Pattern Recognition with Joint Transform Correlators

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Abstract: ***Former works prove that phase input joint transform correlators have better detection efficiency than the amplitude ones. The preprocessed phase input joint transform correlator has the best detection efficiency. This correlator needs as parameters: the amplitude premodulation domain,*** $dfPRE$***, and the phase modulation domain,*** $dfPSLM$***. Computer simulations were done on some combinations of amplitude premodulation domains and phase modulation domains for four kinds of input images. Two kinds of images have black (null) background and grey background and two kinds of images have two types of embedding noise. These simulations were done to find the combination of the amplitude premodulation domain and phase modulation domain that has the best detection efficiency for all images.***

Keywords: ***pattern recognition, phase input-joint transform correlator, embedding noise.***

I. INTRODUCTION

Systems security is nowadys generic issue. Security means to provide or not acces to reasources. Restrictions rules can be built on several criteria. Biometrics is a popular criteria to restrict acces to some systems and preserve its security. One part of biometrics is fingerprint matching. From the several methods developt among the past years phase only correlation (POC) presents importance because its sub-pixel image translation capability.

Continuous surface objects, like human faces, are recognized without difficulties with joint transform correlators or modified models. The embedding and additive noises give more noncontinuous definition to surfaces and make it almost impossible to discriminate between the target image and the reference one from scene image.

There are many modified joint transform correlators: modified amplitude joint transform correlator (MAJTC) [1-3], modified phase input joint transform correlator (MPJTC) [4-9] and preprocessed modified joint transform correlator (preMPJTC) [10, 14] that can detect objects with additive or embedding noises.

In this paper the performances of previously mentioned joint transform correlators are compared at different background levels. It is well known that nonzero background gives better detection efficiency in optical correlation. Using such a background level might give a solution to alleviate the embedding or additive noises effects in optical pattern recognition.

II. THEORETICAL ANALYSIS

A. Classical phase transformation

Starting from this point, the phase modulated image is projected with an (PSLM) as joint image in the input plane of modified input phase hybrid joint transform correlator (MPJTC), (Fig. 1). The corresponding models mathematically consist in the following well known equations [1-3, 6-8] starting with

$$jnt(x,y) = ref(x, y+y_0) + scn(x, y-y_0) \quad (2)$$

where $2y_0$ is the distance between the reference image, $ref(x, y+y_0)$, and the scene image, $scn(x, y-y_0)$, $jnt(x,y)$ is the joint image. The next equation is

$$\begin{aligned} JmPS(u,v) &= JPS(u,v) - SPS(u,v) - RPS(u,v) \\ &= REF(u,v)\cdot SCN^*(u,v)\exp(iv\cdot 2y_0) \\ &\quad + SCN(u,v)\cdot REF^*(u,v)\exp(-iv\cdot 2y_0) \end{aligned} \quad (3)$$

where $REF(u,v)$ and $SCN(u,v)$ are the Fourier transforms of $ref(x,y)$ and $scn(x,y)$, respectively, and $u = \frac{2\pi}{\lambda f}\cdot x$, $v = \frac{2\pi}{\lambda f}\cdot y$ are the coordinates in the Fourier plane, f is the focal length of the lenses, λ is the wavelength of the light used, $JmPS(u,v)$, $JPS(u,v)$, $SPS(u,v)$, $RPS(u,v)$, are the joint modified power spectrum, joint power spectrum, scene power spectrum and reference power spectrum, respectively. Better light diffraction efficiency can be acquired with an amplitude modulated filter placed in the spatial frequency plane (Fourier plane – fig. 1)

$$Flt(u,v) = \begin{cases} \dfrac{1}{REF(u,v)}, & REF(u,v) > \varepsilon \\ \dfrac{1}{REF(u,v)+Z(u,v)}, & REF(u,v) \le \varepsilon \end{cases}, \quad (4)$$

where ε is the lowest positive real value that the computer recognizes and $Z(u,v)$ is a real non-zero function. The final filtered modified power spectrum that generates the correlation result in the output plane is

$$HJmPS(u,v) = Flt(u,v) \cdot JmPS(u,v). \qquad (5)$$

B. Modified input and phase transformation

The phase input joint transform correlator is reported to be noise sensitive. The combined joint transform correlator alleviates this problem, but in certain conditions better pattern discriminability and better light diffraction efficiency is needed. The light diffraction efficiency can be improved if the dc term (which is the zero order diffraction term) of the power spectrum will drop and the high spatial frequencies will increase. The high spatial frequencies are connected to the object details in spatial coordinates. If the power spectrum has a thin dc term and large high spatial frequencies, the correlation process will provide a better pattern discrimination because the objects will be "compared" more in their details.

