第七届机器视觉技术及工业应用研讨会

人脸图象分析的新进展

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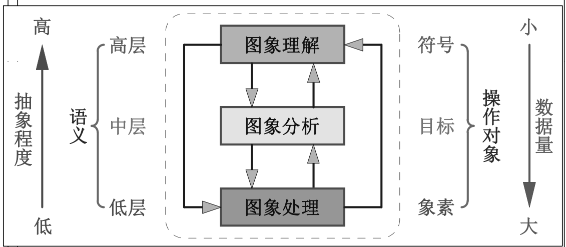
清华大学电子工程系　100084　北京

总目录

引　言

➢ 图象工程：不同层次图象技术的有机结合及应用，三个层次



引　言

➢ 图象工程文献综述系列［章2010］

- 每年《中国图象图形学报》5月那一期
- 已历时 15 年，涉及 15 种刊物，8217（34841）篇论文

主要目的

(1) 概括我国图象工程发展现状

(2) 帮助读者查阅有关研究文献

(3) 对期刊编者和论文作者提供参考

引　言

➢ 图象工程研究文献

- 图象处理（图象 ⇒ 图象）
- 图象分析（图象 ⇒ 数据）
- 图象理解（图象 ⇒ 解释）
- 技术应用（图象处理、分析、理解技术的工程实现和应用）
- 综述（综合图象处理、分析、理解）

引　言

➢ 图象分析

- 边缘检测，图象分割
- 目标表达、描述、测量
- 目标颜色、纹理、形状、空间和运动分析
- 目标检测、提取、跟踪、识别和分类

从2000年起增加

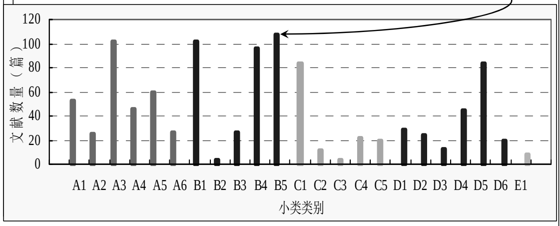
- 人脸和器官的检测、定位与识别

➢人脸图象分析

引　　言

➢ 2009年统计数据

- 人脸和器官的检测、定位与识别

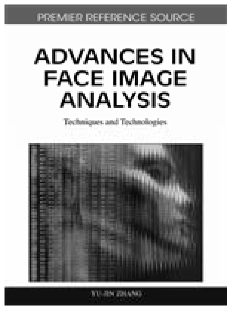


正文目录

Yu-Jin ZHANG (ed.), Advances in Face Image Analysis: Techniques and Technologies.

IGI Global, 2011

- **33 experts from 16 countries and regions**
  - **9 from Asia**
  - **18 from Europe**
  - **2 from North America**
  - **3 from Oceania**



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- ◆ 背景介绍　**Introduction and Background**
- ◆ 特征提取　**Facial Feature Extraction**
- ◆ 特征降维　**Feature Dimensionality Reduction**
- ◆ 人脸识别　**Face Recognition**
- ◆ 表情分类　**Facial Expression Classification**
- ◆ 不变技术　**Invariance Techniques**

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- ◆ 表情分类
- ◆ 不变技术

Chapter 1
Face, Image, and Analysis

Chapter 2
Face Searching in Large Databases

背景介绍

人脸图象分析：

EI中的文献数量

Key word in “Subject/Title/Abstract”

Table 1. The numbers of publications with “face image analysis”.

Years	1960–1969	1970–1979	1980–1989	1990–1999	2000–2009	Total
Numbers	2	12	73	867	6371	7325

每10年增加6~8倍

背景介绍

人脸图象分析模块：

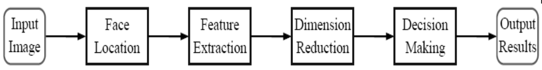

Figure 3. The procedure and modules of face image analysis.

