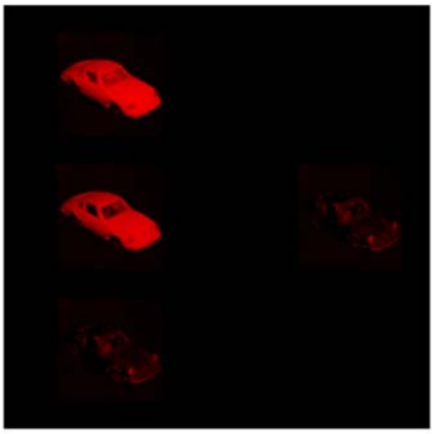

Figure 2(b): Red component of the joint image

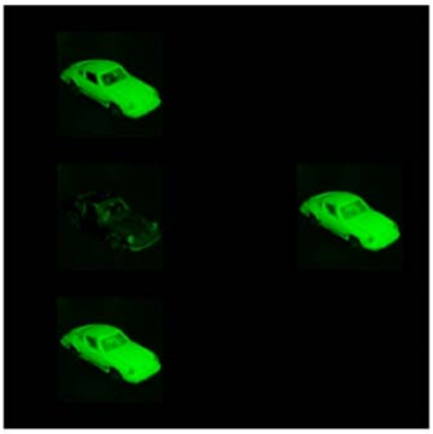

Figure 2(c): Green component of the joint image

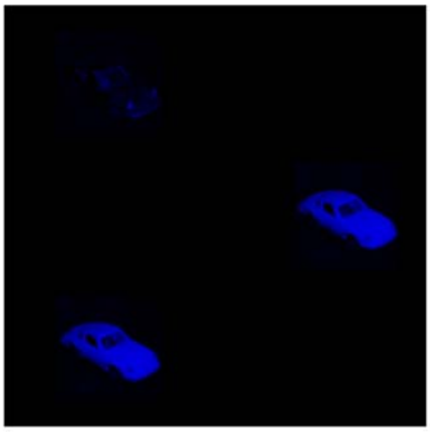

Figure 2(d): Blue component of the joint image

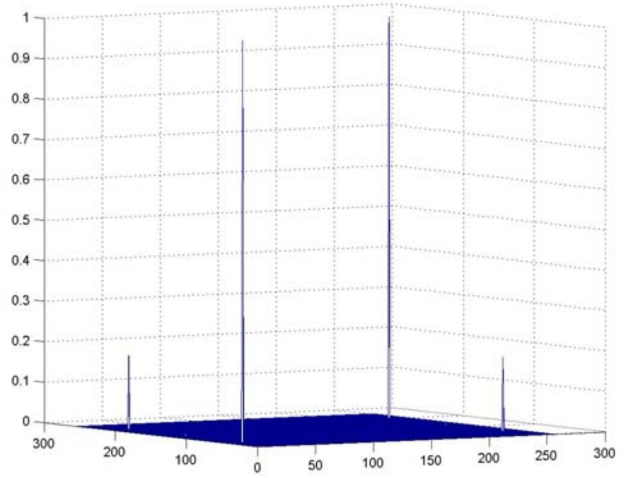

Figure. 3: Correlation output of the joint image in fig. 2(a)

SLM3 respectively. SLM1, SLM2 and SLM3 are red, green and blue light modulators. The three SLMs are modulated through the illumination of three separate Lasers. Laser1, Laser2 and Laser3 illuminate red, green and blue lights respectively. The three components of the joint image are Fourier transformed by the three-lens array, L4, L5 and L6. The SLM and the LCLV are placed at the focal point of the respective lens. The JPS of the three channels are recorded through LCLV1, LCLV2 and LCLV3 respectively. These three LCLVs are gray level detectors and detect only the intensity and no color information. The three JPS are then reflected to the JPS plane to form the overall JPS of the joint color image. The modified JPS are downloaded to SLM4, which is a gray level modulator. The CFAF is downloaded to SLM5. Therefore, after multiplied by the CFAF, the overall modified JPS is inverse Fourier transformed by lens L8 to produce a pair of delta-like correlation peaks in the correlation plane.

