Human versus Machine Performance

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Acknowledgements

- *In collaboration with*
  - P. J. Phillips - *NIST*
  - Fang Jiang - *Univ. of Texas at Dallas (UTD)*
  - Nils Pénard - *UTD*
  - Janet Ayyad - *UTD*
  - Hervé Abdi - *UTD*
- *Work supported by TSWG*

Overview

- rationale
- Face Recognition Grand Challenge
- human-machine comparison

Problem

- Are face recognition algorithms *ready* for security applications?
  - enormous improvements over last decade
  - accuracy of algorithms tested intensively
- *How accurate do they have to be to be useful?*
  - meet or exceed human performance

Why?

- *humans are the competition!*
  - human-machine comparisons *virtually* never done
- putting algorithms in the field
  - security improved or put at greater risk?

How accurate are algorithms?

U.S. Government-sponsored Competitions

- standardize comparisons
  - test multiple algorithms
  - identical, LARGE sets of face image data

  - Face Recognition Grand Challenge
    - (2004-ongoing)

Present work

- purpose
  - extend standardization of FRGC to compare humans and algorithms on a challenging face recognition task
  - matching face identity across changes in illumination (FRGC Exp. 4)

Why Illumination Change?

- recognized to be difficult for:
  - humans (e.g., Braje et al., 2000; Troje & Bülthoff, 1998)
  - algorithms (e.g., Phillips et al. 2005; Gross et al. 2005)

Most Challenging FRGC Experiment

- controlled illumination experiment (Exp. 1)
  - match images with controlled illumination
  - 20 participating algorithms
  - median performance of
    - .91 verification rate
    - .001 false acceptance rate

- uncontrolled illumination (Exp. 4)
  - match images with controlled and uncontrolled illumination
  - 7 participating algorithms
  - median performance
    - .42 verification rate
    - .001 false acceptance rate

FRGC Uncontrolled Illumination Test

- Match identity in target and probe faces
  - *target* - controlled illumination
  - *probes* - uncontrolled illumination

Specifics

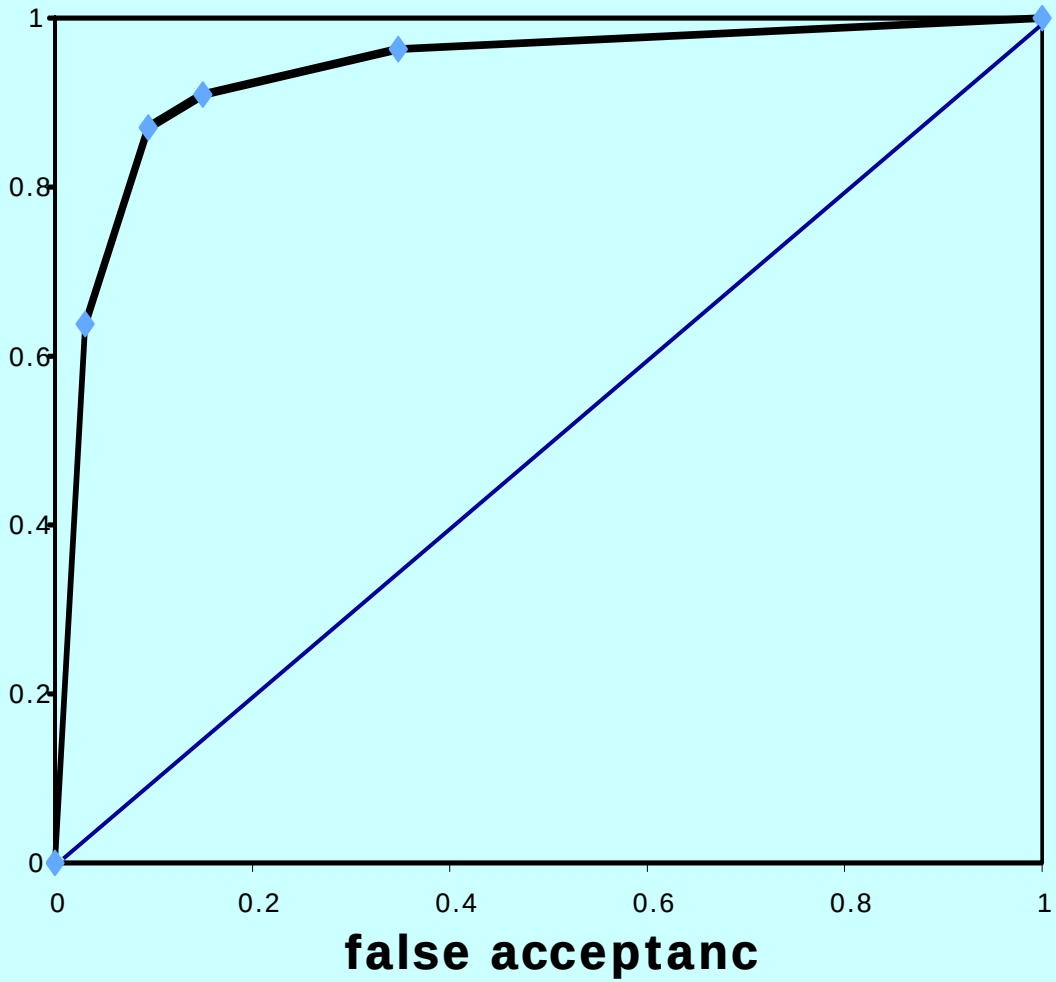
- similarity matrix
  - target (n = 8014)
  - probe (n =16028)

