General Theory Research on Morphological Correlation for Gray-Scale Face Recognition*

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Abstract General morphological correlation (GMC) is proposed and hardware design for a compact joint transform correlator(JTC) is proposed in order to implement GMC. Two kinds of modified general morphological correlation is studied. The gray-scale image is decomposed into a set of binary image slices in certain decomposition method. In the first algorithm, the edge of each binary joint image slice is detected and the joint power spectrum of which is summed. In the second algorithm, one situation is that the joint power spectrum of each pair is binarized or thinned and then summed, and another situation is that the summation of the joint power spectrums of these pairs is binarized or thinned. Computer-simulation results indicate that the modified algorithm can improve the discrimination capabilities with respect to the high similarity gray-scale face images.

Keywords Acquisition/Tracking/Pointing(ATP); Optical tracking; Joint Transform Correlator (JTC); Morphological corrrelation

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0 Introduction

Classical linear correlation (LC) is associated with lower correlation discrimination, large correlation sidelobes, and large autocorrelation bandwidth for gray-scale images. To alleviate these drawbacks, a nonlinear correlation technique, called morphological correlation (CMC)[1], is introduced for pattern recognition. Compared with the LC method, CMC is associated with higher discrimination and larger calculations between similar patterns. After CMC, modified morphological correlation based on bit-representation decomposition (MMC)[2] is reported, which provides even higher discrimination, fewer calculations and higher noise sensitivity than CMC does. The MMC reduces computing amount and saves a lot of correlation operation including in CMC.

The morphological correlation based on bit-representation decomposition is a modified algorithm of CMC. It is not based on linear threshold-decomposition, but on bit-representation decomposition. For example, an image pixel with gray-level intensity of 138 out of 256 levels will be represented as 10001010 by the bit-representation decomposition and decomposed into 8 binary slices which have a value of 1 in the eighth, fourth, twice slices and a value of 0 in the remaining slices. A gray-scale image has 256 gray levels. A set of 256 threshold binary slices is needed for calculating the CMC optically and a set of 8 bit-representation binary slices is needed for calculating the MMC which can improve discrimination capability.

With respect to gray-scale images with near gray-scale distribution and near shape, CMC or MMC is often difficult to recognize. In order to improve recognition effect of CMC or MMC, some researches are done as follows.

General morphological correlation (GMC) is proposed and hardware design for a compact JTC is proposed in order to fulfill GMC. Two kinds of modified general morphological correlation are proposed. The gray-scale image is decomposed into a set of binary image slices in certain decomposition. In the first algorithm, the edge of each binary joint image slice is detected and the joint power spectrum of which is summed. In the second algorithm, one situation is that the joint power spectrum of each pair is binarized or thinned and then summed, another situation is that the summation of the joint power spectrum of these pairs is binarized or thinned. Computer-simulation results indicate that the modified algorithm can improve the discrimination capabilities with respect to the high similarity gray-scale images.

1 General morphological correlation and a compact JTC

In this paper, a kind of compact JTC with

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convolute architecture to implement CMC or MMC is designed (Fig. 1). The volume of the compact JTC with convolute architecture will be controlled within 33 cm×33 cm×25 cm.

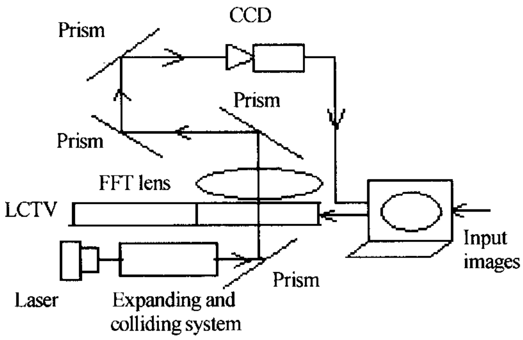


Fig. 1 A compact JTC with convolute architecture

In order to obtain CMC or MMC by the compact joint transform correlator (CJTC), each pair of image slices (one slice from the input image and the other from the reference image) is placed side by side in the input plane. For each pair, optical computation of the joint power spectrum is performed. The summation of the joint power spectrum of these pairs is stored in the computer and finally fed back at the input plane for a second Fourier transformation to produce the CMC or MMC.

