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The investigation of the algorithms of calculation of optical correlation functions

V. Perzhu S. Cazac A. Gurau D. Saranciuc
S. Tsiberneac

Abstract

Efficiency of algorithms of calculation of correlation functions on the basis of amplitude-phase and phase holographic filters for contour, whole objects' images as well as their Fourier spectrum modules have been studied.

1 Introduction

The investigations of the perspective computer systems show that together with the parallel electronic systems (such as multiprocessor and neurocomputer ones, etc.) great attention is being attracted to optical computer means. It is mainly due to the possibility of superhigh speed of responce ($10^{14} - 10^{15}$ bytes/sec) at relatively simple implementation of optical processors and their small weigth and size characteristics. Such processors can be efficiently used when solving a number of problems on image identification, the formers being called intellectual optical Fourier-processors.

Two-dimentional optical correlation is one of the most efficient operations carried out by optical Fourier-processor. In optical systems it is posible to process both input images and their Fourier spectrum modules. As the problem of the analysis of Fourier spectrum modules (FSM) has never been practically studied before, a number of experimental investigations on modelling Fourier-processors has been carried out.

Efficiency of algorithms of calculation of correlation functions on the basis of amplitude-phase and phase holographic filters for contour, whole objects' images as well as their Fourier spectrum modules have been investigated.

2 Correlation algorithms and data base

Let $P(x,y)$ is the input image function and $H(x,y)$ is the filter function. Then the correlation function is described as follows:

$$U(p,q) = P(x,y) * H(x,y) = FT^{-1}[FT[P(x,y)] \cdot FT^{*}[H(x,y)]],$$

where FT, FT^{-1}, FT^{*} is Fourier transform being direct, inverse, and complex conjugated respectively. Function $H(x,y)$ can be amplitude-phased, phased or amplitude.

The modelling of optical correlator has been carried out on the specialized computer system of image processing (CSIP). The image of five aircrafts of different types had been used as initial images (Fig.1), the formers have been introduced into CSIP in size of 256x256 pixels with TV-camera. Further, contour objects' images, Fourier spectrum of the whole and contour images have been formed and correlation functions have been computed by using fast Fourier transform algorithms.

3 Experimental results

On the first stage the maximum correlation function values' change as well as the ratio signal-noise in the correlation field of the whole and contour objects' images processing have been investigated. In both cases amplitude-phase and purely phase filters have been used as standard filters. Fig.2 reprezents the ratio DA of maximum crosscorrelation function I_{Sij} of objects' images N2-5 with object image N1 to maximum autocorrelation function value I_{Sii} of the object N1 ($i = 1, j = 2-5$) for different types of images and filters: $DA = I_{Sij}/I_{Sii}$, where $I_S = maxU(p,q)$. This and other figures contain the following symbols:

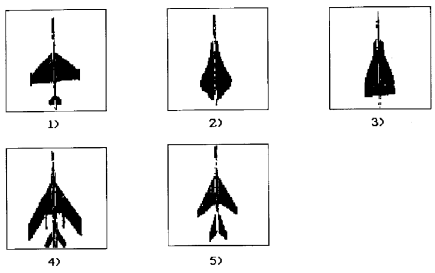

Fig.1. Data base images: 1-M50; 2-SU11; 3-TU144; 4-SU7; 5-TU24.

WI — is for the whole image and CI for contour image; WIS, CIS — for the whole and contour images spectrum; APF, PF for amplitude-phase and phase filter respectively; N is number of standard image.

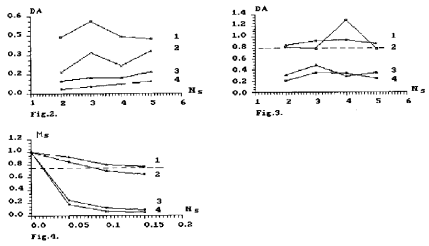

Fig.2. Ratio of DA for object N1 to objects N2-5: 1-WI, AFF; 2-CI,AFF; 3-WI, FF; 4-CI, FF.

