3D-Models for Pose and Neutrality Estimation

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European Association for Biometrics
Face Image Quality Workshop
08.11.2023

Motivation

- Ongoing development of quality measures for different quality elements
    - ISO/IEC CD 29794-5
    - Open source face image quality (OFIQ) framework

- Find mathematical relationship between quality element and its impact on the recognition outcome

$$F(I) = Q \in [0, 100]$$

- How can generative models support in approximating F?
    - Head pose → Syn-YawPitch [1]
    - Facial expression neutrality → NeutrEx [2]

[1] M. Grimmer et al., *Pose Impact Estimation on Face Recognition using 3D-Aware Synthetic Data with Application to Quality Assessment*, 2023.
[2] M. Grimmer et al., *NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality,* IJCB, 2023.

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Syn-YawPitch

- Find function F to estimate utility Q based on pose angles

$$F(\phi_{\text{yaw}}, \phi_{\text{pitch}}) = Q$$

- Use EG3D [1] to generate synthetic dataset (**Syn-YawPitch**) with ...
  - 144,000 face images
  - 1,000 IDs
  - Various yaw-pitch angle combinations

- Use Syn-YawPitch to ...
  1. Analyse pose-utility relationship
 2. Compute lasso regression model (**SYP-Lasso**) to approximate F
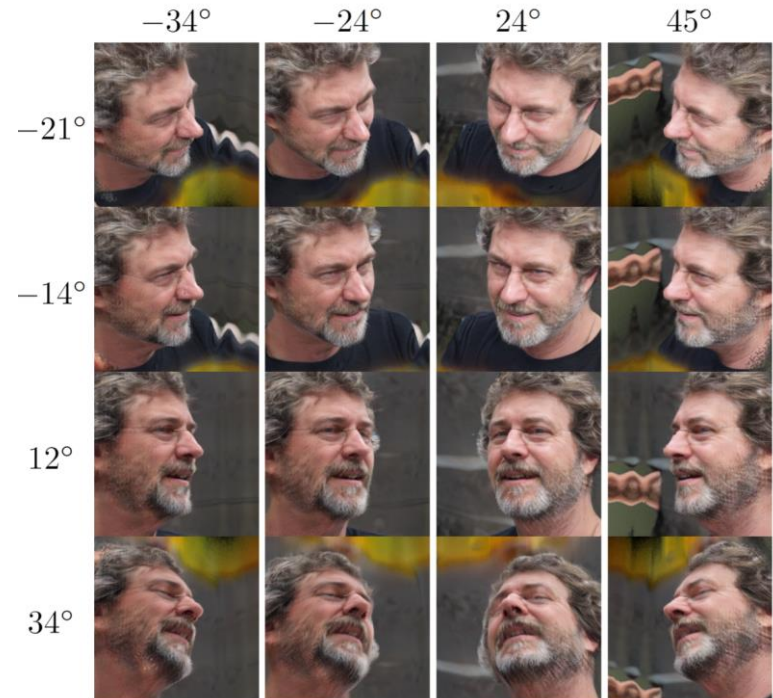
[1] ER. Chan et al., *Efficient geometry-aware 3D generative adversarial networks*, CVPR, 2022.

