

# Face Recognition in Forensics and Beyond

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### Birth to Age 10 in 85 Seconds



http://www.dailymotion.com/video/xfx6cn\_natalie-time-lapse-birth-to-10-years-old-in-1-minute-25-sec\_creation

#### Why Face?

- Face recognition: most common human experience
- Social interaction: expression, emotion, intent, age
- Easy to capture: covert acquisition (surveillance)
- Legacy databases: passport, visa, driver license



#### Automated Face Recognition

Given a query face image (*probe*), identify it from a target population (*gallery*)

Probe

Gallery



1:1 vs. 1:N matching



#### Where is Face Recognition Today?



#### **De-duplication**

Matching 700K faces against 51M gallery (Florida DMV) found 5K duplicates



### Where is Face Recognition Going?



Face recognition technology is moving towards **ubiquity**: reducing violent, unpredictable acts, like the rioting in London last summer

Image from: W.D. Jones, "The future of riots," Spectrum, IEEE , vol.48, no.11, pp.13-14, November 2011

#### Face Recognition and the London Riots

#### Widespread looting and rioting:



#### Extensive CCTV Network (1M CCTV cameras in London & 4M in U.K.):



#### Face recognition lead to many arrests:



Yet, many suspects still unable to be identified by COTS FRS:



#### Surveillance Plane to Circle Lancaster 16 Nov 2011

 Surveillance plane will hover Lancaster, CA for 10 hours a day collecting intelligence and keeping an eye on residents with a suite of video cameras and infrared sensors



http://www.homelandsecuritynewswire.com/surveillance-plane-circle-lancaster-ten-hours-day

# FBI to Launch Nationwide Facial Recognition Service

- The FBI will activate a nationwide facial recognition service to allow local police to identify unknown subjects in photos
- Using the Next-Generation Identification system, law enforcement analysts will be able to upload a photo of an unknown person and, within 15 minutes, receive identified mug shots to inspect for potential matches; New surveillance system: 1 second to search through 36 million faces

http://www.nextgov.com/nextgov/ng\_20111007\_6100.php?oref=rss http://www.homelandsecuritynewswire.com/dr20120325-new-surveillance-system-1-second-to-search-through-36-million-faces

#### Face Recognition for Social Networking



#### Screenshot from iPhone

- SceneTap is a new service (website & app) that uses
  cameras in bars and clubs to detect male-female ratio, avg. patron age
- U.S. Senator Rockefeller recommending legislation to protect face privacy, cited SceneTap as an example

"Senator pushes for greater regulations on facial recognition tech", Homeland Security Newswire. 9 November 2011

## Overview of Automated Face Recognition Algorithms



 Most face recognition algorithms follow this pipeline



### **Appearance-based Methods**

Input face



EigenFaces



**Fisherfaces** 



# Local Binary Patterns



T. Ojala, et al. "Multiresolution Gray-Scale and Rotation Invariant Texture Classification with Local Binary Patterns," TPAMI, 2002

#### How to Learn Salient Features?



# Face Recognition Performance

• Controlled FR (FRGC)



TAR of 99% @ FAR = 0.1%

• Frontal FR with lighting changes and expressions (MBGC)







PittPatt: 84% TAR @ FAR = 0.1%

• Uncontrolled FR (free pose and occlusion)



PittPatt: 43% TAR @ FAR = 0.1%

• FR in video surveillance



Who is this person at the "Occupy Wall Street" protest?



#### **Unconstrained Face Recognition**



### Forensic Face Recognition



 Manual intervention: (i) preprocessing, (ii) examining the top-N retrieved faces from gallery

A. K. Jain, B. Klare, and U. Park, "Face Recognition: Some Challenges in Forensics", 9th IEEE International Conference on Automatic Face and Gesture Recognition (FG), 2011

#### **Challenges in Forensic Face Recognition**

	Pose	Illumination	Expression	Aging	Heterogeneous
Non-forensic					
Access control		$\checkmark$			
De-duplication				$\checkmark$	
Border control		$\checkmark$			
Forensic					
Missing person	$\checkmark$		$\checkmark$	$\checkmark$	
Child trafficking	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	
Surveillance	$\checkmark$	$\checkmark$	$\checkmark$		
Forensic sketch					$\checkmark$

- Non-forensic, fully automated scenarios do not encounter many of these performance degrading factors
- Forensic FR often requires a preprocessing stage of image enhancement or a specialized matcher to perform recognition



#### Matching Degraded Face Images



down-sampled image

- Face images are often degraded during transition
- Given only a degraded face image, how can we improve its quality to make a successful hit?

