Javna agencija za znanstvenoraziskovalno
in inovacijsko dejavnost Republike Slovenije

DifFIQA: Face Image Quality Assessment Using Denoising Diffusion Probabilistic Models

Prof. Vitomir Štruc, PhD

Faculty of Electrical Engineering
University of Ljubljana, Slovenia

vitomir.struc@fe.uni-lj.si

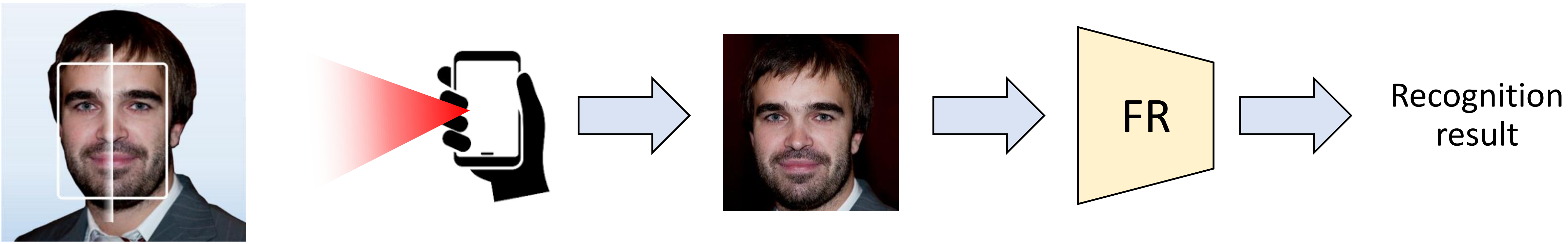
EAB Face Image Quality Workshop

Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)

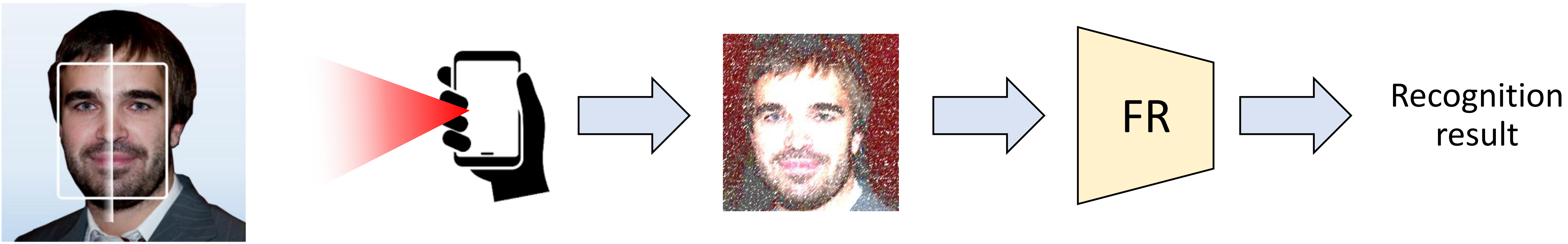
Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - Key use case in Face Recognition



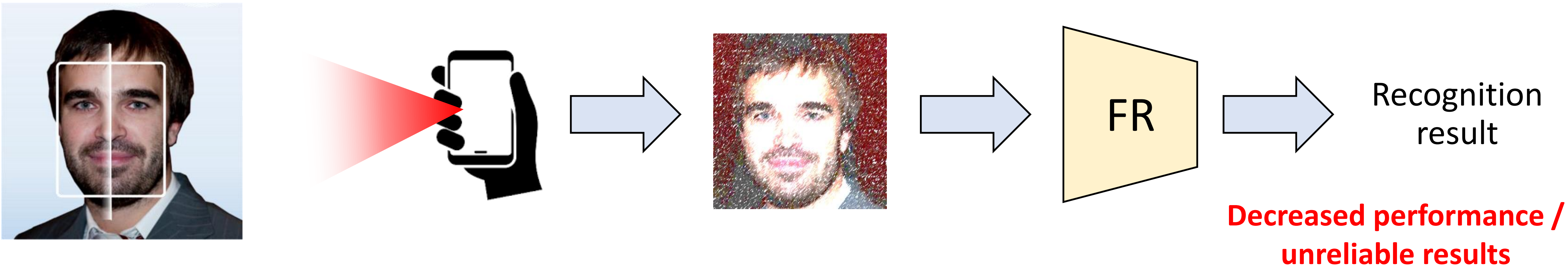
Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - Key use case in Face Recognition