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Pose Impact Analysis
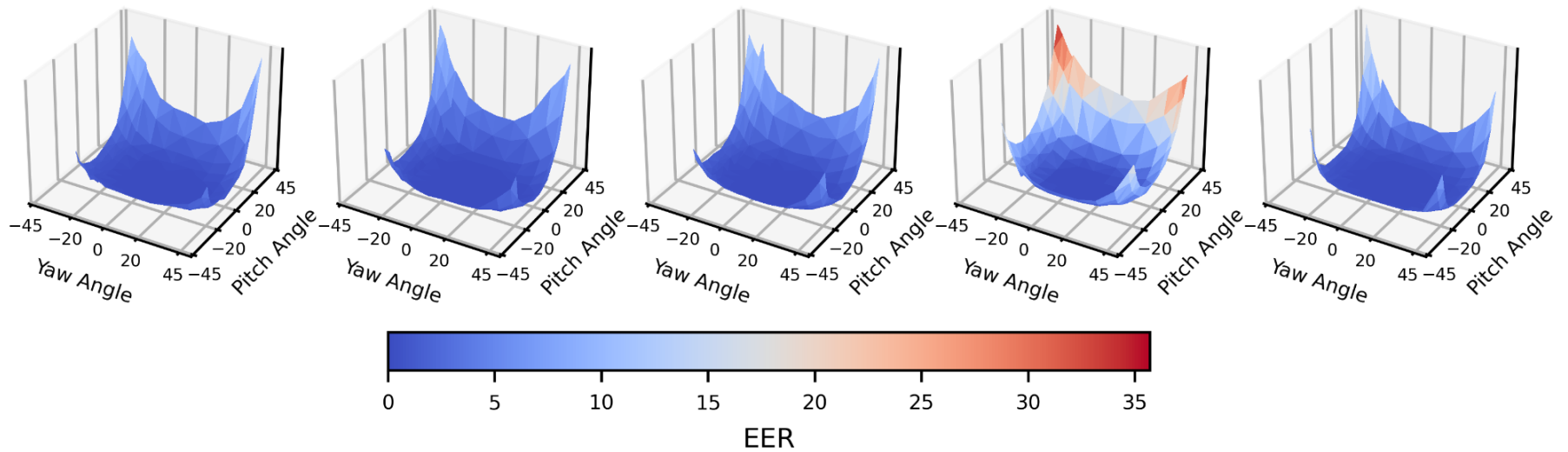
Utility Estimation
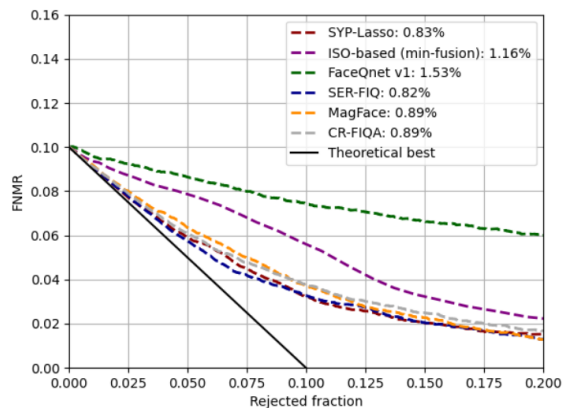
- Pose-based Quality Measures
    - SYP-Lasso
    - ISO/IEC CD 29794-5

- Unified Quality Measures
    - FaceQnet v1
    - SER-FIQ
    - MagFace
    - CR-FIQA