Considering CMC and MMC, general morphological correlation can be gived by

$$GMC(x,y)=\sum_{n=1}^{N}t_n(x,y)*r_n(x,y)=\sum_{n=1}^{N}C_n(x,y) \quad (1)$$

where N is the number of binary image slices based on certain decomposition. C_n represents the LC between binary slices, t_n and r_n, at level n.

When $n=q$, $N=Q-1$, GMC is denoted as CMC. N is the number of binary slices based on threshold-decomposition.

When $n=h$, $N=H$, GMC is denoted as HCMC. N is the number of certain binary slices based on threshold-decomposition.

When $n=g$, $N=M$, GMC is denoted as MMC. N is the number of binary slices based on bit-representation decomposition.

When $n=s$, $N=S$, GMC is denoted as SMC. N is the number of binary slices based on certain decomposition.

With respect to the gray-scale input image and the gray-scale reference image with near gray-scale distribution and near shape, the gray-scale images are difficult to recognize by GMC. In this paper, GMC is improved to recognize this kinds of images.

2 EGMC, BGMC1 (TBGMC1) and BGMC2 (TBGMC2) algorithm

2.1 EGMC algorithm

Edge detection method is used to emphasize the characteristics of each binary joint image slice in order to improve morphological correlation. Accordingly, a new type EGMC, named general morphological correlation based on edge detection, is proposed, which obtains edge characteristics from each binary joint image slice. Each pair of binary joint image slice, one slice from the input image and the other slice from the reference image, is edge detected with Roberts or morphological operators. The summation of the joint transform power spectrums of these pairs is obtained and is finally performed a second Fourier transformation to produce the EGMC. A morphological method of edge width adjustability[4] can be used in EGMC.

According to (1), EGMC can be denoted by

$$EGMC(x,y)=\sum_{n=1}^{N}t_n^T(x,y)*r_n^T(x,y) \quad (2)$$

When $n=q$, $N=Q-1$; $n=h$, $N=H$; $n=g$, $N=M$; $n=s$, $N=S$, ECMC; EHCMC; EMMC; ESMC can be created respectively.

Assume $T='l'$ represents Roberts edge detection which is approximately gradient operation. Then Eq. (8) can be denoted as RGMC.

Assume $T='m'$ represents morphological edge detection. Then Eq. (8) can be denoted as MGMC.

2.2 BGMC1 (TBGMC1) and BGMC2 (TBGMC2) algorithms

Since binary JTC[3] has better recognition ability than classical JTC, it can be used to improve morphological correlation. A kind of modified GMC (BGMC1 and TBGMC1, BGMC2 and TBGMC2), called general morphological correlation based on power spectrum binarized or power spectrum binarized and thinned, are proposed, which binarizes or binarizes and thins the power spectrum of binary joint image slices. Noise image thresholding[3,5] can be applied to BGMCs.

Thinning is a kind of image processing operation. Binary image region can be shrink as lines in order to approach the middle axes of the region. Thinning can be applied in JTC in order to improve recognition effect. Assume the reference face is selected and the input face is the same face or the high similarity different face. The binary joint power spectrum of the same faces is minutely different from the binary joint power spectrum of the high similarity different faces. Since thinnning image is sensitive to minute image change. The minute image change of binary joint power spectrum will cause obvious change of the thinning image of binary joint power spectrum. As a result, the high similarity different faces can be recognized. The binarizing and thinning method will be applied to GMC to modify recognition effect below.

1) BGMC1 and TBGMC1 algorithm

The summation of the power spectrum of each pair of binary joint image slices is binarized and implemented a reverse Fourier transformation to produce the correlation output. According to Eq. (1), the power spectrum of each pair of binary joint image slices is represented by

$$I_n(u,v)=|S_n(u,v)|^2=|T_n(u,v)|^2+\exp\left[\mathrm{i}\frac{4\pi}{\lambda f}\mathrm{d}u\right]T_n(u,v)R_n^*(u,v)+\exp\left[-\mathrm{i}\frac{4\pi}{\lambda f}\mathrm{d}u\right]T_n^*(u,v)R_n(u,v)+|R_n(u,v)|^2 \quad (3)$$

