HYBRID JOINT TRANSFORM CORRELATOR AT RATE GREATER THAN VIDEO FRAME

Joaquín Cornejo, Yezid Torres
Grupo de Óptica y Tratamiento de Señales, Escuela de Física
Universidad Industrial de Santander, A.A. 678, Bucaramanga, Colombia
(Recibido 09 de Sep.2005; Aceptado 20 de Jun. 2006; Publicado 20 de Nov. 2006)

RESUMEN

En este trabajo se implementa un correlador híbrido de transformada conjunta (JTC óptico/electrónico) útil en el reconocimiento de formas cuando la escena está en movimiento. Se utiliza la arquitectura JTC estándar. La primera etapa del proceso de correlación es llevada a cabo opticamente. Así se obtiene la densidad espectral de energía conjunta (JPS) de cada cuadro visualizado sobre un modulador espacial de luz, un LCD CRL XGA4 con 1024x768 de resolución en escala de gris. Éste despliega una secuencia de imágenes donde está incluida una escena móvil y la referencia, entonces, la JPS de cada cuadro se obtiene en tiempo real con el sensor cuadrático (cámara CCD) ubicado en el plano focal posterior de la lente. Para la segunda etapa, se emplean las herramientas del Imaging Developer Kit TMS3206711 DSP (IDK) de Texas Instruments, con el objetivo de tomar ventaja de la aritmética de alta velocidad y de la versatilidad para tomar decisiones del procesador digital de señales (DSP). El IDK es una herramienta de hardware y software que permite capturar, procesar y visualizar imágenes en tiempo real. El DSP realiza una transformada de Fourier de la imagen capturada por la CCD usando un algoritmo de cálculo eficiente para una secuencia de 2N-puntos reales, de ésta forma, se consigue correlacionar escenas en movimiento a una rata superior que la rata de video.

Palabras claves: JTC, DSP, Correlación Híbrida.

ABSTRACT

In this work we implemented a hybrid Joint Transform Correlator (JTC optical/electronic) helpful in the pattern recognition when the scene is in movement. We have been use the JTC standard architecture. The first step of the correlation process is carried out optically. To obtain the joint power spectrum (JPS) of each frame display, we used a spatial light modulator; a LCD CRL XGA4 with 1024 x 768 pixels of resolution in grayscale. It display a sequence of images where is included a mobile and reference scenes, then, the JPS of each frame will be obtain in real time with the quadratic sensor (camera CCD) that is located in the back focal plane of the lens. For the second step, was use the tools of the Imaging Developer Kit TMS3206711 DSP (IDK) of Texas Instruments, in order to take advantage of the high speed arithmetic and the versatility of the Digital Signal Proccessor (DSP). The IDK is a tool of hardware and software that allows capture, processing and display images in real time. The DSP makes a Fourier transform of the image captured by the CCD using an efficient algorithm of 2N-point real sequence, in this way, we obtain the correlation of the scene in movement at rate greater than video frame.

Key Words: JTC, DSP, Hybrid Correlation.

1. Introduction

The pattern recognition plays an important role in applications of vision systems, assisted location of trajectories, protection of changes, tracking systems, and others[1-4]. This type of applications require real-time, therefore, the complementation between optical systems and electronic, in our case the liquid crystal display and digital signal processor, offer the rapidity and versatility necessary[1].

The following equation, shows the correlation result for a linear JTC[5]. The first and second terms in this equation correspond to the autocorrelation of the reference and target objects respectively, and the last two terms are the cross correlation, these are centered in (0, -Y) and (0,Y) on the correlation plane.

$$u_3(x_3,y_3)=\frac{1}{\lambda f}\Big[h(x_3,y_3)*h^*(-x_3,-y_3)+g(x_3,y_3)*g^*(-x_3,-y_3)+ \\ h(x_3,y_3)*g^*(-x_3,-y_3)*\delta(x_3,y_3-Y)+h^*(-x_3,-y_3)*g(x_3,y_3)*\delta(x_3,y_3+Y)\Big] \tag{1}$$

Here λ is the wavelength and f the focal length of the lens in the optical setup (see below, fig.1).