- Evaluated on **real** pose estimation dataset (BIWI [1])
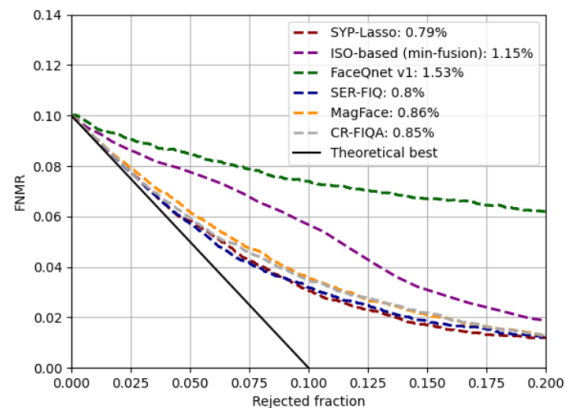   - 15k face images
    - Pose labels based on 3D sensor
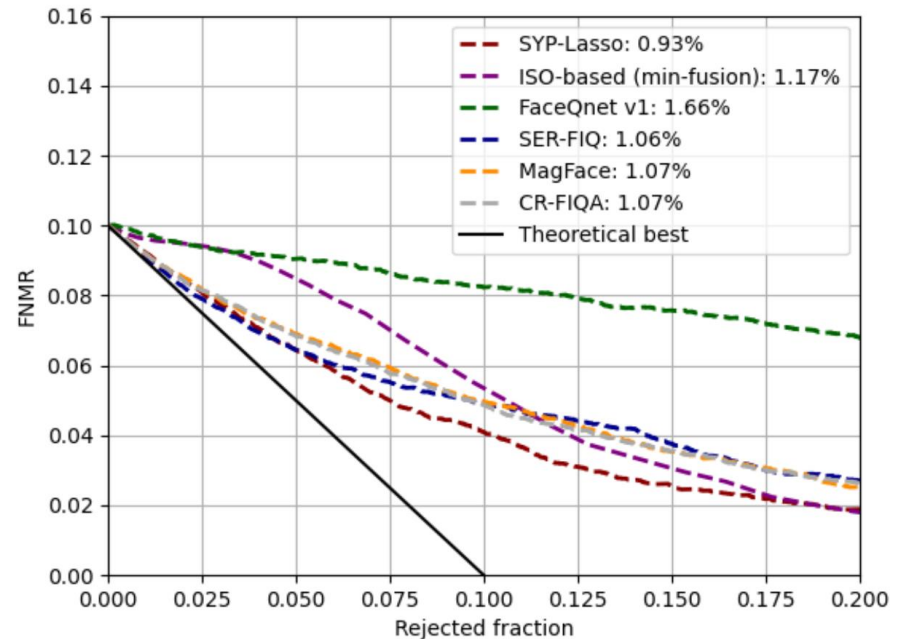
(e) Cognitec

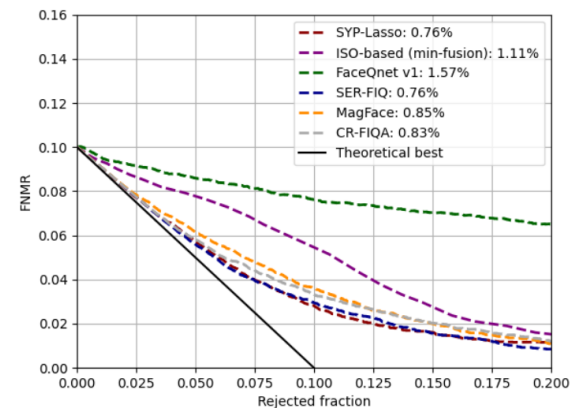[1] G. Fanelli et al., *Real Time Head Pose Estimation from Consumer Depth Cameras*, DGAM, 2011.
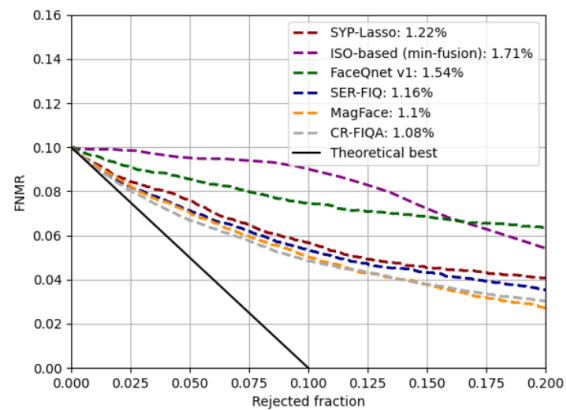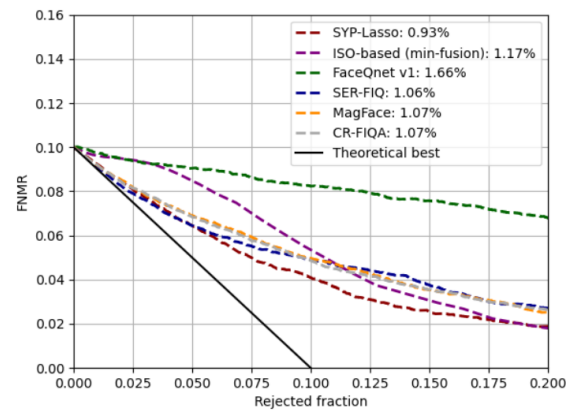
Utility Estimation

