Demographic Effects in Face Recognition

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Talking about face recognition bias, quantitatively

• Bias at what stage:
  • Capture (camera, or sub-system):
    Failure-to-capture rate, Quality
  • Template creation (for enrollment, or recognition):
    Failure-to-extract rate
  • Type II error rates: Failure to associate person with prior sample FNMR, FNIR
  • Type I error rates: Incorrect association of photo from two people FMR, FPIR

• Impact:
  • Is application dependent, so harm in one application is benefit in another
  • Magnitude matters!
    1. Demographic differentials \( \Delta_{AB} \) matter.
    For example, it’s bad if \( |FNMR_A - FNMR_B| > \delta \)
    2. Absolute error rates matter:
    For example, it’s bad if \( FNMR \gg 0 \) is bad

• Algorithms:
  • May differ in their biases
  • Know-Your-Algorithm
    1. Demographic differentials
    2. Other sensitivities
1:N Face  Female-Male Differential Impact
Male-Female Demographic Differential Experiment

GALLERY:
1. N = 1,600,000
2. WHITE
3. MUGSHOTS
4. BALANCED
   1. 800,000 MALE
   2. 800,000 FEMALE
5. AGE 21-40 at FIRST ENROLLMENT

MATED PROBES:
1. 100,000 MALE
2. 100,000 FEMALE
3. COLLECTED IN DIFFERENT YEAR TO GALLERY MATE
4. COLLECTED WITHIN FIVE YEARS OF MATE
5. AGE 21-40

NON-MATED PROBES:
1. 100,000 MALE
2. 100,000 FEMALE
3. AGE 21-40
Male and Female Miss Rates, FNIR(Rank)

FNIR(Rank) is a metric appropriate to investigational applications where human reviewers will adjudicate candidate lists.

N = 1 600 000 subjects, 800 000 each sex. Enrolled with 1 image each.
Male and Female miss rates at non-zero threshold, FNIR(T)

**FNIR(Threshold)** is a metric appropriate to “identification” applications where (false) positives must be limited to available labor supply.

N = 1,600,000 subjects, 800,000 each sex. Enrolled with 1 image each. 

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**Dataset:** Mugshots MF/White 20−40/T<5yrs

Tier-1, N=1,600,000
Gap “A” = rightward shift of male mate distribution vs. female.
- Gap exists for most recognition algorithms
- Male faces are generally more similar to themselves
  - A systematic effect, not confined to left tail.

- This is consistent with, but may not actually be caused by:
  - Better photo quality in males
  - More consistent presentation to camera, e.g. adoption of frontal pose
  - More consistent condition of face, e.g. fewer changes in cosmetics or eyewear
  - More “information-rich” faces, e.g. presence of consistent features.

- The hypotheses can be inverted e.g. “females’ photos have worse quality”

Gallery contains N = 1,600,000 white subjects enrolled with a single image, 800,000 each of men and women. Age, at enrollment is 21-40. The probe images are collected later, in a different calendar year, and within five years.
Gap “B” = rightward displacement of female non-mate distribution relative to male. 

- This gap occurs for most recognition algorithms
- The shift indicates that when a female face is searched against a gallery of different people, balanced 50-50 male and female, it tends to yield higher scores.
- Displacement of the entire distribution shows a systematic effect, not confined to the right tail of the distribution.

- This is consistent with, but may not actually be caused by:
  - Nature: Female faces are naturally more similar to each other
  - Photographic effects: Females’ photos include some artifacts that algorithms match but should not e.g. hairstyles.

- If errors are all that matters, are the score distribution displacements important? They reveal anatomic or photographic interactions with the algorithms.

- This experiment uses only images of whites; different effects might occur in other races

Gallery contains N = 1,600,000 white subjects enrolled with a single image, 800,000 each of men and women. Age, at enrollment is 21-40. The probe images are collected later, in a different calendar year, and within five years.
1:N Face  Black-White Differential Impact
Black-white Demographic Difference Experiment

GALLERY:
1. N = 1,600,000
2. MALE
3. MUGSHOTS
4. BALANCED
   1. 800,000 BLACK
   2. 800,000 WHITE
5. AGE 21-40 at FIRST ENROLLMENT

MATED PROBES:
1. 100,000 BLACK
2. 100,000 WHITE
3. COLLECTED IN DIFFERENT YEAR TO GALLERY MATE
4. COLLECTED WITHIN FIVE YEARS OF MATE
5. AGE 21-40

NON-MATED PROBES:
1. 100,000 BLACK
2. 100,000 WHITE
3. AGE 21-40
Black and White Miss Rates: FNIR(Rank)

FNIR(Rank) is a metric appropriate to investigational applications where human reviewers will adjudicate candidate lists.

N = 1,600,000 subjects, 800,000 each race. Enrolled with 1 image each.
Black White Miss Rates at Non-Zero Threshold, FNIR(T)

FNIR(Threshold) is a metric appropriate to “identification” applications where (false) positives must be limited to available labor supply.

N = 1,600,000 subjects, 800,000 each race.
Enrolled with 1 image each.
• Gap“A” = rightward displacement of black mate distribution relative to white.
  • This gap occurs for many recognition algorithms, including some of the more accurate algorithms
  • Black faces are generally more similar.
  • Displacement of distribution shows a systematic effect, not confined only to the left tail.

• This is consistent with, but may not actually be caused by:
  • Better photo quality
  • More consistent presentation to camera, e.g. adoption of frontal pose
  • More consistent condition of face, e.g. fewer changes in beard presence
  • More “information-rich” faces, e.g. presence of consistent features.

• The hypotheses can be inverted e.g. “white photos have worse quality”
• Gap “B” = rightward shift of black non-mate distribution vs white.
  • This gap occurs for most recognition algorithms
  • The shift indicates that when a black face is searched against a gallery of different people, balanced 50-50 black and white, it tends to yield higher scores.
• The displacement of the entire distribution shows a systematic effect, it is not confined only to the right tail of the distribution.
• This is consistent with, but may not actually be caused by:
  • Nature: Photos of black subjects’ faces are naturally more similar to each other
  • Photographic effects: Photos of black subjects’ faces include some artifacts that match each other e.g. specular reflections.
  • ...

• If errors are all that matters, are the score distribution displacements important? They reveal anatomic or photographic interactions with the algorithms.

• This experiment uses only images of men. Different effects may occur for women.

Gallery contains N = 1,600,000 males enrolled with a single image, 800,000 each of black and white. Age, at enrollment is 21-40. The probe images are collected later, in a different calendar year, and within five years of enrollment.
Next steps

• NIST has given some quantitative feedback to developers
  • 2018-05 and 2018-09
  • Ongoing and expanded tests

• NIST will publish an Interagency Report Q1 2019 on demographics effects in face recognition
  • Existing content for 1:1 algorithms in FRVT Ongoing Reports
  • https://www.nist.gov/programs-projects/face-recognition-vendor-test-frvt-ongoing

Thanks

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