To achieve this goal the author suggests an alternate transformation, which consists of applying an amplitude preprocessing function. The amplitude preprocessing function is the sine function, which stretches the dc term and enlarges the high spatial frequencies

$$\begin{aligned} PhaseOB(x,y) &= \exp[i \cdot \sin[Tf[IntensityOB(x,y)]]] \qquad (6) \\ &= \exp\left\{ i \cdot \left[\sin\left[\left(\frac{IntensityOB(x,y) - Min}{Max - Min} \right) \cdot dfPRE + \right.\right.\right. \\ &\quad \left.\left.\left. + fPRE_1 \right] \cdot dfPSLM \right] \right\} \end{aligned}$$

where $dfPRE = fPRE_2 - fPRE_1$ is the amplitude premodulation domain [10, 14].

One reason why the preprocessing function stretches the dc term and enlarges the high spatial frequencies is that it automatically adjusts the background level in order to have best detection efficiency. This preprocessing function has an amplitude premodulation domain, $dfPRE = fPRE_2 - fPRE_1$, that is, in fact, an extra freedom degree. The amplitude premodulation domain can be used to adjust the background levels in order to achieve different pattern discriminability. The preprocessed modified phase input joint transform correlator (preMPJTC) is the correlator that provides this kind of correlation process.

III. RESULTS

Simulations were done with joint input images with seventeen background grey levels: from null background (like in fig. 1 and fig. 3) to 255 background grey level (like in fig. 2 and fig. 4). Also, it was applied one large embedding environment, like in fig. 3 and fig. 4.

The phase modulation domain for both phase input joint transform correlators is $dfPSLM = \pi - 0$. The amplitude premodulation domain for the preprocessed modified phase input joint transform correlator, (preMPJTC), is set at $dfPRE = [-\pi/2; \pi/2]$.

The correlations results in the output plane for the three joint transform correlators are presented in fig. 5 and fig. 6. These numerical results were obtained by introducing the detection efficiency coefficient named signal to clutter ratio, $SCR = API/CPI$, where API is the autocorrelation peak intensity and CPI is the highest value cross-correlation peak intensity.

The embedding noise has a poor effect on detection efficiency (one can see and compare the SCR coefficients for 2N512 with 2N512z and 2N512f with 2N512fz images – fig. 5) for all three modified joint transform correlators. Thus these correlators are very robust to any embedding noise. This is the reason that in fig. 6 are presented correlation results only for image 2N512f with a very small embedding noise.

Figure 1 Input image with black (null) background and small embedding noise (image code 2N512)

Figure 2 Input image with grey background and small embedding noise (image code 2N512f)

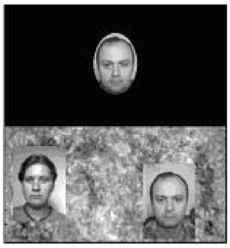

Figure 3 Input image with black (null) background and large embedding noise (image code 2N512z)

Figure 4 Input image with grey background and large embedding noise (image code 2N512fz)

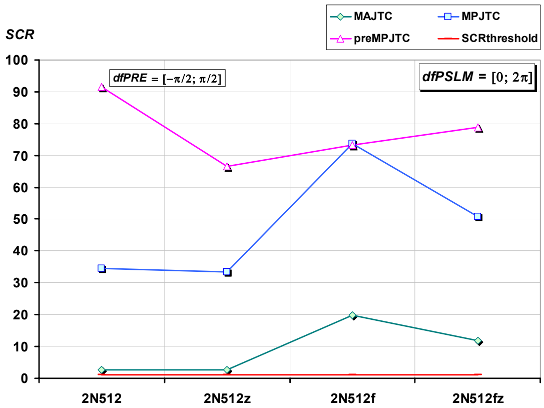

Figure 5 Output correlation results for each studied joint transform correlators with two types of embedding noise and two kinds of background.

The grey background performs better detection efficiency (higher *SCR* coefficient – fig. 5 and fig. 6) with or without the embedding noise for all three modified joint transform correlators.
According with the results from fig. 6, the two joint transform correlators – (MAJTC) and (MPJTC) – have the same behaviour for all grey backgrounds. Thus background grey levels between 64 and 160 generate greater *SCR* detection efficiency coefficients than the other background grey levels. The proposed joint transform correlator, (preMPJTC), with $dfPRE = [-\pi/2; \pi/2]$ has a different behaviour to grey background as the other two. The reason of different behaviour is that this correlator performs