(a) ArcFace

(b) MagFace

(c) CurricularFace

(d) AdaFace

(e) Cognitec

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  - Head pose $\rightarrow$ Syn-YawPitch [1]
  - **Facial expression neutrality $\rightarrow$ NeutrEx [2]**

[1] M. Grimmer et al., *Pose Impact Estimation on Face Recognition using 3D-Aware Synthetic Data with Application to Quality Assessment*, 2023.
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NeutrEx Measure

- Find function F to estimate utility Q based on facial expression neutrality

$$F(V_{\text{Probe}}, V_{\text{Anchor}}) = Q$$

- NeutrEx operates within 3D Morphable Face Model: FLAME[1]
    - Each face represented by 5,023 vertices
    - Full vertex correspondance
    - Parametrization of facial attributes

- **Idea:** Calculate cumulative Euclidean distances between V_{Probe} and V_{Anchor} to approximate F

(a) Input   (b) 3D Mesh   (c) Residuals   (d) Anchor

(e) Input   (f) 3D Mesh   (g) Residuals   (h) Anchor
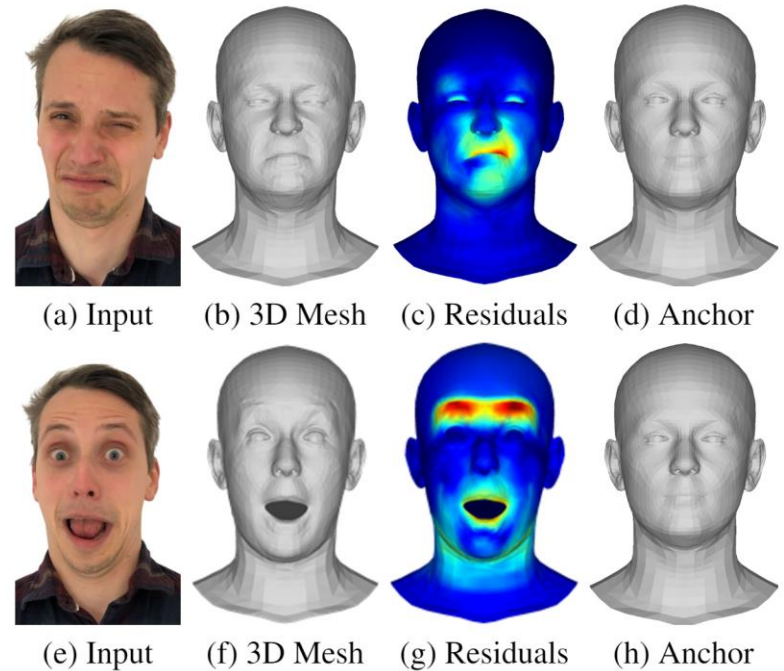
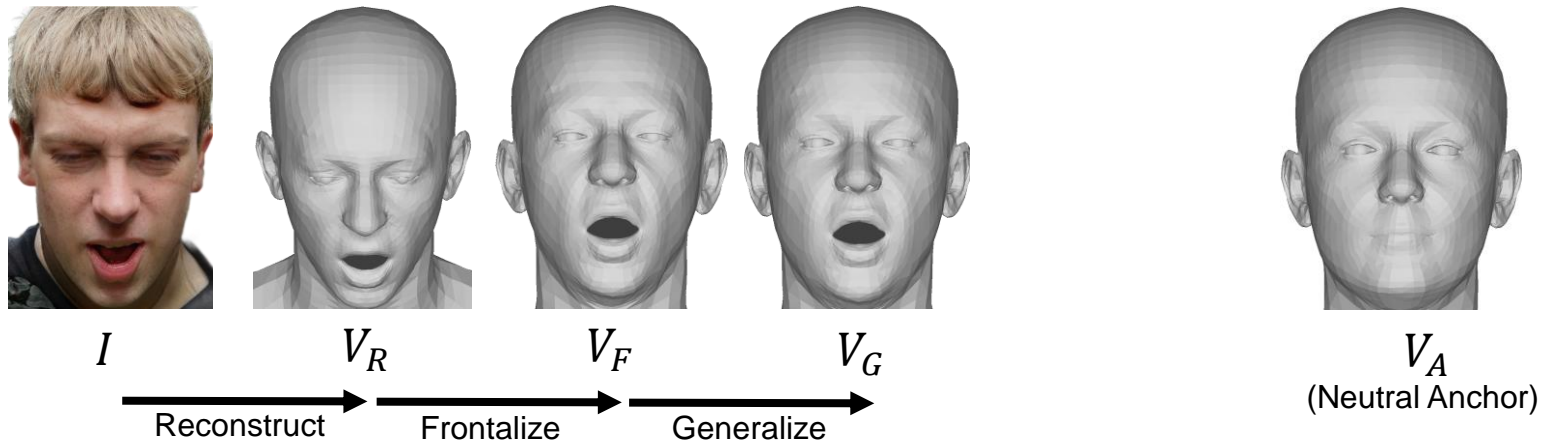[1] T. Li et al., *Learning a model of facial shape and expression from 4D scans,* ToG, 2017.