There are two major drawbacks with the conventional (optical) JTC, owing to the existence of zeroth-order spectra, and the need of a high quality SLM, such as, high spatial resolution requirement, for display the JPS and obtain the correlation output. In the next section, we propose a hybrid optical/electronic system that can perform in real-time the correlation and keeps in mind these critical drawbacks.

On the other hand, the imaging developer's kit with DSP, is a plataform to develop image processing applications[6]. The performance of the system involves components that go from a CCD camera to a monitor interface to visualize the results of the processing. The principal software tool is the Code Composer Studio IDE®[7].

2. Hybrid JTC based on DSP device[8,9]

The fig.1 shows the hybrid correlator JTC, the input plane of the correlator is a liquid crystal display (LCD) CRL XGA4 of 1024 x 768 pixels in gray scale. In it display a sequence with the mobile and the reference scenes, then, optically is calculated in real-time the JPS for each frame over the CCD sensor. The hybrid architecture of correlation, that we propose, uses a DSP device to carry out the second stage in the JTC correlator, in other words, to process the JPS.

The DSP system capture in real-time the JPS and process its Fourier transform to obtain the result in digital way. The numerical representation of the correlation allows eliminate the zeroth-order spectral peaks or dc term, thus, the drawbacks of JTC optical system mentioned above have been avoided.

The DSP processor must be programmed for calculate efficiently the two-dimensional Fourier transform and display the correlation result in suitable form; in order to fulfill this objective, we used the symmetries offered by the Fourier transform and the algorithm "efficient calculus of 2N-point real sequence" [1,10]. The use of conjugate symmetry of the FFT, allow calculate only N/2+1 Fourier transformations of one-dimension instead of N transformations:

$$X(k)\xleftrightarrow[N]{DFT}x(n)\in R\Rightarrow X(N-k)=X^*(k) \tag{2}$$

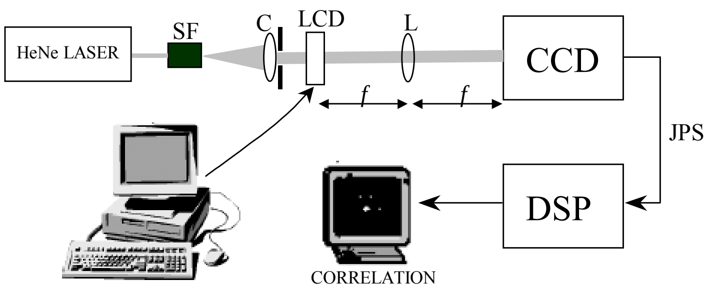

Fig.1 Hybrid JTC correlator.

The fig.2 resume the procedure, the small character represent a real number while the capital character represent a complex number. The bold letters are the complex numbers that can be expressed in function the other element of the arrange, so, the symmetry of the discrete transformation result,

$$\begin{aligned} C_d\left(N/2+j,k\right) &= C_d^*\left(j,M-k\right) \\ C_d\left(N/2+j,0\right) &= C_d^*\left(j,0\right) \end{aligned} \quad if \begin{cases} k=1,2,3,\ldots,M-1 \\ j=1,2,3,\ldots,\dfrac{N}{2}-1 \end{cases} \tag{3}$$

a	t	c	d	q	f	z	r
y	u	d	r	s	v	a	n
l	q	w	d	f	a	k	t
o	u	g	d	s	r	g	n
n	h	g	e	w	y	u	z
p	i	u	n	h	g	k	x
v	b	h	k	f	d	s	a
d	t	y	n	g	v	s	p

(a) C_a (N columns × M rows)

G	H	S	R	Q	**R***	**S***	**H***
N	G	J	K	W	**K***	**J***	**G***
L	P	U	T	R	**T***	**U***	**P***
P	R	A	S	F	**S***	**A***	**R***
O	J	G	H	T	**H***	**G***	**J***
K	M	L	R	E	**R***	**L***	**M***
C	V	B	D	S	**D***	**B***	**V***
J	H	Y	T	E	**T***	**Y***	**H***

(b) C_b (N columns × M rows)