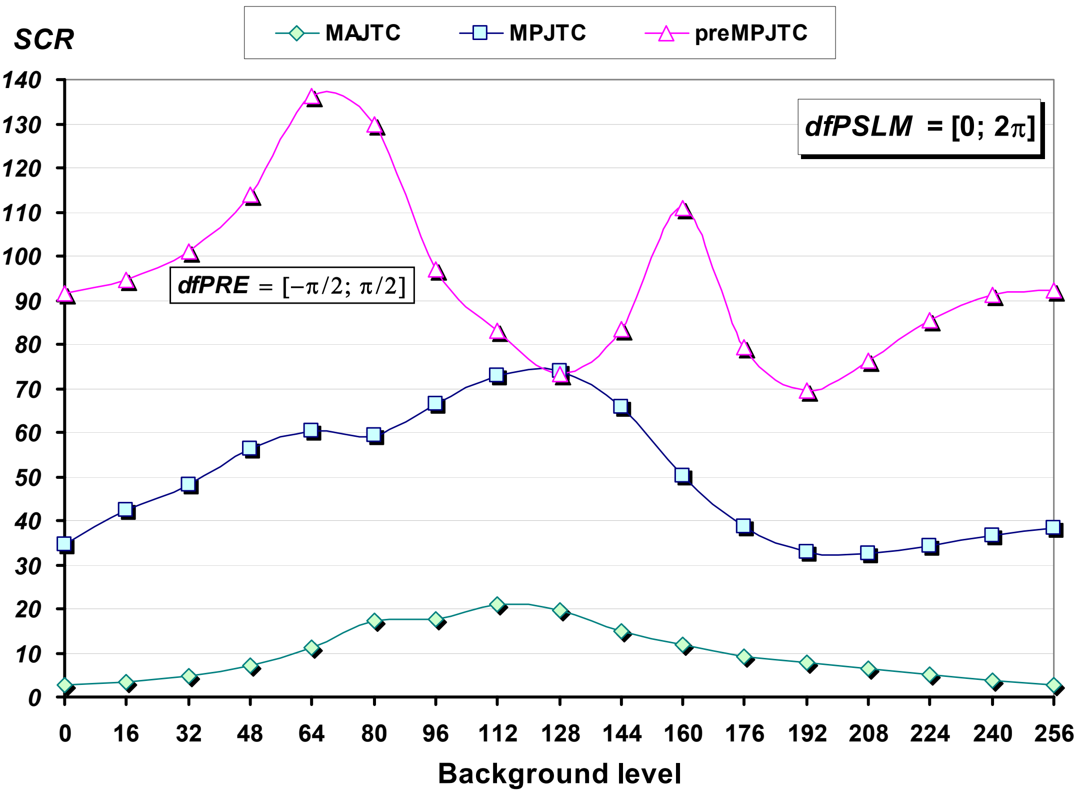

Figure 6 Output correlation results for each studied joint transform correlators with 17 grey levels background in 2N512f image.

automatic adjusting of the background in the processing step. The detection efficiency is decreasing betweeen the following background grey levels: 80 and 160, where the other two correlators has increasing detection efficiency. The detection efficiency of (preMPJTC) with null background, $SCR = 91.6042$, is greater then the highest detection efficiency of the other two correlators with grey background. This proves that the modified phase input joint transform correlator (preMPJTC) doesn't need a grey background to generate higher values for SCR detection efficiency coefficient.

The highest SCR values along all background grey levels are presented in fig. 7.

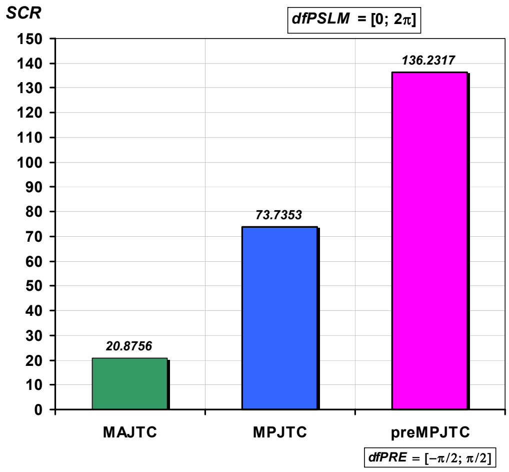

Figure 7 Highest SCR detection efficiency coefficient from results in figure 6, for all three joint transform correlators over the entire grey background range.

IV. CONCLUSIONS

The modified amplitude joint transform correlator (MAJTC) and modified phase input joint transform correlator (MPJTC) need a grey background to improve their pattern recognition efficiency (fig. 5 and fig. 6).

The modified phase input joint transform correlator (preMPJTC) has the best detection efficiency with or without embedding noise for $dfPRE = [-\pi/2; \pi/2]$ in combination with $dfPSLM = 2\pi$ (fig. 7). One reason for this performance is that the amplitude domain preprocessing function automatically adjusts the background level, no matter if it is a nonzero level or not. Results prove that for the modified phase input joint transform correlator (preMPJTC) is best not to have a small background grey level.

Future work can involve the additive noise effect combined with embedding noise for several background grey levels in the same fashion as in this paper.

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