NeutrEx Measure

3D Face Normalization
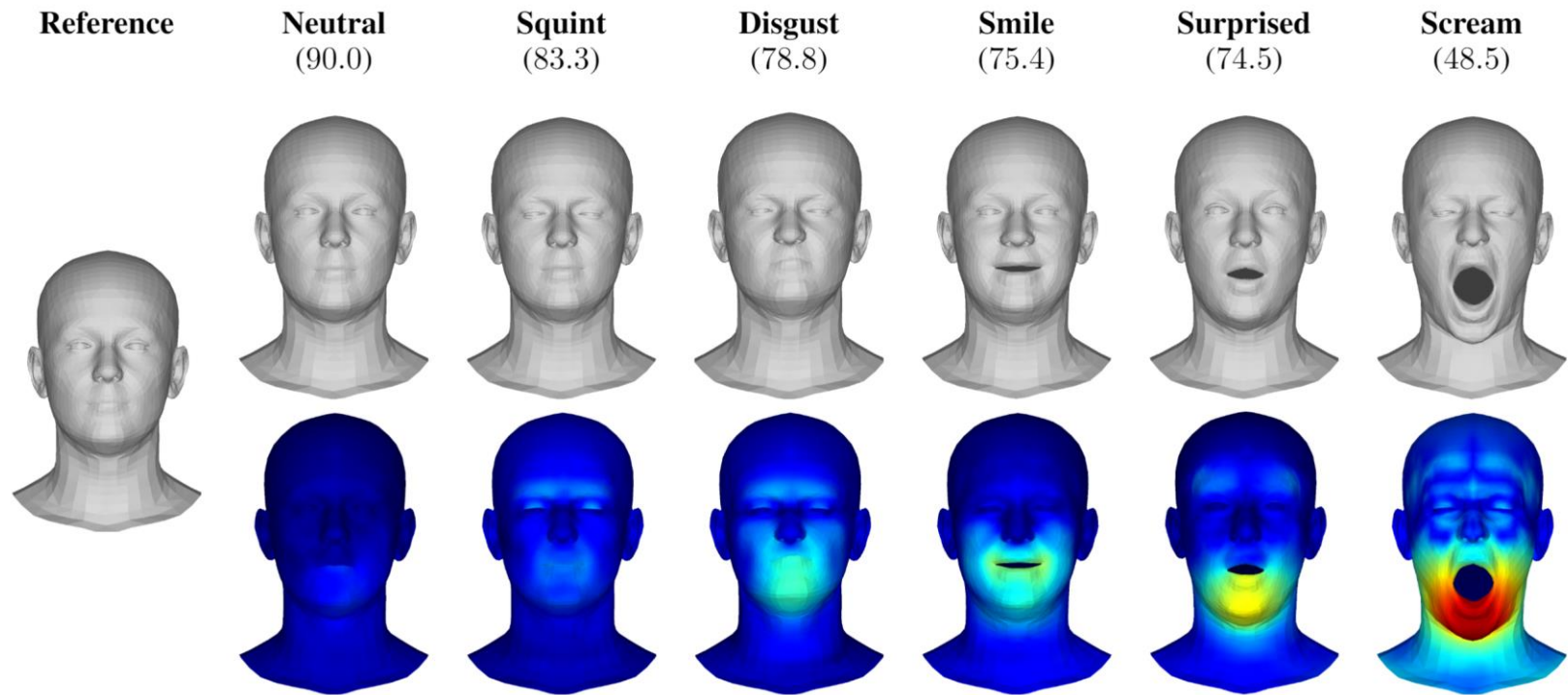
- Avoid identity-specific and pose-specific distortions
- Compute expression-specific distances only