  - s(i,j) = similarity between the i^{th} and j^{th} faces
    - 128,041,040 similarity scores
    - 407,352 of same people
    - remainder of different people

Results

- ROC
  - verification rate
  - false acceptance rate

Algorithm Performar



Comparing Humans and Algorithms

- problem
  - 128 million face pairs?
- solution
  - sample face pairs
    - most difficult
    - easiest

Sampling

- homogeneous
  - caucasian males/females 20-30 yrs
  - comparisons made on identity not
    - age, race, sex
- caution on the FRGC results

Easy and Difficult

- PCA Baseline Algorithm
  - scaled and aligned images (SAIC)
  - available and widely used since the 90's
  - but not state-of-the-art

Match Pairs

- *"easy" match pairs*
  - 2 "similar" images of same person
    - similarity scores > 2 sd ***above*** mean similarity of match pairs
- *"difficult" match pairs*
  - 2 "dissimilar" images of same person
    - similarity scores < 2 sd ***below*** mean similarity of match pairs

No-Match Pairs

- *"easy" no-match pairs*
  - 2 "dissimilar" images of different people
    - similarity scores < 2 sd ***below*** mean similarity of no-match pairs
- *"difficult" no-match pairs*
  - 2 "similar" images of different person
    - similarity scores < 2 sd ***above*** mean similarity of no-match pairs

- Experiment 1
  - unlimited exposure time
  - male face pairs

- Experiment 2
  - 2 sec. exposure time
  - male and female face pairs

- Experiment 3
  - 500 msecs. exposure time
  - male and female face pairs

Methods

- Stimuli
  - 240 pairs of faces
    - 120 male pairs
      - 60 easy
      - 60 difficult
    - 120 female pairs
      - 60 easy
      - 60 difficult

- Subjects
  - 91 volunteers from UTD
    - Expt. 1
      - *n* = 22 (12 males; 10 females)
    - Expt. 2
      - *n* = 49 (24 males; 25 females)
    - Expt. 3
      - *n* = 20 (10 males; 10 females)