(1)　人脸定位（检测/跟踪）

(2)　特征提取（表达和描述）

(3)　特征降维（减小计算量，增加精度）

(4)　制定决策（男女、年龄、身份）

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背景介绍

子空间技术：

Abbreviation	Full Name	References
2D-LDA	2D Linear Discriminant Analysis	(Li & Yuan, 2005)
2D-PCA	2D Principal Component Analysis	(Yang et al., 2004)
B2D-PCA	Bidirectional 2D-PCA	(Zuo, Zhang & Wang, 2006)
Bayesian	Bayesian	(Moghaddam, Jebara & Pentland, 2000)
CFA	Class-dependence Feature Analysis	(Vijaya et al., 2006)
DLDA	Direct LDA	(Yu & Yang, 2001)
EFM	Enhance Fisher linear discriminant model	(Liu & Wechsler, 2000)
FDA	Fisher Discriminant Analysis	(Kurita & Taguchi, 2005)
FF	Fisher Faces	(Belhumeur, Hespanha & Kriegman, 1997)
FNMF	Fast Non-negative Matrix Factorization	(Li & Zhang, 2009)
GSVD	Generalized Singular Value Decomposition	(Howland & Park, 2004)

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背景介绍

子空间技术（续）：

ICA	Independent Component Analysis	(Bartlett, Movellan & Sejnowski, 2002)
K2D-PCA	Kernel 2D-PCA	(Wang, Zheng & Hu, 2007)
KFDA	Kernel Fisher Discriminant Analysis	(Mika et al., 1999)
KLDA	Kernel LDA	(Park & Park, 2008)
KPCA	Kernel-based PCA	(Kim, Jung & Kim, 2002)
KTS	Kernel Tensor-Subspace	(Park & Savvides, 2007)
LDA	Linear Discriminant Analysis	(Price & Gee, 2005)
LF	Laplacian Face	(Sundaresan & Chellappa, 2008)
LFA	Local Feature Analysis	(Penev et al., 2004)
LPP	Locality Preserving Projection	(Yu, Teng & Liu, 2006)
NLPCA	Non-Linear PCA	(Kramer, 1991)
NSLDA	Null Space LDA	(Chen et al., 2000)

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背景介绍

子空间技术（续）：

NMF	Non-negative Matrix Factorization	(Lee & Seung, 1999)
NMSF	Non-negative Matrix Set Factorization	(Li & Zhang, 2007)
NN	Neural Networks	(Micheli-Tzanakou et al., 1995)
OFLD	Optimal LDA	(Yang & Yang, 2001)
PCA	Principal Component Analysis	(Kirby & Sirovic, 1990)
PM	Principal Manifold	(Moghaddam, 2002)
PSA	Probabilistic Subspace Analysis	(Moghaddam, 2002)
SVD	Singular Value Decomposition	(Hong, 1991)
TCF-CFA	Tensor Correlation Filter based CFA	(Yan & Zhang, 2008b)
TPCA	Topological PCA	(Pujol et al., 2001)
UPCA	Unified PCA	(Shan et al. 2008)

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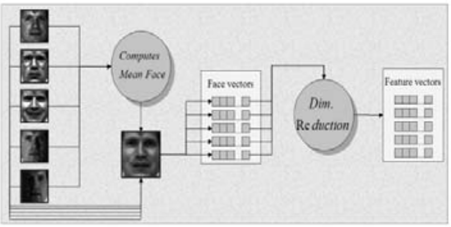
背景介绍

线性/非线性方法：

Figure 1. The general scheme of the Linear/Non-linear methods



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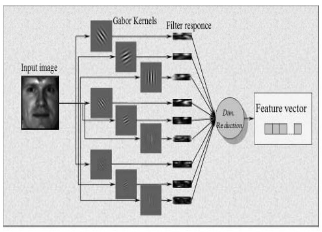
背景介绍

盖伯核卷积和滤波器响应的降维：

Figure 3. The convolution of Gabor kernels and dimensionality reduction of the filter responses



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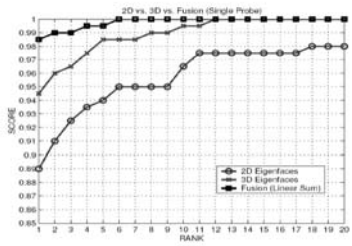
背景介绍