According to Eq. (3), the summation of the power spectrum is gived by

$$I_{\mathrm{nsum}}(u,v)=\sum_{n=1}^{N}I_n(u,v) \quad (4)$$

If the median value of the summation of the power spectrum is T_{nsum}, the summation of the power spectrum is binarized and represented by

$$E_{\mathrm{nsum}}(u,v)=\begin{cases} & \text{if } I_{\mathrm{nsum}}(u,v)\geqslant T_{\mathrm{nsum}} \\ 0 & \text{if } I_{\mathrm{nsum}}(u,v)<T_{\mathrm{nsum}} \end{cases} \quad (5)$$

$E_{\mathrm{nsum}}(u,v)$ is performed a reverse Fourier transformation to obtain BGMC1.

In order to improve recognition effect further, morphological thinning algorithm based on the binary power spectrum is proposed. The binarized power spectrum is thinned and the thinning image can be represented by $\mathrm{thin}(E_{\mathrm{nsum}}(u,v))$.

$$T_{\mathrm{tnsum}}=\mathrm{thin}(E_{\mathrm{nsum}}(u,v)) \quad (6)$$

T_{tnsum} is performed a reverse Fourier transformation to obtain TBGMC1.

When $n=q, N=Q-1$ or $n=h, N=H$ or $n=g, N=M$ or $n=s, N=S$, BCMC1 and TBCMC1 or BHCMC1 and TBHCMC1 or BMMC1 and TBMMC1 or BSMC1 and TBSMC1 are created respectively.

2) BGMC2 and TBGMC2 algorithm

The power spectrum of each pair of binary joint image slices is first binarized and then summed. The summation of the binary power spectrums is implemented a reverse Fourier transformation to produce the correlation output. If the median value of the power spectrum of each pair of binary joint image slices is T_{neach}, the binary power spectrum of each pair of binary joint image slices could be represented by

$$E_{\mathrm{neach}}(u,v)=\begin{cases}1 & \text{if } I_n(u,v)\geqslant T_{\mathrm{neach}} \\ 0 & \text{if } I_n(u,v)<T_{\mathrm{neach}} \end{cases} \quad (7)$$

The binary power spectrum of each pair of binary joint image slices is summed by $\sum_{n=1}^{N}E_n(u,v)$ and then a reverse Fourier transformation is implemented to obtain BGMC2.

In order to improve recognition effect further, morphological thinning algorithm based on the binary power spectrum is proposed. The binary power spectrum is thinned and the thinning image is represented by $\mathrm{thin}(E_{\mathrm{neach}}(u,v))$. The thinning image of the binary power spectrum is summed by $\sum_{n=1}^{N}\mathrm{thin}(E_{\mathrm{neach}}(u,v))$ and then a reverse Fourier transformation is implemented to obtain TBGMC2.

When $n=q, N=Q-1$ or $n=h, N=H$ or $n=g, N=M$ or $n=s, N=S$, BCMC2 and TBCMC2 or BHCMC2 and TBHCMC2 or BMMC2 and TBMMC2 or BSMC2 and TBSMC2 can be created respectively.

3 Computer simulation results

A group of computer simulation targets are constructed. Basic shapes of the targets are shown in Fig. 2. Face targets can be regarded as combination of distortion appended, hole appended and texture appended of basic shape circle.

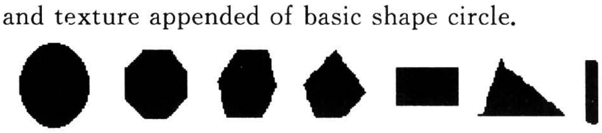


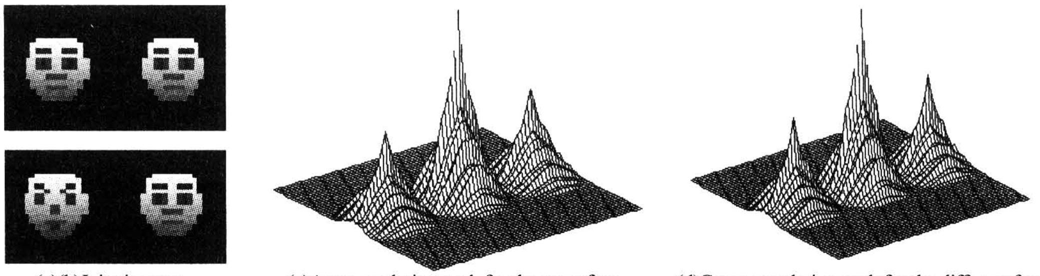
Fig. 2 Basic shape

GMC can be denoted as CMC, HCMC, MMC, SMC . In this paper, the computer simulation results of MMCs is given. Similar computer simulation research can be implemented for other GMCs, for example CMCs, HCMCs, SMCs etc, because the theory of GMCs has been studied above. Compared with GMC, fractional fourier Transform correlation is also being studied by some researchers[6].

