Evaluation of Automated Identity Masking Method (AIM) in Naturalistic Driving Study (NDS)

Asal Baragchizadeh[1], Thomas P. Karnowski[2], David S. Bolme[2], Alice J. O'Toole[1]
[1]School of Behavioral and Brain Sciences, The University of Texas at Dallas, [2]Oak Ridge National Laboratory, USA

Background

Naturalistic Driving Study (NDS) → Transportation Research Board of US Academy of Sciences

- **goal of NDS**: determine role of driver performance & behavior in transportation safety
- **SHRP2 dataset:** 1.2 million! hours naturalistic video
  - cameras (at 16 Hz) in car
  - ~ 3100 driver-car volunteers
  - 2-yr of driving
- **advantage:** opportunities for computer vision, face & gesture recognition, video analytics, autonomous vehicle research, transportation studies
- **limitation:** videos include personally identifiable information of drivers (e.g., facial video)
- **biometrics application:** de-identification algorithms
  - Automated Identity Masking (AIM)
    - to **obscure identity** of drivers & **preserve actions**

de-identification methods:

1. **Personalized Supervised Bilinear Regression Method for Facial Action Transfer (FAT)[3]** by **Carnegie Mellon University** → **FAT mask**
2. **3x3 Prewitt Edge Filter[4]** → **edge-detection mask**

NOTE : face recognition ability in humans, in many cases, superior to machine recognition algorithms[5] → true test of de-identification performed by *human* evaluators

Research Goals & Questions

1. *How effective is de-identification algorithm?*
   - Facial Recognition Preservation experiment
2. *How effectively does algorithm preserve actions?*
   - Facial Behavior Preservation experiment

Data

Head Pose Validation Dataset by VTTI[6] – replicated for purpose of sharing dataset with researchers

1. **low resolution unmasked & masked videos:** 36 different identities; 360 short (5-6 sec pre-processed video clips); each contains one prominent action (e.g., checking rear-view mirror)
2. **high resolution [4320 x 3240] color photos:** 36 different identities; frontal & profile view

Acknowledgements & References:

PI: Alice J' O'Toole
Work was supported through collaboration with Oak Ridge National Laboratory & the Federal Highway Agency under the Exploratory Advanced Research Program (Contracting Officer's Representative: Lincoln Cobb)
Guidance from Thomas Karnowski & David Bolme

1. The University of Texas at Dallas, USA
2. Oak Ridge National Laboratory, Oak Ridge, TN, USA
3. De la Torre, F., Chu, W., Xiong, X., Vicente, F., Ding, X., & Chohn, J. (2015). Facial expression analysis (IntraFace). In *IEEE International Conference on Automatic Face & Gesture Recognition (FG). Ljubljana, Slovenia*.
4. J. M. Prewitt, "Object enhancement and extraction," Picture processing and Psychopictorics, vol. 10, no. 1, pp. 75–149, 1970.
5. P. J. Phillips and A. J. O'Toole, "Comparison of human and computer performance across face recognition experiments," Image and Vision Computing, vol. 32, no. 74-85, 2014.
6. Virginia Tech Transportation Institute

Contact:

Asal Baragchizadeh: asal.baragchizadeh@utdallas.edu

Facial Recognition Preservation

Goal: assess recognizability of drivers; compare "masked" & "unmasked" recognition

Learning phase:

n = 18; still images, presentation: 5s + 2s blank page
replay presentation: twice; random

High-resolution photo
profile (left) , frontal (right)

Test phase:

n = 36; unmasked & masked videos (counter-balanced)
Have you seen this driver before?
replay as many times as needed.