2-D/3-D本征脸：

Figure 8. PCA-based recognition experiments performed using 2D and 3D Eigenfaces



背景介绍

3-D人脸模型库：

Table 2. Most important databases of 3D face models. Image variations are indicated by: (p) pose, (e) expression, (o) occlusion

Name	Type	Data Size	Number of people	3D Models / person	Number of conditions	Texture Image	Available	Web Address
3D RMA	Cloud of points	4000 points	120	3	p	No	Yes	http://www.sic.rma.ac.be/~beumier/DB/3d_rma.html
SAMPL	Range Image	200 x 200	10	33 (for 2 sub.), 1 (for 8 sub.)	p,e	Yes	Yes	http://sampl.eng.ohio-state.edu/~sampl/
Univ. of York 1	Range Image	-	97	10	p,e,o	No	Yes	http://www-users.cs.york.ac.uk/~tomh/3DfaceDatabase.html
Univ. of York 2	Range Image	-	350	15	p,e	No	Yes	http://www-users.cs.york.ac.uk/~tomh/3DfaceDatabase.html
Gavab-DB	Tri-Mesh		61	9	p,e.	No	Yes	http://gavab.escet.urjc.es/recursos_en.html

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- 特征降维
- 人脸识别
- 表情分类
- 不变技术

Chapter 3 Review of Facial Feature Detection Algorithms

Chapter 4 Gabor and Log-Gabor Wavelet for Face Recognition

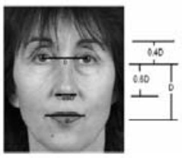
Chapter 5 Efficient Face Retrieval Based on Bag of Facial Features

特征提取

人脸特征检测：

人脸几何模型

Figure 3. Geometric face model used in (Shih & Chuang, 2004)



性能准则

$$d_{eye} = \frac{\max(d_l, d_r)}{s} < T_{eye}$$

$$m_e = \frac{1}{ns}\sum_{i=1}^{n} d_i < T$$

特征提取

盖伯核和对数盖伯核：

Figure 3. The magnitude of the Gabor kernels at three different scales (v={0,1,2})

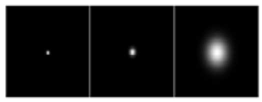
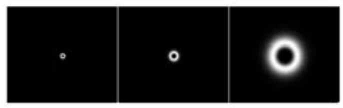


Figure 6. The magnitude of the Log-Gabor kernels at three different scales

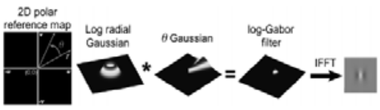


特征提取

对数盖伯小波：

$$LG(r,\theta) = \exp\left\{-\frac{\left[\log\left(\frac{R(r_i,\theta_j)}{f}\right)\right]^2}{2\log\left(\frac{\sigma_r}{f}\right)^2}\right\}\exp\left\{-\frac{\Phi(r_i,\theta_j)^2}{2\sigma_\theta^2}\right\}$$

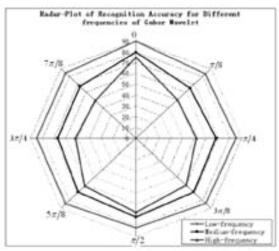
Figure 5. An illustration of the different stages of the Log-Gabor filter creation



特征提取

盖伯小波实验结果：

Figure 17. Rader Plot of best accuracies for Gabor wavelet at different frequencies for the in-house database



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- 表情分类
- 不变技术

Chapter 6 Feature Selection in High Dimension

Chapter 7 Transform Based Feature Extraction and Dimensionality Reduction

Chapter 8 Efficient NMF Algorithm for Reducing Feature Dimension

特征降维

特征选择：

前100个特征常已能给出接近最优的效果

一些相关方法选择的特征有一定共性

Table 2. Number of selected features shared by the several used methods over 100 most important variables

MIT-CBCL database ORL database	OFW+SVM	RFE	L0-SVM	RF	Fisher	Relief
OFW+SVM	#	55	45	10	12	8
RFE	65	#	40	18	20	10
L0-SVM	46	52	#	23	22	12
RF	17	18	11	#	48	15
Fisher	3	6	8	65	#	38
Relief	3	6	7	12	32	#