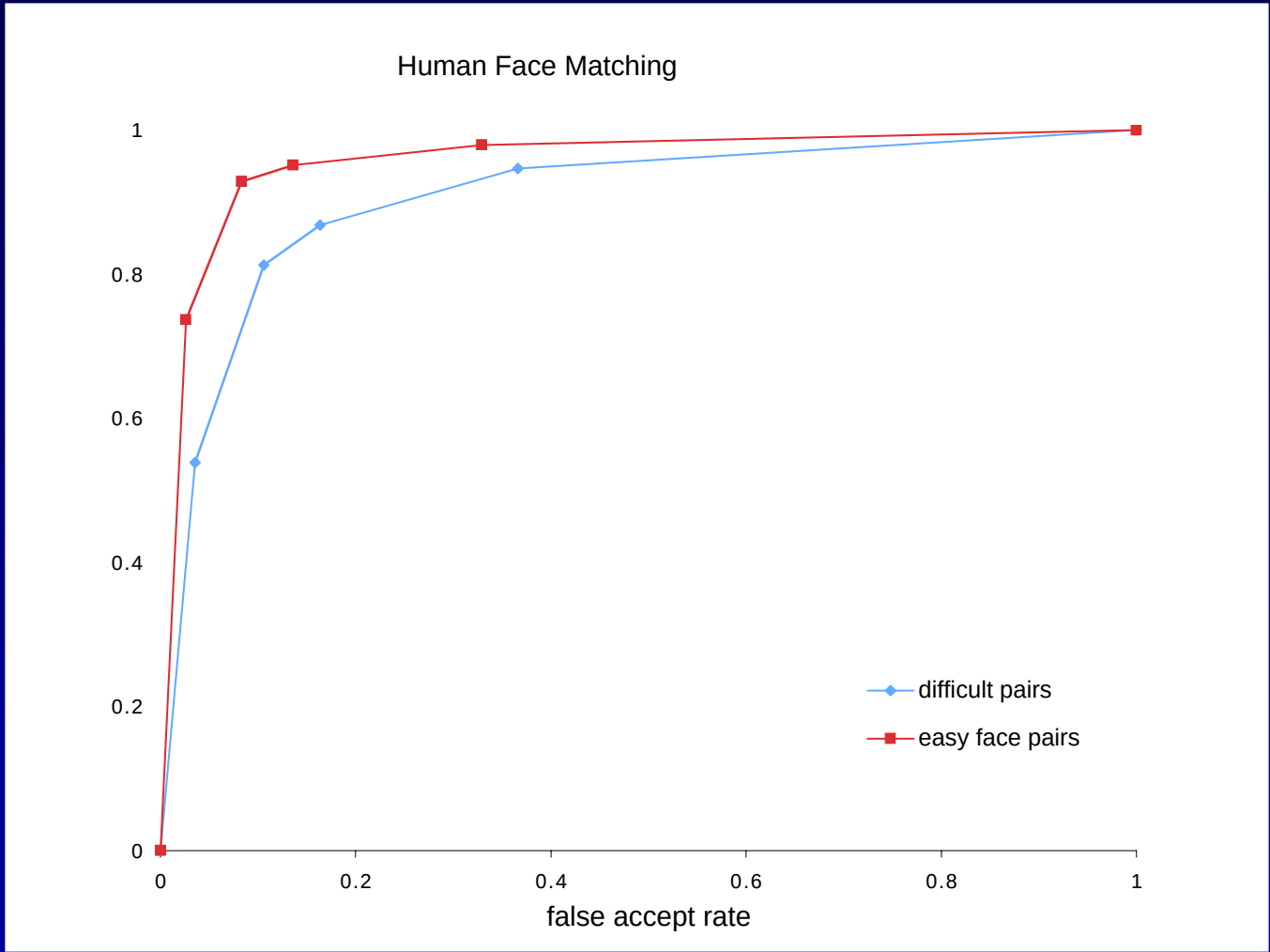
Procedure

- 2 faces appear side by side
- Human subject raters respond…
  - 1. sure they are the same person
  - 2. think they are the same person
  - 3. not sure
  - 4. think they are not the same person
  - 5. sure they are not the same person

Results

- *PCA predicts difficulty (d' analysis)*
  - Experiment 1
    - $F(1,20) = 19.78$, $p < .002$
  - Experiment 2
    - $F(1,48) = 96.53$, $p < .0001$
  - Experiment 3
    - $F(1,18) = 62.65$, $p < .0001$

Experiment 2



Experiment comparison

- Humans no more accurate with unlimited time than with 2 secs. presentations
  - $F(1,176)= 2.01$, *ns*.
- Human accuracy declined with exposure times of 500 msecs.
  - $F(1,176)= 26.97$, $p < .0001$