The performance of the Fourier plane JPS addition technique of fringe-adjusted color JTC was investigated by developing a detailed simulation program using the MATLAB software package. Fig. 2(a) shows the joint color image. The size of the input images and reference is 64×64 pixels and the overall size of the joint images and the output plane is 256×256 pixels. The reference image is placed in the right, where the input images are placed in the left of the joint image plane. The input plane contains three same objects with different colors. The red, green and blue components of the joint image are shown in Fig. 2(b), Fig. 2(c) and Fig. 2(d) respectively. The JPS of the red, green and blue components of the joint image are added to find the overall JPS for the color joint image. Fourier plane subtraction is employed to eliminate zero order terms. The CFAF was calculated using equation (7) with $C(u, v)$ set to 0.00001 and $D(u, v)$ set to 1. The correlation output after using FAF is shown in Fig. 3. From Fig. 3 it is clear that for each detected target, two sharp delta-peaks with no side-lobs are present in the output plane. No zero-order term is present in the output correlation plane. Therefore, from the simulation results it is evident that this technique can perfectly detect the color objects and shows better performance when compared to the existing systems of optical color pattern recognition.

5. CONCLUSION

In this paper, an improved approach for optical color pattern recognition has been proposed. This technique requires three color channels to produce three JPS for each channel. These three JPS are added to obtain the overall JPS of the joint color image. The proposed technique uses the fringe-adjusted joint transform correlator to aid the discrimination in correlation output. The one channel operation for the filtering and the inverse Fourier transform process reduces the system complexity and instrument size. A modified FAF, called the color fringe-adjusted filter is used in this technique. This technique produces only one pair of delta-like peaks for each detected target and no zero order term is present in the output plane. It does not require any special formation in the input plane and thus the processing speed is not hampered. No gray level processing in the input plane in required and the off-line processing is reduced. Simulation results are formulated in this paper that reflect the excellent effectiveness and better performance of the proposed scheme when compered to alternative techniques.

REFERENCES

[1] C. S. Weaver and J. W. Goodman, "Technique for optically convolving two functions," *App. Opt.,* vol. 5, pp. 1248-1249, 1966.

[2] F. T. S. Yu and X. J. Lu, "A real-time programmable joint transform correlator," *Opt. Commun.,* vol. 52, pp. 10-16, 1984.

[3] F. T. S. Yu, C. Li, and S. Yin, "Comparison of detection efficiency for nonzero-order and conventional joint transform correlation," *Opt. Eng.,* vol. 37(1), pp. 52-57, 1988.

[4] C.T. Li, S. Yin, and F.T.S Yu, "Nonzero-order joint transform correlator," *Opt. Eng.,* vol. 37(1), pp. 58-65, 1998.

[5] X. W. Chen, M. A. Karim and M. S. Alam, "Distortion-invariant fractional power fringe –adjusted joint transform correlation," *Opt. Eng.,* vol. 37(1), pp. 138-143, 1998.

[6] F. T. S. Yu, Z. Yang, and K. Pan, "Polychromatic target identification with color liquid- crystal-TV-based joint-transform correlator," *Appl. Opt.,* vol. 33, pp. 2170-2172, 1994.

[7] M. Corbalan and M. S. Millan, "Color image acquisition by charge-coupled device cameras in polychromatic pattern recognition," *Opt. Eng.,* vol. 35, pp. 754-758, 1996.

[8] M. Deutsch, J. Garcia, and D. Mendlovic, "Multichannel single-output color pattern recognition by use of a joint-transform correlator," *Appl. Opt.,* vol. 35, pp. 6976-6982, 1996.

[9] Mohammad S. Alam, and C. N. Wai, "Color pattern recognition using fringe-adjusted joint transform correlation," *Opt. Eng.*, vol. 40(11), pp. 2407-2413, 2001.