特征降维

特征选择：

利用最优加权算法（Optimal Features Weighting algorithm, OFW）选出的15个用边缘检测器得到的特征

Figure 7. Representation of the main aggregation of edges detectors selected by Hybrid OFW process for the MIT-CBCL database

特征降维

基于变换的方法：

利用拉东变换

将转动变换为平移

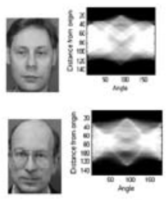
对平面内转动不变

对照度变化不敏感

对零均值高斯噪声不敏感

具有与数据无关的基

Figure 2. (a) shows the original images while (b) shows the respective Radon transforms for angle of 0° to 179°



(a) (b)

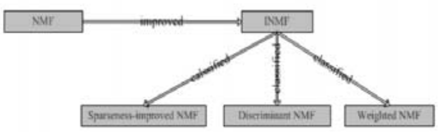
特征降维

快速NMF：

非负矩阵分解——非负数据特征提取和非负降维

有心理学和生理学的依据（对整体的感知基于对其组成部分的感知）

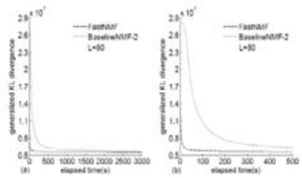
Figure 1. The relationship of NMF and INMF methods



特征降维

快速NMF：

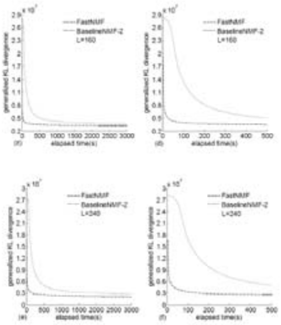
Figure 8. The iterative curves of implementing the dimensionality reduction and feature extraction of all 400 face images of ORL database by FastNMF and BaselineNMF-2, in which iterative outcomes are evaluated and represented by the generalized KL divergence. (a) L=80, 3000 seconds' iteration; (b) L=80, 500 seconds' iteration; (c) L=160, 3000 seconds' iteration; (d) L=160, 500 seconds' iteration; (e) L=240, 3000 seconds' iteration; (f) L=240, 500 seconds' iteration.



特征降维

快速NMF：

FastNMF的迭代曲线下降得比基线NMF要快得多，尤其在最初的迭代过程中更明显（收敛得更快）



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人脸识别

稀疏表达：

压缩感知理论——一种新的信号处理理论

绝大多数实际信号都是可压缩的，将信号变换到新的空间可使其变得稀疏，更易用较少数量的系数来近似表示，并可更有效地计算和加工

根据压缩感知理论，可借助稀疏表达进行人脸识别。在稀疏表达分类中，特征空间的选择不再那么至关重要的，要考虑的主要是特征空间的维数和分类器的设计

人脸识别

利用稀疏表达的人脸识别：

Yale Database

Table 1. Results for Yale database using leave-one-out method

Evaluation Method	Approach	Recognition Rate
Leave-one-out	ICA	71.52%
	Kernel Eigenfaces	72.73%
	Edge map	73.94%
	Eigenfaces	75.60%
	Correlation	76.10%
	Linear subspace	78.40%
	2DPCA	84.24%
	Eigenface w/0 1st 3	84.70%
	LEM	85.45%
	Fisherfaces	92.70%
	SRC	98.18%

人脸识别

利用稀疏表达的人脸识别：

AR Database

Figure 4. Gesture variations in the AR database; note the changing position of head with different poses

(a) (b) (c) (d)

Table 4. Recognition results for gesture variations under Experiment Set 2

Approach	Recognition Accuracy			
	Smile	Anger	Scream	Overall
FaceIt	96.00%	93.00%	78.00%	89.00%
MIT	94.00%	72.00%	41.00%	60.00%
SRC	92.24%	91.38%	83.62%	89.08%