T. Bourlai, A. Ross, and A. K. Jain, "Restoring Degraded Face Images: A Case Study in Matching Faxed, Printed and Scanned Photos", *IEEE Transactions on Information Forensics and Security*, Vol. 6, No. 2, pp. 371-384, June 2011.

#### Forensic Face Recognition Approaches



Aging simulation

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Age 1

#### **Preprocessing methods:**

- Enhance the quality of a face image prior to submission to a face recognition system
- Compatible with the COTS FRS already in use

[1] V. Blanz and T. Vetter, "Face Recognition Based on Fitting a 3D Morphable Model," TPAMI, 2003

#### Forensic Face Recognition Approaches

**Face Mark Matching** 

**Infrared Recognition** 

**Sketch Recognition** 



#### **Specialized face recognition systems:**

- Designed to solve a specific matching task
- Any aspect of the face recognition process (e.g. representation, learning) can be modified



# **Applications within Forensics**

- Heterogeneous Face Recognition
  - Sketch Recognition
- Face Aging
  - Synthesis (Preprocessing)
  - Feature-based discriminative (Specialized Matcher)
- Demographic-based Matcher
- Partial Face
- Face Mark
- FR at a Distance



#### Heterogeneous Face Recognition



Frontal face image exists for majority of the population







Near Infrared



**Thermal Infrared** 



Many security scenarios necessitate identification from different sensing modalities (e.g. forensic sketch, infrared image)





Heterogeneous Face Recognition (HFR): Matching non-photograph face images (probe) to large gallery of frontal photos

**Forensic Sketch** 





#### **HFR using Kernel Prototypes**



Method does not require direct similarity measure between modalities

B. Klare and A. K. Jain, "Heterogeneous Face Recognition using Kernel Prototype Similarities", IEEE Transactions on Pattern Analysis and Machine Intelligene 2011 (Under Review)

#### Matching Sketches to Mug Shot Photos

- Forensic sketches used in most egregious crimes
- Ability to match these sketches to mug shot databases has strong benefits for safety and security
- Current FR technology is unable to perform this task



A, K. Jain, and B. Klare, "Matching Forensic Sketches and Mug Shots to Apprehend Criminals", *IEEE Computer*, Vol.44, No. 5, pp. 94-96, May 2011 B. Klare, Z. Li, and A. K. Jain, "Matching Forensic Sketches to Mugshot Photos", IEEE Trans. Pattern Analysis and Machine Intelligence, March 2011

# Sketch From Video

#### The New York Times

Los Angeles Officials Identify Video Assault Suspects

"Composite drawings of four of the suspects have been made based upon video images"



http://www.lacrimestoppers.org/wanteds.aspx http://www.nytimes.com/2011/01/08/us/08disabled.html



# **Facial Aging**



Accuracy of FR Systems vs. Time Lapse (TAR at FAR = 1.0%)





Aging-invariant FR algorithms

- Learn invariant features
- Synthesize appearances that offset facial variations over time

### Approaches to Aging-Invariant FR



Z. Li, U. Park, and A. K. Jain, "A Discriminative Model for Age Invariant Face Recognition," IEEE Trans on Information Forensics and Security, 2011

#### **Aging Recognition Examples**





Age 51



Age 42



Age 40

Age 55





Age 41 Age 34

FaceVACS and generative model fail; discriminative approach succeeds



Discriminative approach fails; FaceVACS and generative model succeed



Age 38

Age 54

All three methods fail; fusion of generative and discriminative models succeeds

#### Generalization of Aging-Invariant FR

- FR systems designed for aging have lower accuracy in non-aging scenarios
- Implies need for multiple FR systems

Test set: 0 to 1 year time lapse							
RS-LDA trained on (time lapse in years):					Baselines:		
(0-1)	(1-5)	(5-10)	(10+)	(All)	MLBP Only	COTS1	COTS2
94.5%	94.1%	93.1%	91.8%	94.1%	71.2%	96.3%	89.8%
			# of Match Comparions:		19,996		
		# 0	# of Non-Match Comparions:		239,572,034		
lest set: 1 to 5 year time lapse							
KS-L	RS-LDA trained on (time lapse in years):			Baselines:			
(0-1)	(1-5)	(5-10)	(10+)	(All)	MLBP Only	COTS1	COTS2
90.3%	90.5%	89.1%	87.7%	90.2%	62.9%	94.3%	84.6%
			# of Match Comparions:		33,443		
		# 0	of Non-Match Comparions:		401,282,557		
lest set: 5 to 10 year time lapse							
RS-LDA trained on (time lapse in years):				Baselines:			
(0-1)	(1-5)	(5-10)	(10+)	(All)	MLBP Only	COTS1	COTS2
75.2%	81.2%	82.0%	80.4%	81.3%	46.7%	88.6%	75.5%
			# of Match Comparions:		24,036		
# of Non-Match Comparions:			215,795,208				

B. Klare and A. K. Jain, "Face Recognition Across Time Lapse: On Learning Feature Subspaces", IJCB, Washington, DC, Oct. 11-13, 2011

#### Face Recognition Across Demographics



• Are FR algorithms biased towards or against certain demographic prototypes?