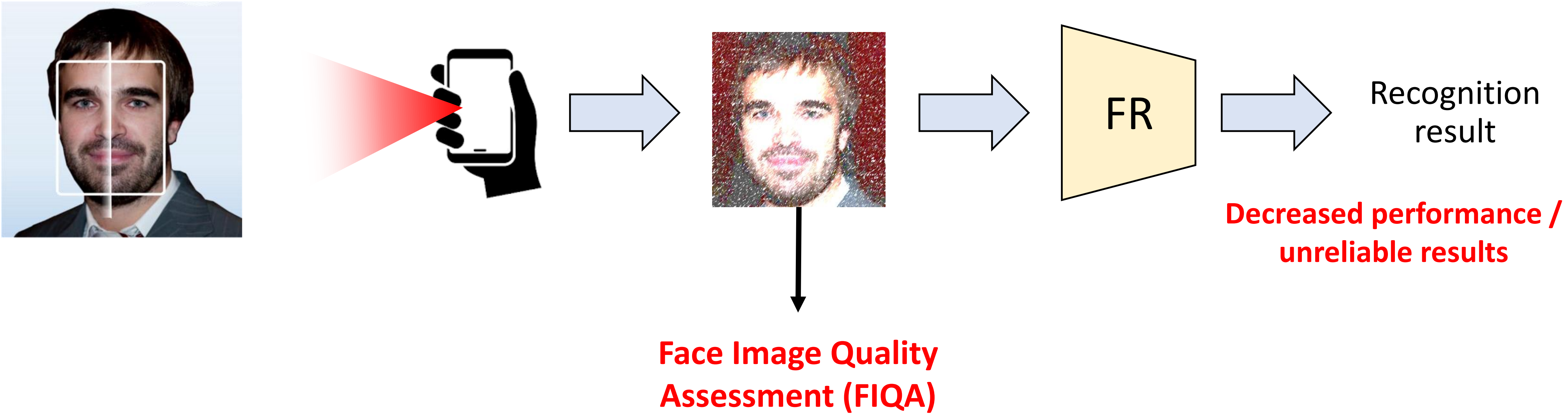
Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - Key use case in Face Recognition



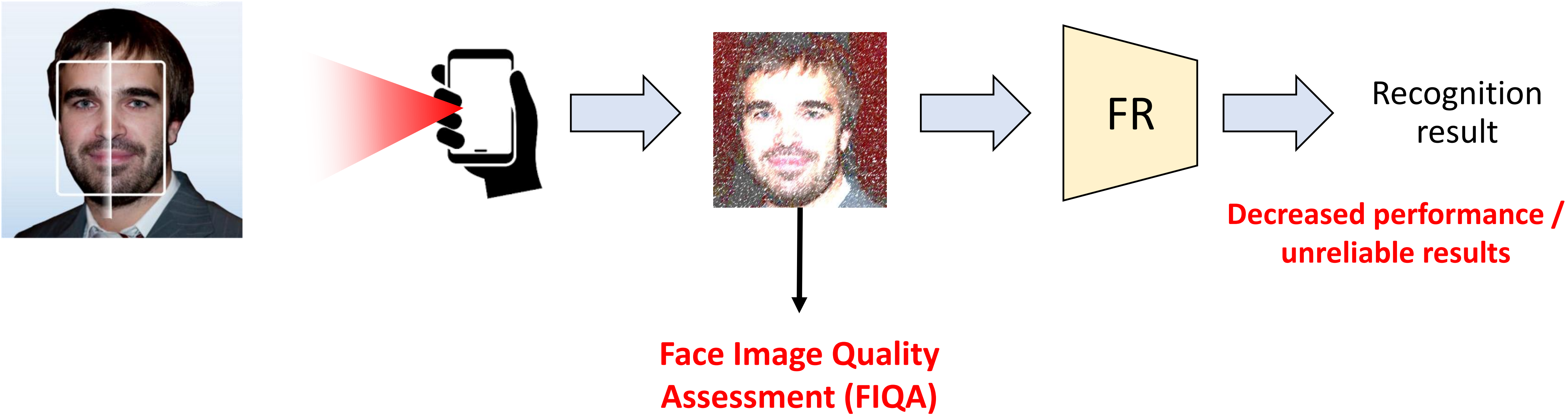
Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - Key use case in Face Recognition



Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - Key use case in Face Recognition



  - Reject sample, use quality for recognition, etc.

Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - ISO/IEC 29794-1 differentiates between three quality aspects:

Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - ISO/IEC 29794-1 differentiates between three quality aspects:
    - **Character** – attributes inherent to the biometric cahracteristic (faces) being acquired (e.g., skin texture, scars, etc.)

Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - ISO/IEC 29794-1 differentiates between three quality aspects:
    - **Character** – attributes inherent to the biometric cahracteristic (faces) being acquired (e.g., skin texture, scars, etc.)
    - **Fidelity** – reflects the degree of similarity with the source face, e.g., blurred or noisy faces have low fidelity

Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - ISO/IEC 29794-1 differentiates between three quality aspects:
    - **Character** – attributes inherent to the biometric cahracteristic (faces) being acquired (e.g., skin texture, scars, etc.)
    - **Fidelity** – reflects the degree of similarity with the source face, e.g., blurred or noisy faces have low fidelity
    - **Utility** – the fitness of a sample for face recognition, e.g., confidence in the recognition result

Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - ISO/IEC 29794-1 differentiates between three quality aspects:
    - **Character** – attributes inherent to the biometric cahracteristic (faces) being acquired (e.g., skin texture, scars, etc.)
    - **Fidelity** – reflects the degree of similarity with the source face, e.g., blurred or noisy faces have low fidelity
    - **Utility** – the fitness of a sample for face recognition, e.g., confidence in the recognition result

Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - ISO/IEC 29794-1 differentiates between three quality aspects [1]:
    - **Character** – attributes inherent to the biometric characteristic (faces) being acquired (e.g., skin texture, scars, etc.)
    - **Fidelity** – reflects the degree of similarity with the source face, e.g., blurred or noisy faces have low fidelity
    - **Utility** – the fitness of a sample for face recognition, e.g., confidence in the recognition result

High perceptual quality

High face image quality

Face Image Quality Assessment

- Face Image Quality Assessment (FIQA)
  - ISO/IEC 29794-1 differentiates between three quality aspects [1]:
    - **Character** – attributes inherent to the biometric characteristic (faces) being acquired (e.g., skin texture, scars, etc.)
    - **Fidelity** – reflects the degree of similarity with the source face, e.g., blurred or noisy faces have low fidelity
    - **Utility** – the fitness of a sample for face recognition, e.g., confidence in the recognition result

High perceptual quality

High face image quality

High perceptual quality

Low face image quality

Face Image Quality Assessment

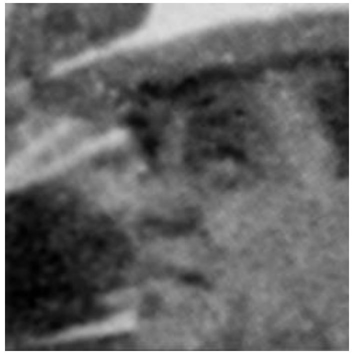
- Face Image Quality Assessment (FIQA)
  - ISO/IEC 29794-1 differentiates between three quality aspects [1]:
    - **Character** – attributes inherent to the biometric characteristic (faces) being acquired (e.g., skin texture, scars, etc.)
    - **Fidelity** – reflects the degree of similarity with the source face, e.g., blurred or noisy faces have low fidelity
    - **Utility** – the fitness of a sample for face recognition, e.g., confidence in the recognition result