人脸识别

利用稀疏表达的人脸识别：

AR Database

Table 3. Recognition results for gesture variations under Experiment Set 1

Approach	Recognition Accuracy			
	Smile	Anger	Scream	Overall
20-eigenvectors	87.85%	78.57%	34.82%	67.08%
60-eigenvectors	94.64%	84.82%	41.96%	73.80%
112-eigenvectors	93.97%	87.50%	45.54%	75.67%
112-eigenvectors w/o 1st 3	82.04%	73.21%	32.14%	62.46%
EM	52.68%	81.25%	20.54%	51.49%
LEM	78.57%	92.86%	31.25%	67.56%
SRC	93.75%	91.07%	83.93%	89.58%

SRC都取得了总体最好的性能

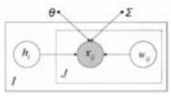
人脸识别

概率LDA：

Latent Identity Variable

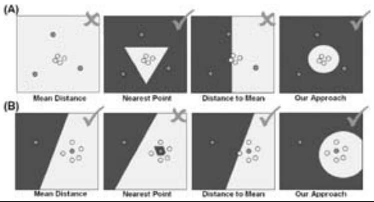
A generative model

Figure 1. Graphical model of typical latent identity variable model



与3种基于距离的模型比较

决策区域



人脸识别

概率LDA：

人脸配准

LIV模型描述了围绕关键点的图象的概率密度函数，如果关键点位置错误，概率密度就低

9个关键点　　图象　　预测分布　　估计

人脸识别

训练空间划分：

基于动态训练的迭代聚类

Figure 2. Flow-chart of the DTIC algorithm

Dynamic Training and Iterative Clustering

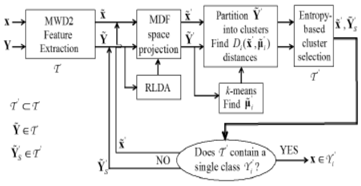


Table 4. Recognition rates, R_{rec} (%), for HDA (Swets 1999) and DTIC, for various number of training samples, (N_T), and face classes, Y

N_T	Method	Y=27	Y=48	Y=66	Y=90	Y=103	Y=119	Y=130	Y=255	Y=480
2	HDA	79.24	75.53	71.42	66.83	65.14	64.30	62.52	56.21	48.61
	DTIC	88.65	82.34	77.34	73.85	71.65	69.14	67.72	62.57	57.34
3	HDA	89.24	88.73	86.86	83.35	82.42	82.13	81.59	77.25	-
	DTIC	96.46	95.30	94.79	94.06	93.82	93.64	93.34	92.54	-
4	HDA	93.67	92.54	91.22	89.31	88.45	87.53	85.70	-	-
	DTIC	98.48	98.18	97.53	97.40	97.24	96.95	96.17	-	-
5	HDA	95.96	95.11	94.42	92.37	91.85	90.32	-	-	-
	DTIC	99.24	99.17	98.83	98.65	98.48	98.61	-	-	-
6	HDA	97.63	96.40	94.95	93.54	92.76	-	-	-	-
	DTIC	99.49	99.34	98.96	98.85	98.67	-	-	-	-
7	HDA	99.22	98.83	98.26	97.61	-	-	-	-	-
	DTIC	100	100	99.35	99.38	-	-	-	-	-
8	HDA	100	99.56	99.03	-	-	-	-	-	-
	DTIC	100	100	100	-	-	-	-	-	-
9	HDA	100	99.71	-	-	-	-	-	-	-
	DTIC	100	100	-	-	-	-	-	-	-
10	HDA	100	-	-	-	-	-	-	-	-
	DTIC	100	-	-	-	-	-	-	-	-

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Chapter 12 From the Face to Facial Expression

Chapter 13 Facial Expression Analysis by Machine Learning

Chapter 14 Subtle Facial Expression Recognition in Still Images and Videos

表情识别

表情表达：

借助情感：表情是情感的外部体现，6种对应情感的表情：幸福、惊奇、悲哀、厌恶、愤怒、害怕

Figure 1. The six universal emotional facial expressions

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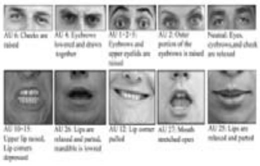
表情识别

表情表达：

借助表情肌肉运动：人脸动作编码系统（FACS）

46个动作单元（AU），7000多种组合

Figure 2. Examples of Action Units (AUs) defined by the FACS system. First row: upper AUs, second row: lower AUs (Ekman & Friesen, 1978).