Neutral Anchor

- $V_A = \frac{1}{|V_T|} \sum_{V \in V_T} V$
- Computed over training samples with neutral expression

$I \qquad\qquad V_R \qquad\qquad V_F \qquad\qquad V_G$

Reconstruct Frontalize Generalize

V_A
(Neutral Anchor)

3D Neutrality Residuals

| Reference | Neutral (90.0) | Squint (83.3) | Disgust (78.8) | Smile (75.4) | Surprised (74.5) | Scream (48.5) |

Utility Estimation

- Expression neutrality measures
  - NeutrEx
  - OFIQ candidate algorithms

- Evaluated on two datasets with expression variations
  - Multi-PIE [1] (~2,5k controlled face images)
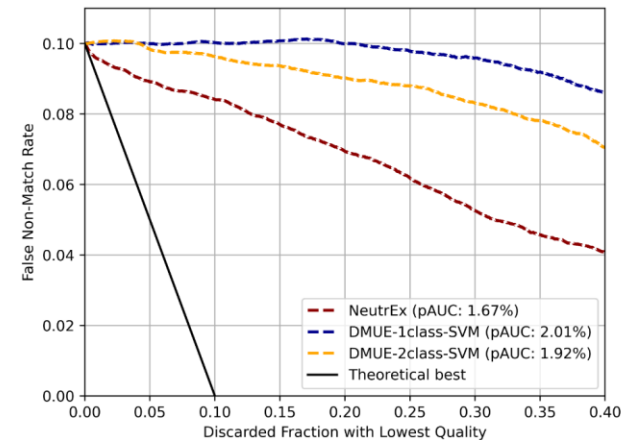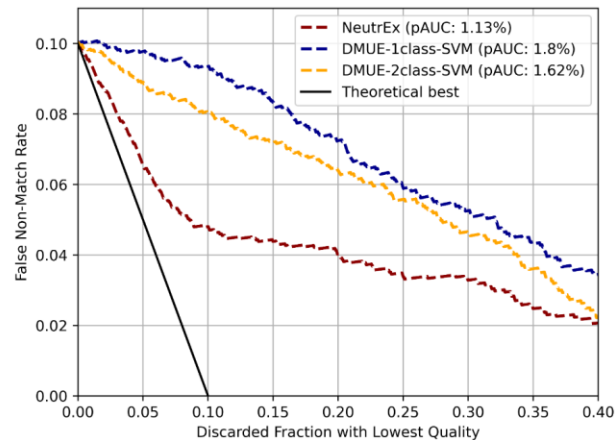 - FEAFA+ [2] (~41k semi-controlled face images)
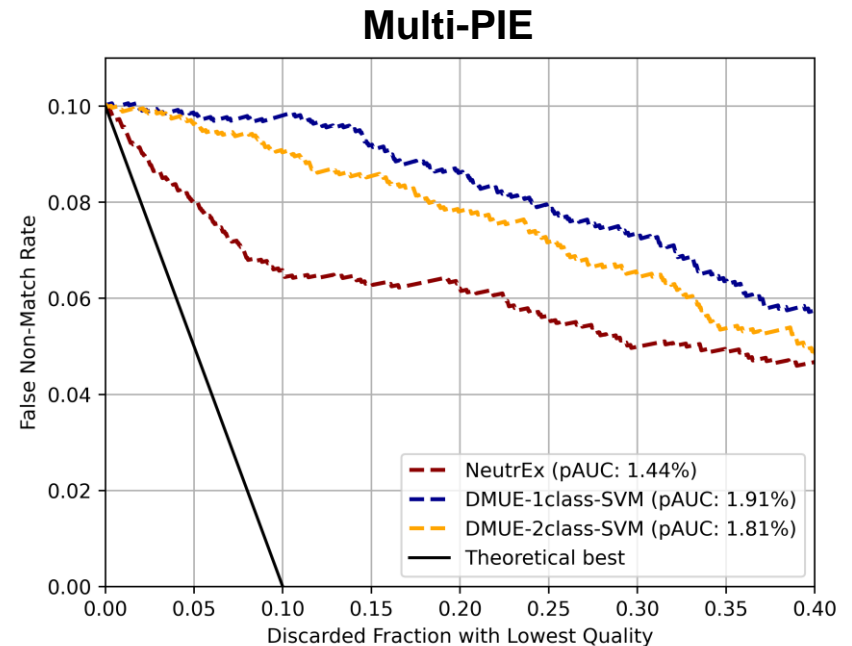
Multi-PIE
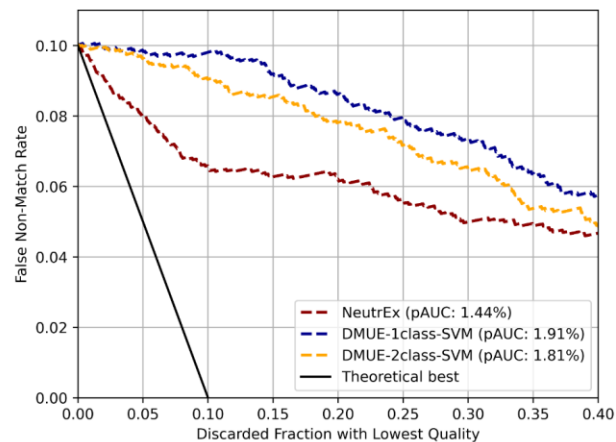