Stability of human performance

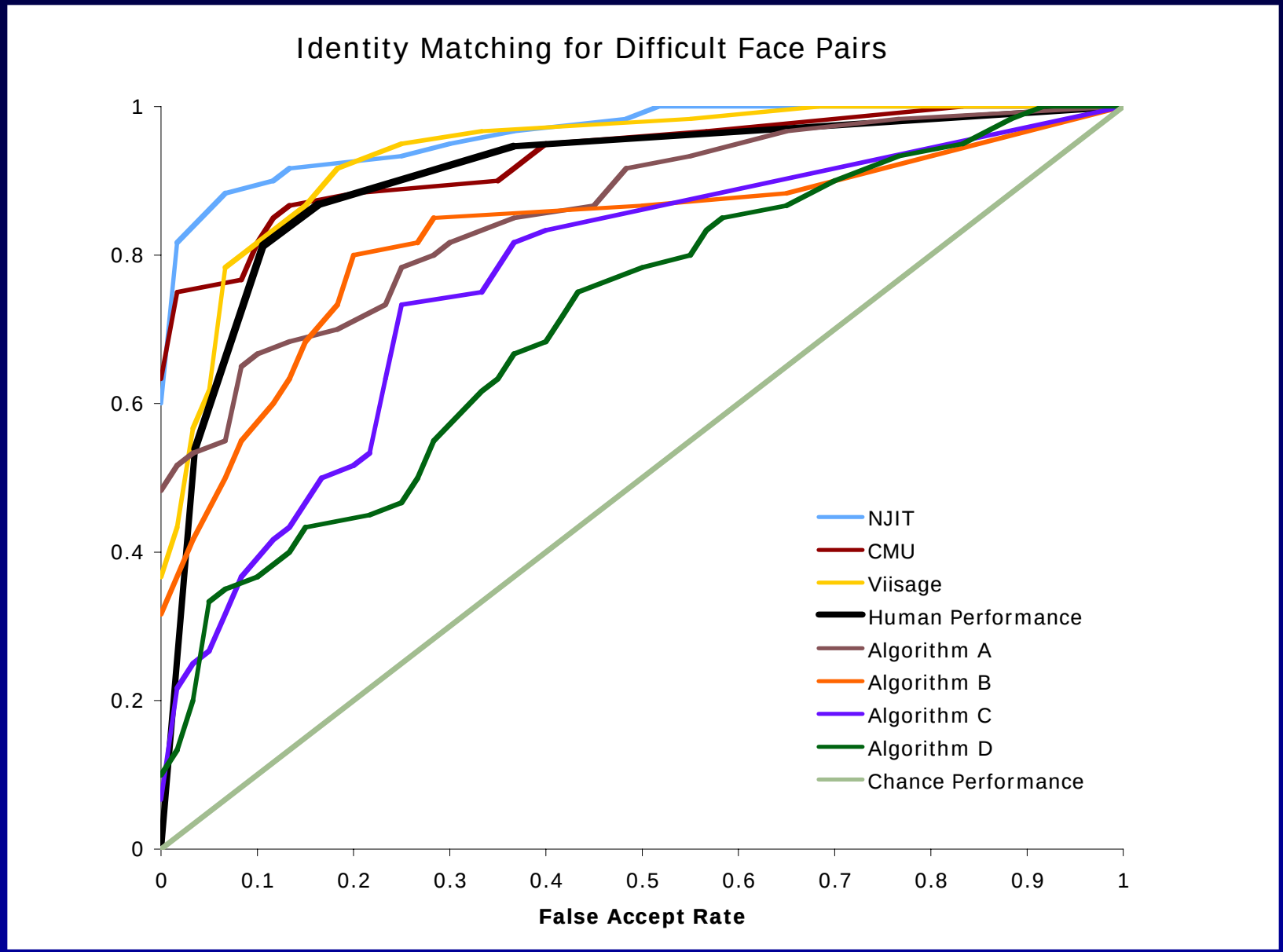
- supports use of these data for benchmark comparisons with machines

Human-Machine Comparisons

- Seven state-of-the-art algorithms
  - 4 from industry
  - 3 from academic institutions