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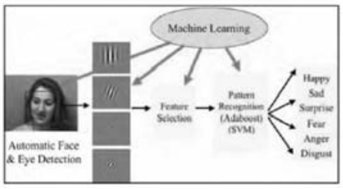
表情识别

机器学习：

利用机器学习方法克服照明条件、脸部朝向、图象质量、脸部遮挡等带来的问题

Figure 4. Outline of the real-time expression recognition system of Littlewort et al. (2006)



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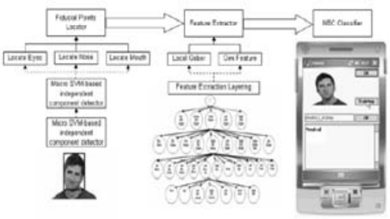
表情识别

机器学习：

系统示例

Figure 5. A system is proposed to recognize four types of facial expressions using Naïve Bayesian Boost



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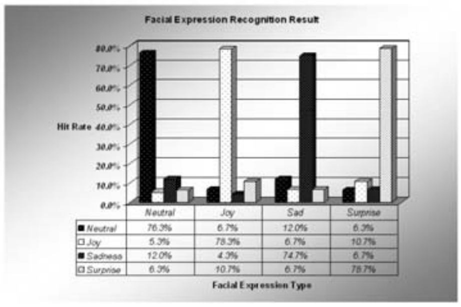
表情识别

Figure 8. Facial expression recognition result of the system

系统性能



	Neutral	Joy	Sad	Surprise
Neutral	76.3%	6.7%	12.0%	6.3%
Joy	5.3%	78.3%	6.7%	10.7%
Sadness	12.0%	4.3%	74.7%	6.7%
Surprise	6.3%	10.7%	6.7%	78.7%

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正文目录

- 背景介绍
- 特征提取
- 特征降维
- 人脸识别
- 表情分类
- 不变技术

Chapter 15 Photometric Normalization Techniques for Illumination Invariance
Chapter 16 Pose and Illumination Invariance with Compound Image Transforms
Chapter 17 Configural Processing Hypothesis and Face-Inversion Effect

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不变技术

照度不变性：

图象增强

γ校正

对数变换

Figure 1. Two examples of gamma intensity corrected images for two different gamma values

Figure 2. Impact of the logarithmic transform: original images (upper row), logarithm transformed images (lower row)

不变技术

照度不变性：

图象增强

直方图

均衡化

Figure 3. Impact of histogram equalization: original images (upper row), histogram equalized images (lower row)

不变技术

照度不变性：

图象增强

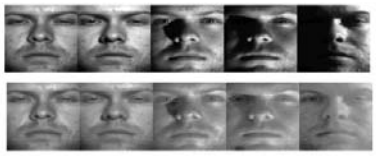
利用对数

正态分布

的直方图

重映射

Figure 4. Impact of histogram remapping using a lognormal distribution: original images (upper row), images with a remapped histogram (lower row)



不变技术

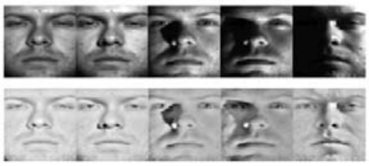
照度不变性：

光度归一化

单尺度视网

膜皮层技术

Figure 5. Impact of the single scale Retinex technique: original images (upper row), processed images (lower row)



不变技术

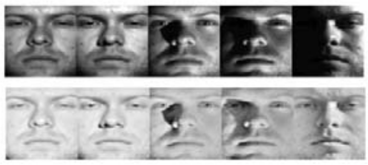
照度不变性：

光度归一化

多尺度视网

膜皮层技术

Figure 6. Impact of the multiscale Retinex technique: original images (upper row), processed images (lower row)