#### **Dynamic Face Matcher Selection**



dynamic face matcher selection

B. Klare, M. Burge, J. Klontz, R.W. Vorder Bruegge, and A. K. Jain, "Face Recognition Performance: Role of Demographic Information", IEEE Transactions on Information Forensics and Security, 2011 (under review).

#### **Dynamic Face Matcher Selection Example**

#### **Probe Images:**





#### **Dynamic Face Matcher Selection Example**

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#### Probe Images:





# Facial Marks







**Partial face** 



Non-frontal video frame



Large birth mark



Tattoo

 Facial marks can be useful to filter gallery (from even verbal query), and generate a small set of candidate face images

U. Park and A. K. Jain, "Face Matching and Retrieval Using Soft Biometrics," IEEE Trans. Information Forensics and Security, 2010.

#### Face Finder



• Query based on:

Rank 1 Rank 2

Rank 3

• Face marks, Date of birth, Date of arrest, Gender, Ethnicity, Height, Weight

U. Park, S. Liao, B. Klare, J. Voss, and A. K. Jain, "Face Finder: Filtering a Large Database Using Scars, Marks and Tattoos", MSU Technical Report, MSU-CSE-11-15, 2011.

# Facial Tattoo Caught in Surveillance Camera



Detroit police linked at least six armed robberies at an ATM after matching a tipster's description of the suspect's distinctive tattoos

www.DetroitisScrap.com/2009/09/567/

#### A Tattoo Revealed True Identity



This person gave his name as "Darnell Lewis" to an officer, but the officer noticed the man had "Frazier" tattooed on his neck, his real surname. He was arrested on four misdemeanor warrants. (Dec. 2008, St. Paul.)

#### **Distinguishing Identical Twin Pairs**

The New Hork Times

Identical Twins, One Charged in a Fatal Shooting, Create Confusion for the Police

By MARC LACEY Published: August 8, 2011

CHANDLER, Ariz. — At first, the murder case against Orlando Nembhard seemed solid, as witness after witness came forward to say they saw someone that looked just like him brandish a pistol in February outside a

#### Pairs of identical twins:









It was

him

It was

him

Facial marks (e.g. moles) can help distinguish identical twin pairs

B. Klare, A. A. Paulino, and A. K. Jain, "Analysis of Facial Features in Identical Twins", IJCB, Washington, DC, Oct. 11-13, 2011

#### Face Recognition at a Distance

Visible still images and NIR images up to a distance of 200m



H. Maeng, H.-C. Choi, U. Park, S.-W. Lee, and A. K. Jain, "NFRAD: Near-Infrared Face Recognition at a Distance", IJCB, Washington DC, 2011

#### **Daytime Images**





IPD	489	187	114	73	56
SCORE	-	1.000	1.000	1.000	1.000

### Nighttime Images





0.000



#### **Caricature Recognition**



- Humans recognize caricature sketches more easily than realistic sketches
- Studying caricatures may lead to improved face representations

B. Klare, S. Bucak, T. Akgul, and A. K. Jain, Automated Caricature Recognition, International Con-ference on Biometrics, 2012

#### **Studies in Cognitive Science**

- Despite extreme exaggeration of facial features, people may be better at recognizing caricature than veridical portrait [Mauro & Kubovy]
- Caricature can be considered as an extrapolation in "face space"



R. Mauro and M. Kubovy. "Caricature and face recognition". Memory & Cognition, 1992.

Image from: D. A. Leopold, et al, "Prototype-referenced shape encoding revealed by high-level aftereffects." Nature Neuroscience, 2001

### **Caricature Recognition**

Histogram

Difference

Caricature





### **Partial Face Recognition**

- Occlusions by other objects
- Pose (self occlusion)
- Facial accessories: hat, sunglasses, scarf, mask
- Limited field of view











### Summary

- Requirements in forensic face recognition are paving the way for research in unconstrained face recognition
- Many challenges in using low quality video data to ascertain an identity
- In most difficult and critical circumstances, human analysts can intervene to improve recognition accuracy



## Summary



- Eventually galleries will span the entire population
- Safety and security can be greatly improved by leveraging large face databases



\* PAT. PEND.