Face targets with 16 gray levels are adopted for computer simulation. Correlation of 4 binary image slices is needed for implementing MMC. Simulation operation is based on 64 × 64 fast

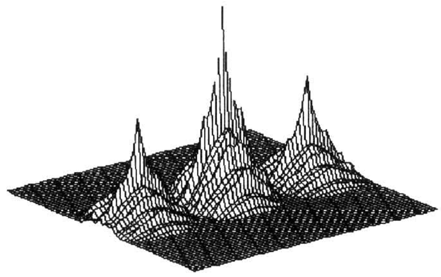
Fourier transform. Image dimension of each image is 12 × 12. Each image has 16 gray levels. Amplitude output is adoped for correlation peak output. Middle peak is dc and two side peaks are correlation peak in Fig. 3~Fig. 5.

MMC has bad recognition effects with high similarity gray-scale faces as shown in Fig. 3. MMMC can recognize high similarity gray-scale faces as shown in Fig. 4.

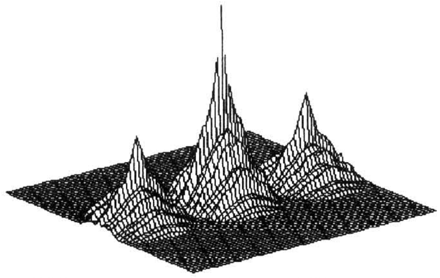


(a)(b)Joint images (c)Autocorrelation peak for the same face (d)Cross-correlation peak for the different face

Fig. 3 MMC recognition results for the faces

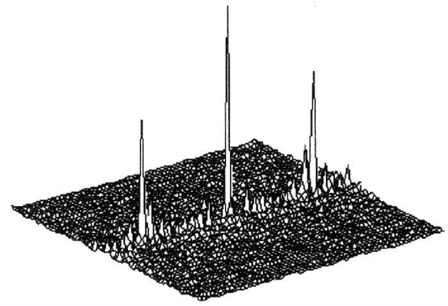


(a)Autocorrelation peak for the same face

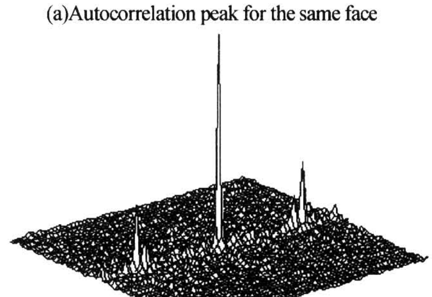


(b)Cross-correlation peak for the different face

Fig. 4 MMMC recognition results for the faces



(a)Autocorrelation peak for the same face



(b)Cross-correlation peak for the different face

Fig. 5 TBMMC2 recognition results for the faces

TBMMC1 has good recognition effects with high similarity gray-scale faces similar to Fig. 5 and TBMMC2 has good recognition effects with high similarity gray-scale faces shown in Fig. 5.

With regard of recognition of high similarity gray-scale faces , RMMC 、MMMC 、BMMC 1 、TBMMC 1 、BMMC 2 and TBMMC 2 are proposed . Compared with MMC, the discrimination of each MMCs is increased by 15. 85%,13. 71%,30. 16%,41. 17%, 45. 18%,52. 06%, and other evaluating parameters are also improved greatly. Therefore face recognition can be improved with modified MMCs.

Table. 1 presents simulation results of all kinds of MMCs.