不变技术

照度不变性：

光度归一化

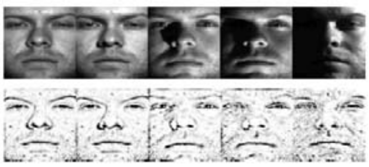
单尺度视网

膜皮层技术

（结合自适

应平滑技术）

Figure 7. Impact of the single scale Retinex with adaptive smoothing technique: original images (upper row), processed images (lower row)



不变技术

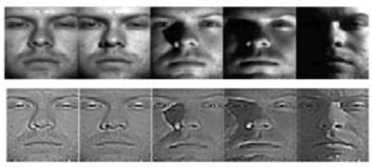
照度不变性：

光度归一化

同态滤波

技术

Figure 8. Impact of the homomorphic filtering technique: original images (upper row), processed images (lower row)



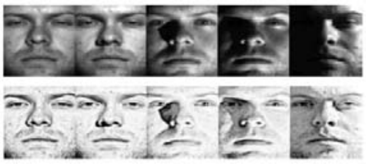
不变技术

照度不变性：

光度归一化

自商图象（SQI）技术

Figure 9. Impact of the self-quotient image technique: original images (upper row), processed images (lower row)



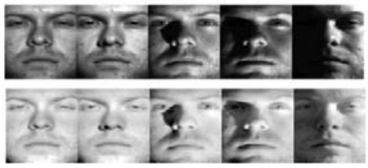
不变技术

照度不变性：

光度归一化

基于DCT归一化技术

Figure 10. Impact of the DCT-based normalization technique: original images (upper row), processed images (lower row)



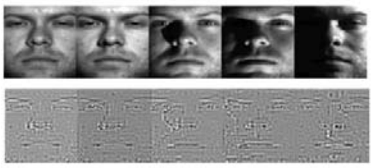
不变技术

照度不变性：

光度归一化

基于小波的图象消噪技术

Figure 11. Impact of the wavelet-based image denoising technique: original images (upper row), processed images (lower row)



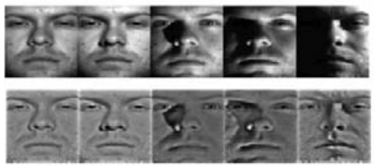
不变技术

照度不变性：

光度归一化

各向同性平滑技术

Figure 12. Impact of the isotropic smoothing technique: original images (upper row), processed images (lower row)



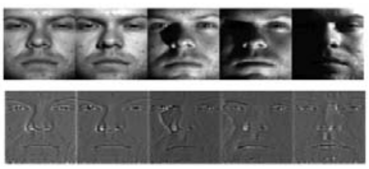
不变技术

照度不变性：

光度归一化

非各向同性平滑技术

Figure 13. Impact of the anisotropic smoothing technique: original images (upper row), processed images (lower row)



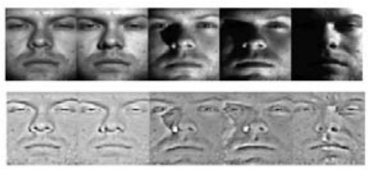
不变技术

照度不变性：

光度归一化

对数全变分模型

Figure 14. Impact of the logarithmic total variation model: original images (upper row), processed images (lower row)



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不变技术

照度不变性：

效果评价

实验图象

Figure 15. Sample images of two subjects from the YaleB face database drawn from (from left to right): image set 1 (S1), image set 2 (S2), image set 3 (S3), image set 4 (S4) and image set 5 (S5).

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不变技术

照度不变性：（识别）效果评价

Table 1. Rank one recognition rates obtained on the YaleB database with the tested image enhancement techniques

Image set	GR	HQ	GC	LT	HL
S2 (120)	100	100	100	100	100
S3 (120)	93.3	99.2	73.3	67.5	95.8
S4 (140)	42.1	53.6	35.7	33.6	75.0
S5 (190)	13.7	53.2	35.8	35.3	75.0

Table 3. Rank one recognition rates obtained with the tested photometric normalization techniques