[1] R. Gross et al., *Multi-PIE*, FG, 2008.
[2] W. Gan et al., *FEAFA+: An Extended Well-Annotated Dataset for Facial Expression Analysis,* ICDIP, 2022.
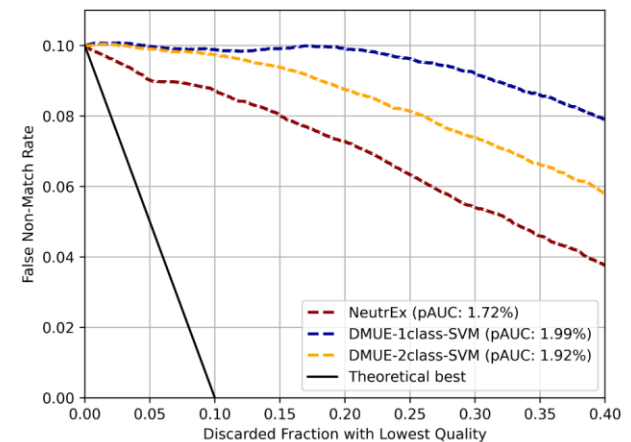
Utility Estimation

MagFace

FaceVACS 9.6.0
(Cognitec)

(a) Multi-PIE

(b) FEAFA+

Conclusion

- (Deep) generative models are effective in development of quality measures
  - Controllability
  - Identity preservation
  - Representativeness of synthetic data

- Future work
  - FLAME encoder involves ~50 mio. parameters → optimize network efficiency
  - Investigate potential of diffusion models

Syn-YawPitch

NeutrEx

Thank you!
Questions?

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