Table. 1 Correlation results of MMCs

Type of MMC	Input image		PSR		dc/Peak		η/(%)		Δ/(%)
MMC	Same faces	Different faces	40. 63	32. 50	4. 00	4. 85	2. 07	1. 65	13. 67
RMMC	Same faces	Different faces	47. 18	35. 89	4. 00	5. 56	2. 42	1. 84	29. 52
MMMC	Same faces	Different faces	50. 74	35. 90	4. 00	5. 65	2. 61	1. 84	27. 38
BMMC1	Same faces	Different faces	288. 31	169. 65	7. 68	12. 47	30. 65	17. 14	43. 83
TBMMC1	Same faces	Different faces	470. 02	240. 70	2. 12	3. 66	30. 33	14. 97	54. 84
BMMC2	Same faces	Different faces	281. 53	113. 58	8. 38	23. 84	32. 40	16. 36	58. 85
TBMMC2	Same faces	Different faces	493. 04	184. 59	2. 94	10. 32	37. 25	16. 85	65. 73

PSR \ dc/Peak \ η \ Δ are used as evaluating standard of all kinds of GMCs. Where PSR is ratio of correlation peak intensity to average intensity of noise (sidelobe). dc/peak is ratio of dc to correlation peak intensity. η is ratio of correlation peak intensity to illumination energy. $\Delta=(API-CPI)/API$, API is the autocorrelation-peak intensity and CPI is the maxium cross-correlation-peak intensity.

4 Conclusions

General morphological correlation (GMC) is proposed and the hardware design for a compact JTC is given in order to implement GMC. Two kinds of modified morphological correlation algorithm that are based on general morphological correlation are proposed. The gray-scale image is decomposed into a set of binary image slices in certain decomposition. In the first algorithm, the edge of each binary joint image slice is detected and the joint power spectrum of which is summed. In the second algorithm, one situation is that the joint power spectrum of each pair is binarized or thinned and then summed, another situation was that the summation of the joint power spectrums of these pairs was binarized or thinned. Computer-simulation results indicate that the modified algorithm can improve the discrimination capabilities with respect to the high similarity gray-scale face images.

References

1 Zhang S, Karim M A. Illumination _ invariant pattern recognition with joint-transform-correlator-based morphological correlation. *Appl Opt*, 1999, **38**(35): 7228～7236

2 Shemer A, Mendlovic D, Shabtay G. Modified morphological correlation based on bit-map representations. *Appl Opt*, 1999, **38**(5): 781～787

3 Javidi B, Wang J. Binary nonlinear joint transform correlation with median and subset median thresholding. *Appl Opt*, 1991, **30**(8): 967～976

4 Yu Yang, Zhang Xuping. Research on adjustability of morphological processing of joint transform correlator. *Acta Photonica Sinica*, 2005, **34**(3): 460～463

5 Wu Dongmei. Noisy image estimation with translation invariant wavelet thresholding. *Acta Photonica Sinica*, 2005, **34**(2): 306～309

6 Zhao Wei, Zhao Xiaoming. The research of fractional fourier transform correlation applied on speckle measure. *Acta Photonica Sinica*, 2005, **34**(3): 464～467

灰度人脸识别形态学相关的一般理论研究

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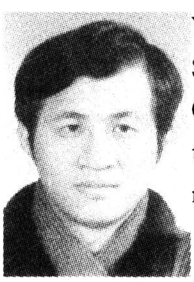
摘　要　提出一般形态学相关概念，并提出一种小型联合变换相关器的硬件设计以实现一般形态学相关．提出两种改进的一般形态学相关算法，灰度图像按某种分解方法分解成一系列二值图像片．在第一种算法中，每片二值联合图像片的边缘被检测，其功率谱求和．在第二种算法中，一种情况是每片的联合变换功率谱被二值化或细化再求和；另一种情况是这些片的联合变换功率谱的总和被二值化或细化．计算机模拟结果表明，改进后的算法能改善高相似度灰度人脸图像识别的鉴别率．

关键词　捕获、跟踪、瞄准(ATP)，光学跟踪，联合变换相关器，形态学相关



Yu Yang　was born on May 4, 1966, in Nanjing, China. He received the Doctor's degree in Southeast University in Nanjing. He is currently a Postdoctor in the Institute of Optical Communication Engineering of Nanjing University. His research areas include acquisition/tracking/pointing(ATP), optical tracking, joint transform correlator(JTC), mathematical morphology and optical pattern recognition.