Fig.3. Ratio of DA for spectrum of object N1 to spectrum objects N2-5: 1-CI, AFF; 2-WI, AFF; 3-WI, FF; 4-CI, FF.

Fig.4. Dependence μ_S. on change of noisy probability p of the input image: 1-CI, AFF; 2-WI, AFF; 3-CI, FF; 4-WI, FF.

Parameter DA determines the discrimination ability of the recognition method. The less DA value is the higher the probability of the correct object recognition will be. As follows from the presented data the highest discrimination ability is ensured by the method based on contour images' processing using phase filters. Corresponding values DA for image spectrum are shown in Fig.3.

Influence of the noise in input image on to normalized value of autocorrelation function $\mu_S = I'_S/I_S$ of object N1 for different types of images (whole, contour) and filters (amplitude-phase, phase) have been investigated. Value I'_S and I_S corresponds to maximal value of autocorrelation function of noise and clear images respectively. Research results show (Fig.4) that at the same types of filters the contour images have been more stable to the noise and the best results are got while using amplitude-phase filters.

Discrimination ability DA of different methods of correlation function calculation on the images' sets have been researched. The value DA has been defined as

$$DA = I_{Sij}/I_{Sii}, \quad i = 1-5; \quad j = 1-5; \quad i \neq j.$$

The investigation results show (Fig. 5–8) that the most critical is the filtration method based on processing of the whole objects' images and while using amplitudephase filters (Fig.5). At the threshold level DA=0.8 (it corresponds to practical problems) the false recognition of the object N4 is possible on the standard N2. In case of module spectrum Fourier image (MSFI) processing (Fig. 9–12) the recognition methods based on using amplitude-phase filters are also critical.

Fig.13 shows absolute SN and relative values μ_{SN} of a signal/noise ratio in the correlation field at processing images' spectrum of objects' groups by different ways. Ratio SN has been defined as $SN = I_S/I_N$, where I_N is the mean — square noise value. As it follows from the presented data, while the objects number M in initial image is increased the ratio SN in correlation fields is higher at the processing both image and their MSFI. At the increasing M up to 4 the relative value SN is decreasing from 1 up to 0.87 that it is possible in practical problems.

The image scale change SC and its angle orientation Θ as well as its MSFI influence on the relative value μ_S of the correlation signal of the object N1 has been investigated (see Fig.14). The results of the research show that in both cases the filtration method based on phase filters' application is critical. While processing MSFI using the amplitude-phase filters allow to get higher stability to the parameters SC, Θ change than while obects' images processing.

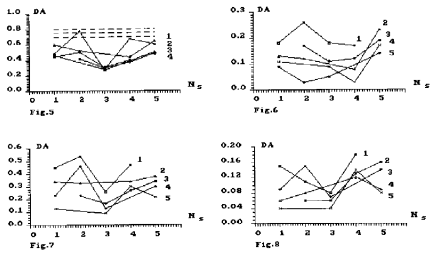

Fig.5. Ratio DA for whole objects' images at using amplitude-phase filters: 1-object N3; 2-object N2; 3-object N4; 4-object N1; 5-object N5.

Fig.6. Ratio DA for whole objects' images at using phase filters: 1-object N5; 2-object N3; 3-object N1; 4-object N2; 5-object N4.

Fig.7. Ratio DA for contour object' images at using amplitude-phase filters: 1-object N5; 2-object N3; 3-object N1; 4-object N2; 5-object N2.

Fig.8. Ratio DA for contour objects' images at using phase filters: 1-object N5; 2-object N1; 3-object N4; 4-object N3; 5-object N2.