G	N	L	P	O	K	C	J
H	G	P	R	J	M	V	H
S	J	U	A	G	L	B	Y
R	K	T	S	H	R	D	T
N	W	R	F	T	E	S	E
R*	**K***	**T***	**S***	**H***	**R***	**D***	**T***
S*	**J***	**U***	**A***	**G***	**L***	**B***	**Y***
H*	**G***	**P***	**R***	**J***	**M***	**V***	**H***

(c) C_c (M columns × N rows; last rows: N/2 - 1)

S	D	R	G	V	B	N	L
A	W	E	R	U	A	S	Z
X	K	C	M	P	O	U	T
H	K	G	F	N	M	P	O
R	E	Q	W	D	S	A	B
H*	**O***	**P***	**M***	**N***	**F***	**G***	**K***
X*	**T***	**U***	**O***	**P***	**M***	**C***	**K***
A*	**Z***	**S***	**A***	**U***	**R***	**E***	**W***

(d) C_d (M columns × N rows; last rows: N/2 - 1)

Fig.2 Procedure to calculate the discrete Fourier transform using conjugate symmetry. (a) Input signal. (b) FFT of each row of matrix C_a. (c) Transposition of matrix C_b. (d) FFT of each row of matrix C_c.

Thus, the hybrid correlator perform 31,5 correlations per second, actually. This result show that the DFT 2D calculus through the strategy previously allows to duplicate the rapidity of the correlator, in contrast with reference 8.

On the other hand, Neema et al[11] report that its correlador 100% digital, made 30 correlations per second, but with resolution of 128x128 pixels (half resolution of the correlador implemented in this work), in addition, the prototype developed uses from 10 to 14 DSPs.

The reference 1 is other correlator completely digital (architecture VanderLugt), it uses a DSP with the same characteristics, there is reported that the correlator executes approximately 12 correlations per second with equal resolution that ours, 256x256 píxeles. These comparisons allow to emphasize the advantage, as far as time of calculation, offered by the hybrid JTC.

Of a sensitivity test of the hybrid JTC was observe that the correlation peak intensity and the peak sharpness fall 50% when the input scene is 10% greater, while, with only 1° of target rotation the correlation peak intensity falls 15% approximately, and the peak sharpness 10%, according to the PCE criteria. For the maxima rotation used, 10°, the correlation decay 60%, for both characteristics. The discrimination capability of the correlator is 0.694 ± 0.022, the test was carry out with similar objects.

3. Conclusion

A hybrid JTC based on DSP device was implemented. This correlator at low cost is capable of perform 31.5 correlation per second with 256 x 256 pixels of resolution. The sensitivity test show the typical result of the mathed filter.

References

[1] H. Arguello y O. Gualdrón, VII Simposio de Tratamiento de Señales Imágenes y Visión Artificial, 55-60, 2002.
[2] Smith, "The Scientist and Engineer's Guide to Digital Signal Processing", Technical Publishing, (on line), California, 1997.
[3] W. Hardin, "DSP array upgrades optical correlation", Vision Sytems Desingd (on line), Octubre, 2001.
[4] M. Cavadini et al, IEEE trans. On very large scale Int. systems, 439-449, 2001.
[5] C. Weaver and J. Goodman, Appl. Opt., 1248-1249, 1966.
[6] TEXAS INSTRUMENTS, Imaging Developer's Kit [on line]. Available from Internet: http://dspvillage.ti.com/docs/catalog/dspdetails/dspplatformdetails.jhtml?navigationID=59&familyID=132.
[7] TEXAS INSTRUMENTS, Code Composer Studio, Getting Started Guide, Dallas: Soyink, 208p, 2001.
[8] J. Cornejo and Y. Torres, Proc. of SPIE Vol. 5776, 340-346, 2005.
[9] J. Cornejo and Y. Torres, Memorias IX Encuentro Nacional de Óptica, Accefyn, Junio, 2005.
[10] R. Matusiak, "Implementing Fast Fourier Transform Algorithms of Real-Valued Sequences with the TMS320 DSP family", Texas Instruments, 1997.
[11] S. Nema, et al, "Real Time Reconfigurable Image Recognition System", IEEE Instrumentation and Measurement. Technology Conference, Budapest, 2001.