- Comparisons
  - 120 difficult face pairs
  - 120 easy face pairs

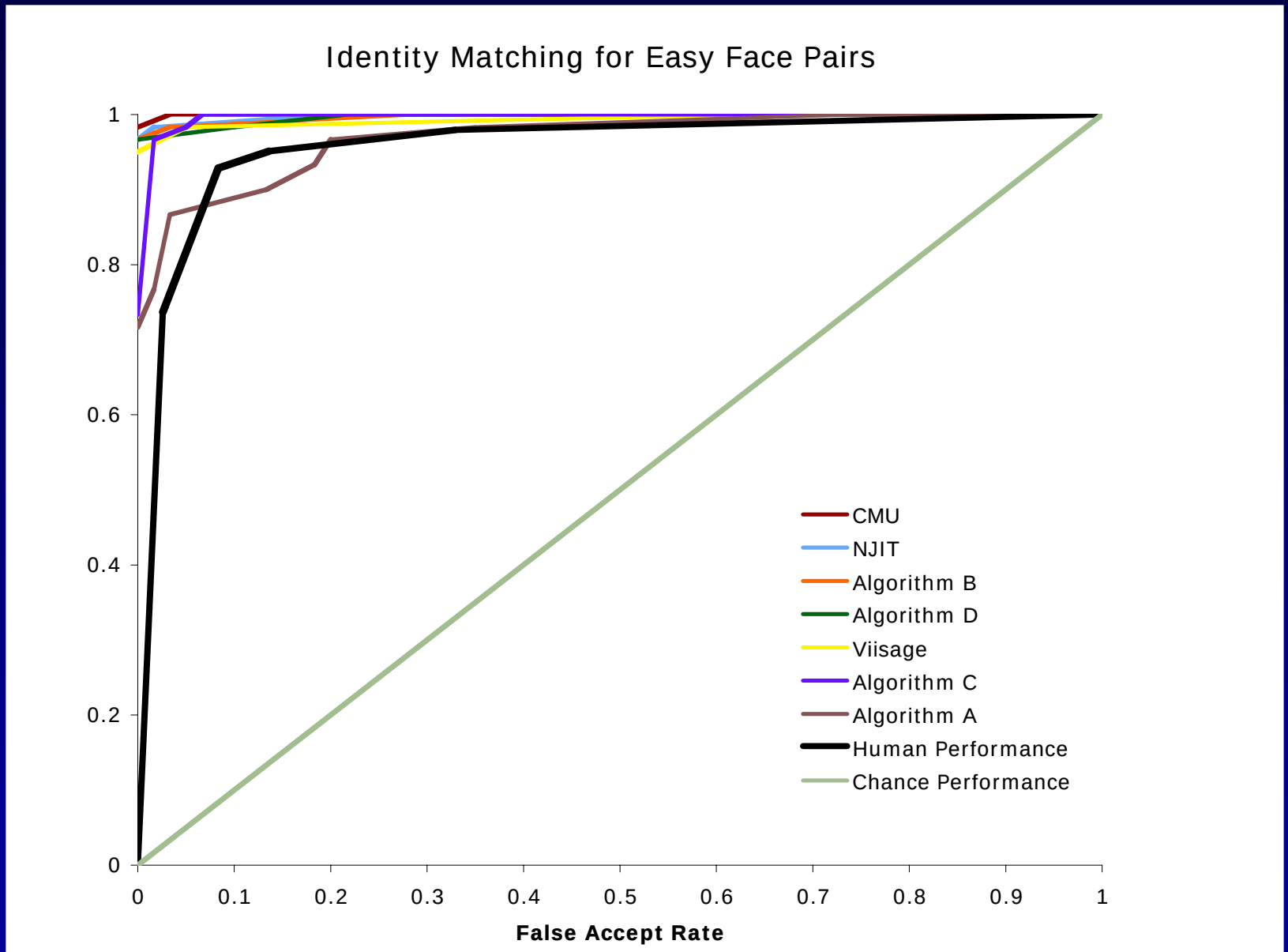
Results


Identity Matching for Difficult Face Pairs
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
False Accept Rate
NJIT
CMU
Viisage
Human Performance
Algorithm A
Algorithm B
Algorithm C
Algorithm D
Chance Performance

Results Summary
Difficult Face Pairs

- 3 algorithms surpass humans
  - NJIT (Liu, *IEEE: PAMI, in press*)
  - CMU (Xie et al., 2005)
  - Viisage (Husken et al., 2005)

- 4 less accurate than humans


Identity Matching for Easy Face Pairs
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
False Accept Rate
CMU
NJIT
Algorithm B
Algorithm D
Viisage
Algorithm C
Algorithm A
Human Performance
Chance Performance

Results Summary
Easy Face Pairs

- 6 algorithms surpass humans!
- 7th less accurate than humans at high false acceptance rates

Human Attention

- Did attention waver during experiment?
  - no correlation between accuracy and trial
    - verification (r = .07, *ns*)
    - false acceptance rate (r = -.04, *ns*.)