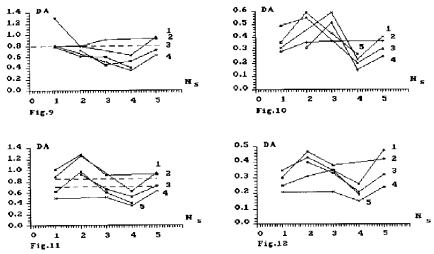

Fig.9. Ratio DA for spectrum of whole objects' images at using amplitude-phase filters: 1-object N3; 2-object N4; 3-object N1; 4-object N2; 5-object N5.

Fig.10. Ratio DA for spectrum of whole objects' images at using phase filters: 1-object N2; 2-object N4; 3-object N3; 4-object N1; 5-object N5.

Fig.11. Ratio DA for spectrum of contour objects' images at using amplitude-phase filters: 1-object N4; 2-object N3; 3-object N1; 4-object N2; 5-object N5.

Fig.12. Ratio DA for spectrum of contour objects'images at using phase filters: 1-object N3; 2-object N4; 3-object N1; 4-object N2; 5-object N5.

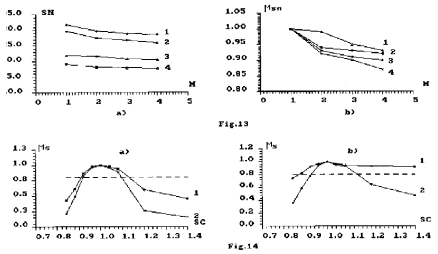

Fig.13. Absolute (a) and relative (b) values SN at changing objects' number M in an image. For (a): 1-CIS, FF; 2-WIS, FF; 3-CIS, AFF; 4-WIS, AFF. For (b): 1-CIS, AFF; 2-WIS, AFF; 3-CIS, FF; 4-WIS,FF.

Fig.14. Dependence μ_S at processing images (a) and spectrum of contour images (b) on scale change SC: 1-AFF; 2-FF.

Fig.15, 16 give investigation results of the whole and contour image angle orientation Θ in the Cartesian coordinate system (CCS) influence on the relative value μ_{SN} of the parameter SN as well as in the case of image transform into Polar coordinate system (PCS). The presented data show that at the threshold value $\mu_{SN} = 0.75$ in the case of image processing given in CCS, critical angles rotation Θ are 20° while using amplitude-phase filters and Θ are 3° while using phase filters.

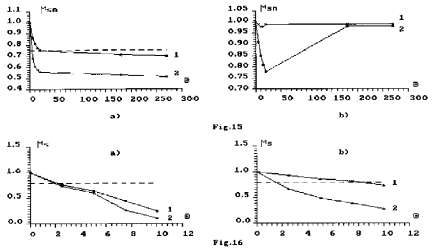

Fig.15. Dependence μ_S at whole images' processing presented in the Cartesian (a) and Polar (b) coordinates' system on change of angle objects' orientation Θ: a) 1-AFF; 2-FF; b) 1-FF; 2-AFF.

Fig.16. Dependence μ_S at processing contour images (a) and of contour images' spectrum (b) on change of angle orientation Θ: 1-AFF; 2-FF.

Fig.17 prezents investigation results of the input image foreshortening Ψ influence on the value μ_S at correlation functions computation in CCS(a) and PCS(b). The results show that in the case of image

processing in CCS, the critical angles according to the foreshortening are the following: while using phase filters

$$\Psi_{DF} > 12^{\circ}$$

and

$$\Psi_{DAF} > 26^{\circ}$$

at amplitude-phase. While processing images in PCS

$$\Psi^{PF} > 20^{\circ},$$

$$\Psi_{PAF} > 24^{\circ}.$$

It is possible to conclude on the basis of the given data that, firstly, the ways of correlation based on phase filters application are more critical. Secondly, while processing images in PCS and at phase filters application the value is increased sufficiently (1.7 times).