Definition of de-identification:

- chance performance for masked videos; *d'* = 0
- effective (but not perfect masking); *d'* unmasked > *d'* masked
- conservative response: higher C; C close to one

Analysis:

Signal Detection Theory:
measure *d'* & C

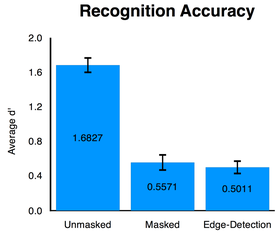
- **Accuracy:** *d'* = z(HR) – z(FA)
- **Response Bias:** C = 0.5 * [z(HR) + z(FA)]

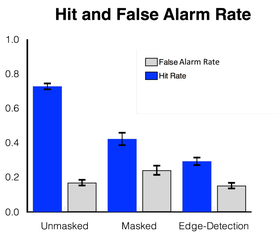
HR: proportion of correct "known"
FR: proportion of incorrect "known"

unmasked videos

FAT masked videos

edge-detection videos





- unmasked: good but not perfect
- unmasked > FAT & edge (p<.0001)
- FAT & edge (p=*n.s.)*
- *d'* FAT & edge > chance (p<.0001)

- HR: same pattern as *d'*
- HR: unmasked > FAT > edge (p<.01)
- FA: different pattern

- all positive: conservative responses
- C: edge > FAT > unmasked (p<.001)

Conclusions:

- neither mask eliminated recognition completely (*d'*)
- decrease in *d'* due to decreasing HR rather than increasing FA
  → fail to recognize known drivers, rather than incorrectly recognizing unknown drivers
- criterion changed; most conservative in Edge-Detection
  →although de-identification was not perfect, identification was not confident

Facial Behavior Preservation

Goal: assess annotation accuracy for driver action; compare "masked" & "unmasked" driver action

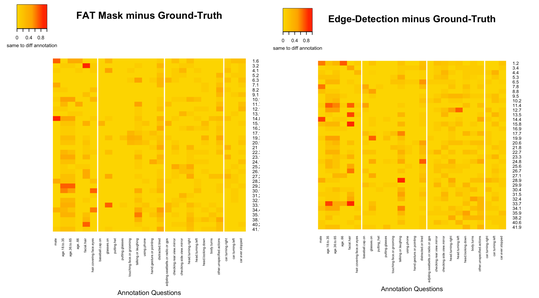
4 sub-studies:

1. *driver demographics* (e.g., male? 18–35 yr old?)
2. *driver accessories* (e.g., using cell-phone? putting on glasses?)
3. *driving-related annotations* (e.g., checking rear-view mirror? looking down?)
4. *car-related action annotations* (e.g., car turning right? car ever stopped?)

Ground-Truth Annotation (GTA): annotation in unmasked videos
Controlled Comparison Annotation (CCA): annotation in FAT & edge-detection mask videos

Analysis & Results:

Abs|(average response in GTA – average response in CCA)|, for each question (presence of an action =1, absence = 0)

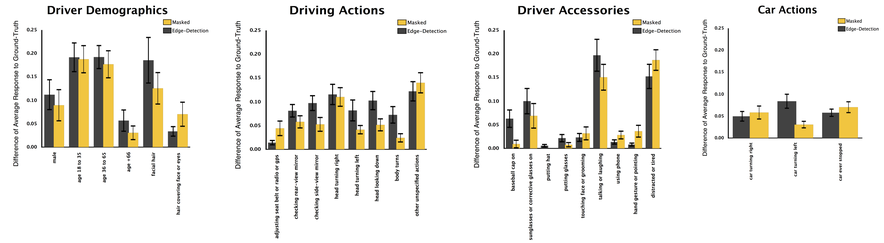


Conclusions:

- largest errors in **driver demographics** ✔
- **car actions** preserved best
- 85% actions failed perfect preservation ✖
- FAT mask preserved actions better

SUMMARY:

- Computer vision should take into account recognition confidence as a measure of identity-masking effectiveness.



- perfect preservation: FAT: age +66
- perfect preservation: NONE
- perfect preservation: *edge:* putting on hat *FAT:* baseball cap on, putting hat, putting glasses
- Perfect preservation: NONE