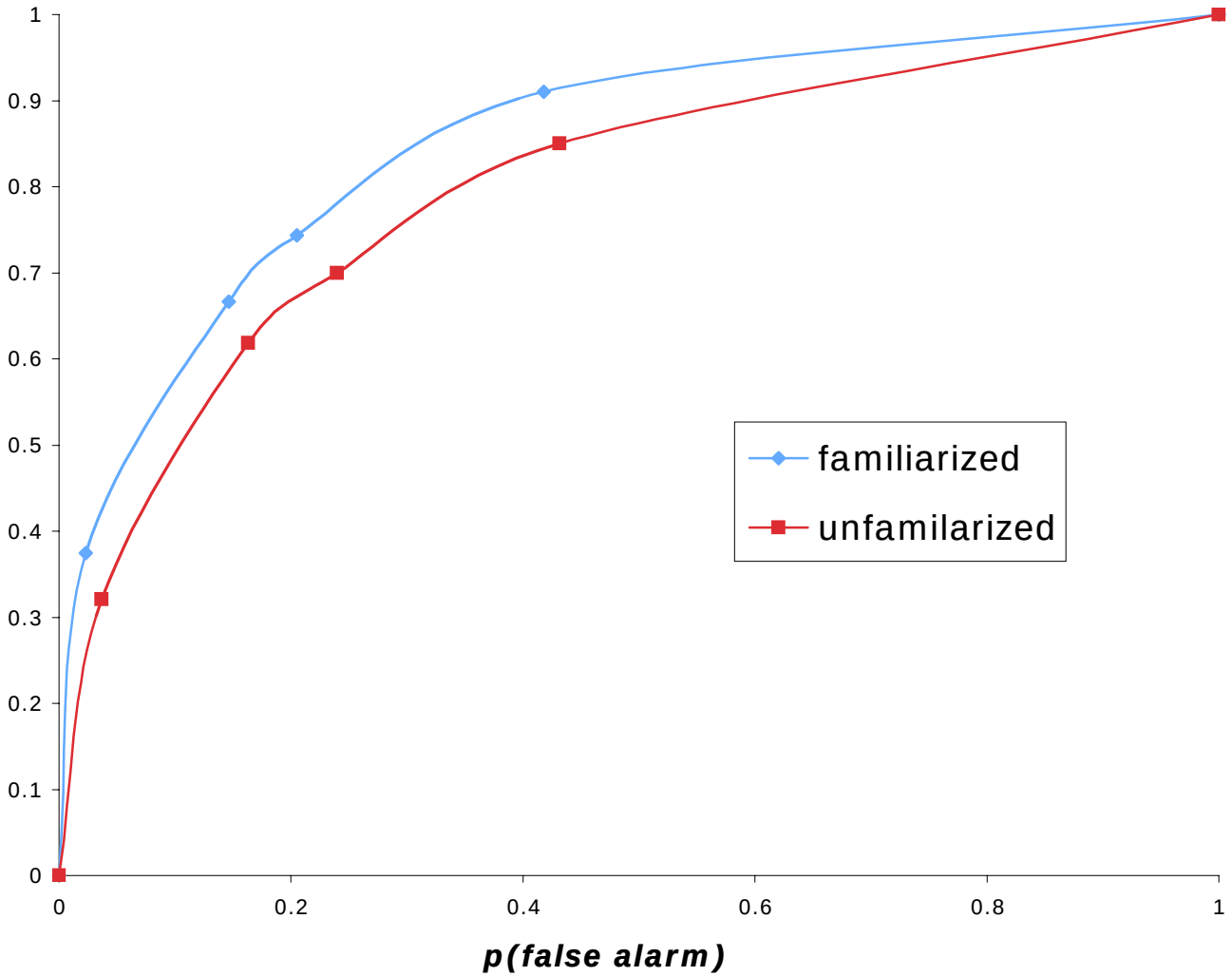
Are human skills overrated?

- "familiar" versus "unfamiliar"
- unfamiliar matching
  - *correct* task for comparing "human" and machine security systems
- evidence that human expertise for faces may be limited to recognizing "familiar faces (Hancock et al., 2001; O'Toole et al., 2003)

Familiarization

- Can we improve human performance?
- Experiment 4
  - select face pairs that generated errors in Exp. 2
  - familiarize subjects with people in pairs
    - 5 exposures to one face in pair
  - n = 77 subjects
  - results
    - improvement, but not significant ($F(1,76)=1.3$, $p < .25$)

Human Performance with Familiarization



Conclusions

- Algorithms compete favorably with humans on the difficult task of matching faces across changes in illumination
  - some algorithms are *better* than humans on “difficult” face pairs
  - nearly all are *better* than humans on “easy” face pairs

Implications

- Algorithms may improve security in some situations
  - *even if they perform poorly in absolute terms*

Implications

- We accept on “face” value the need to test any algorithm that we put in the field for an important security application
- Tools available for testing humans
  - We rarely do!?

What next?

- Why?
  - Analysis of the variability of algorithms
  - Which face pairs separate algorithms?
    - Hybrid strengths & weaknesses


FRGC