Sets	SR	MR	SRA	HO	SQ	DCT	WD	IS	AN	LTV
S2 (120)	100	100	100	100	100	100	100	100	94.2	100
S3 (120)	99.2	94.2	100	100	100	95.0	100	94.2	97.5	100
S4 (140)	82.9	71.4	98.6	84.3	98.6	59.3	98.6	84.3	80.1	99.3
S5 (190)	81.1	66.8	99.5	81.1	100	42.6	99.5	76.8	87.4	99.5

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不变技术

姿态和照度不变性：实验特征

- Chebyshev-Fourier features
- Radon transform features
- Chebyshev Statistics
- Multi-scale Histograms
- Edge Statistics features
- Tamura Texture features
- Gabor Filter
- First Four Moments
- Object Statistics
- Haralick features
- Zernike features

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不变技术

姿态和照度不变性：实验数据

Table 1. Recognition accuracies tested using the datasets ORL, JAFFE, the Indian face dataset (females and males) and ESSEX-96

Dataset	No. of Subjects	Images per subject	Recognition accuracy (%)
ORL (Samaria & Harter, 1994)	40	10	100
JAFFE Lynos, Akamatsu, Kamachi, & Gyboa, 1998)	10	21	100
Indian Face Dataset (females) (Jain & Mukherjee, 2002)	22	11	99
Indian Face Dataset (males) (Jain & Mukherjee, 2002)	39	11	97
ESSEX-96 (Spacek, 2002)	132	20	99
Color FERET	994	~11	~85
Yale B	10	576	100

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不变技术

姿态和照度不变性：实验结果

Table 2. Performance comparison of the proposed method to previous algorithms using the ORL face dataset

Algorithm	Recognition accuracy
Fisherface (Belhumeur, Hespanha, & Kriegman, 1997)	82.4
Direct LDA (Yu & Yang, 2001)	91.55
Huang et al. (Huang, Liu, Lu, & Ma, 2002)	95.40
Regularized LDA (Chen et al., 2004)	96.65
The proposed method	100

Table 3. Comparison of the proposed method to previous algorithms using the color FERET face dataset

Algorithm	Recognition accuracy (%)
LFA (Penev & Atick, 1996)	92.3
CF (Savvides, Vijaya Kumar & Khosla, 2002)	93.8
(Singh et al., 2005)	94
The proposed method	95.2

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不变技术

姿态和照度不变性：实验结果

原始数据、变换数据、组合变换数据的比较

Table 4. Recognition accuracies (%) of face datasets when using images features extracted from raw pixels only, raw pixels and image transforms, and raw pixels, transforms and compound transforms

Dataset	Raw pixels only	Raw pixels + image transforms	Raw pixels + image transforms + compound transforms
FERET (rank-10, fb)	84	89	98
FERET (rank-10, qr)	75	84	91
FERET (rank-10, hr)	77	87	94
ORL (rank-1)	95	95	100
JAFFE (rank-1)	92	98	100
Indian Female Face Dataset (rank-1)	94	96	99
Indian Male Face Dataset (rank-1)	94	96	97

不变技术

（特殊的）姿态不变性：

Face-Inversion Effect

对正立的人脸的感知和识别比对颠倒的人脸的感知和识别要好

这种效果在对人脸的识别中要比在对非人脸（建筑、汽车等）的识别中要强

这种效果可用“结构形成处理”假设来解释（颠倒减弱了对结构形成信息的处理，相对不触动对眼、鼻、嘴等特征信息的加工）

不变技术

（特殊的）姿态不变性：

Face-Inversion Effect

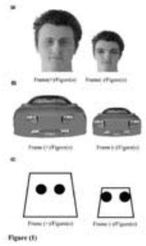
测试了三种假设：

(1) Eye-illusion （人脸）

(2) Headlight-illusion （车正面）

(3) Form-illusion （几何体）

Figure 1. Presents decreased and increased Eye-Illusion (a), Headlight-Illusion (b), and Form-Illusion (c). In each pair, the size of the inner Figure is the same.



结　　语

➢ **Future Trends:**

- **Analysis with Sets of Images**
- **Multi-Modality Analysis**
- **Mimic of the Human’s Skill**
- **New Theories and Tools**

结　　语

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