Image in CCS centering precision influence on the value μ_S at correlation function image computation in PCS has been investigated. Research results show (Fig.18) that while using phase filters the maximum object shift value SH should not exceed one neighbour pixels distance and at amplitude-phase filters application the exces should not be more that three neighbour pixels distances. Thus, phase filters are more critical to the centering precision at space-dependent filtration algorithms.

Influence of the digitization Q step of the input image on parameter μ_S value for different types of images and filters has been investigated. The research has been carried out the following way. For an initial image introduced into the computer in the format 128x128 pixels the neighbour pixels distance Q value has been considered to be a standard. The new images with the digitization step

$$Q' = K \cdot Q$$

have been formed on the basis of initial image and correlation functions between initial image and each of the new ones have been computed. The investigation results presented in Fig.19 show the following. While

computing correlated functions of the whole images using amplitude-phase filters the value K (at the level μ_S=0.8) is maximum admitted. In the case of whole images' processing using phase filters or contour images using amplitude-phase filters fast decrease of parameter μ_S can be seen even at $K = 2$.

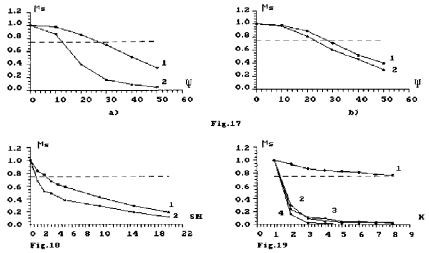

Fig.17. Dependence μ_S on foreshortening Ψ change of the object at whole images' processing in the Cartesian (a) and Polar (b) coordinates' systems: 1-AFF; 2-FF.

Fig.18. Dependence μ_S on the objects shift SH: 1-AFF; 2-FF.

Fig.19. Dependence μ_S on the change of digitization coefficient K of the image: 1-WIS, AFF; 2-CIS, AFF; 3-WIS, FF; 4-CIS, FF.

4 Conclusion

Analysis of the research results shows a possibility to propose the efficient image processing correlation algorithms.

1) While recognizing clear objects' images and their MSFI it is advisable to contour input images and to use phase filters.

2) Under processing conditions of noisy images it is rather rational to compute correlation functions of contour images on the basis of amplitude-phase filters.

3) Phase filters are more sensitive to the angle orientation and to the scale changes both for objects' images and their modules of Fourier spectrum at image reprezentaion in the CCS. That is why it is rather advisable to use amplitude-phase filters. In the case of space-dependent filtration implementation, i.e. at the transformation of the images to the PCS, it is more advisable to use phase filters.

4) If image is subjected to foreshortening distortion and implementation of linear space-invariant filtration (at the processing in CCS) it is advisable to use amplitude-phase filters. In the case of space-dependent filtration (at the processing in PCS) it is possible to use both amplitude-phase and phase filters.

5) At space-dependent filtration high requirements are to be met to center initial image presented in CCS.

6) Maximum value of correlation functions sufficiently depend on the digitization step accuracy (DS) of the initial images. The introducing of preliminary DS computation in correlation system will allow to increase reliability of computation results.

References

[1] Duvernoy J. Extraction of invariant directional signatures of terrain textures from Fourier spectra. Optics communication, No.2, Vol.48, 1983, pp.80–84.

[2] Duvernoy J. Optical-digital processing of directional terrain textures invariant under translation, rotation and change of scale. Applied Optics, No.6, Vol.23, 1984, pp.828–837.

[3] Perzhu V.L. The construction of adaptive computing means for image processing. Proc. of International conf. on microelectronics and computer science ICMSC-92. 21–23 Oct., Chisinau, 1992, pp.71–76.

Veacheslav Perzhu, Sergiu Cazac,
Adrian Gurau, Dorian Saranciuc,
Stanislav Tsiberneac

Tehnical University of Moldova
Bd. Shtefan Mare, 168, Kishinev
MD-2004, Moldova
phone: (373–2)497016
Fax: (373–2)237509
E-mail: *Perju@mail.utm.md*

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