High perceptual quality

High face image quality

High perceptual quality

Low face image quality

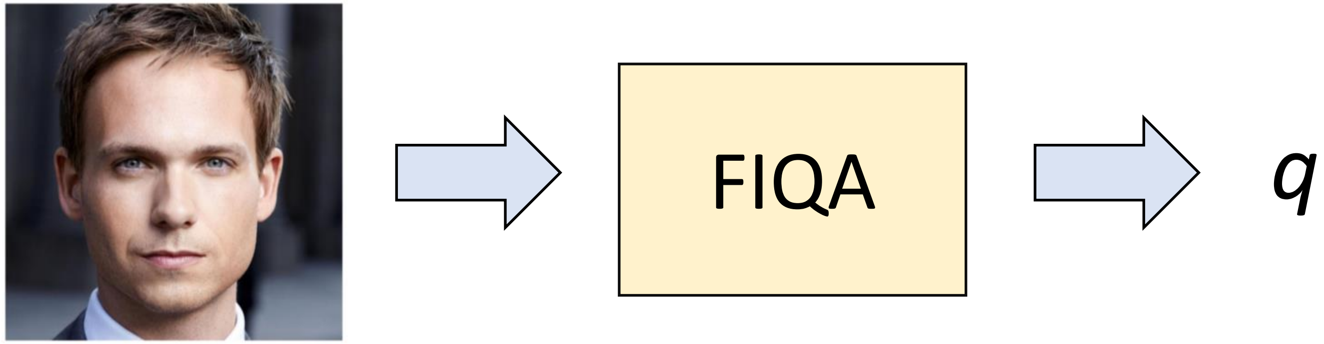


Low perceptual quality

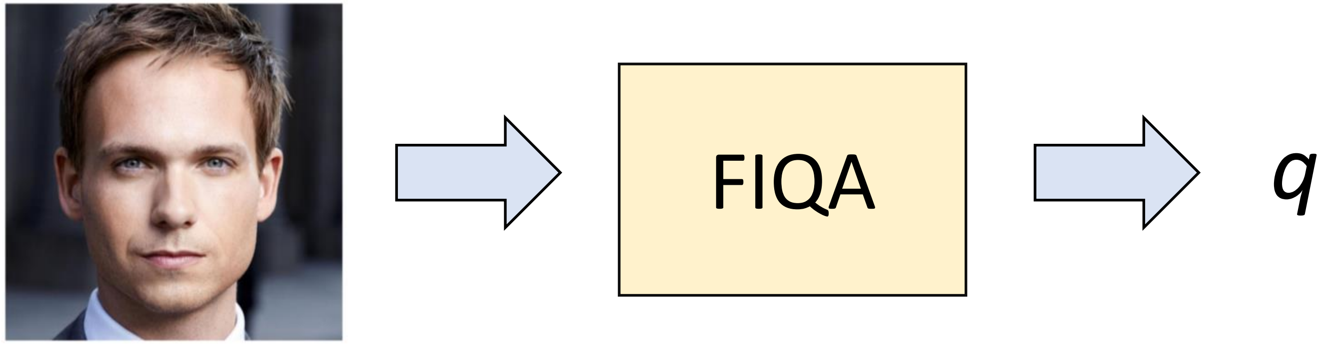
Low face image quality

Face Image Quality Assessment

Face Image Quality Assessment



Face Image Quality Assessment



q_1 > q_2

Higher scores mean better quality

Face Image Quality Assessment

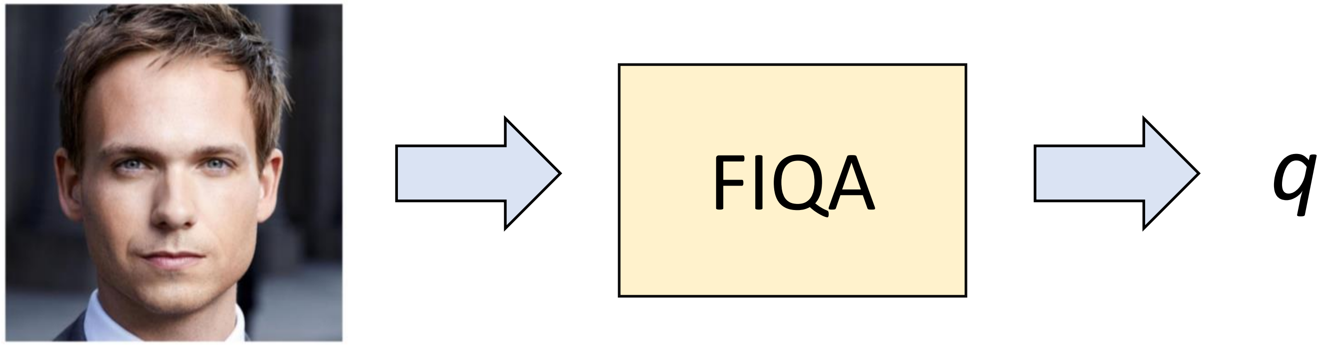
FIQA → q

$q_1 > q_2$

Higher scores mean better quality

Existing solutions:

Face Image Quality Assessment



Higher scores mean better quality

Existing solutions:

Analytical:
Compute scores directly from the input sample.

Regression based:
Train regression model on extracted pseudo-quality labels.

Model based:
Combine recognition and quality estimation tasks.

DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

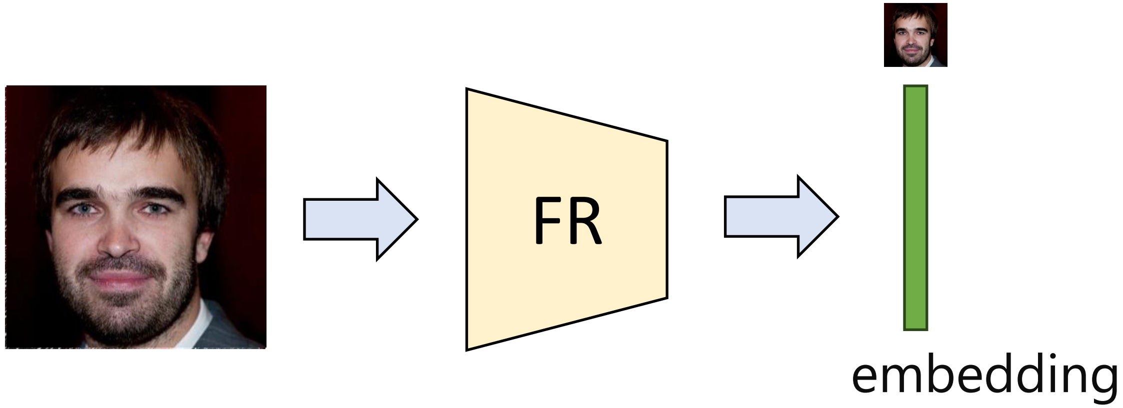
Perturbation robustness

Reconstruction quality

DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness **Reconstruction quality**

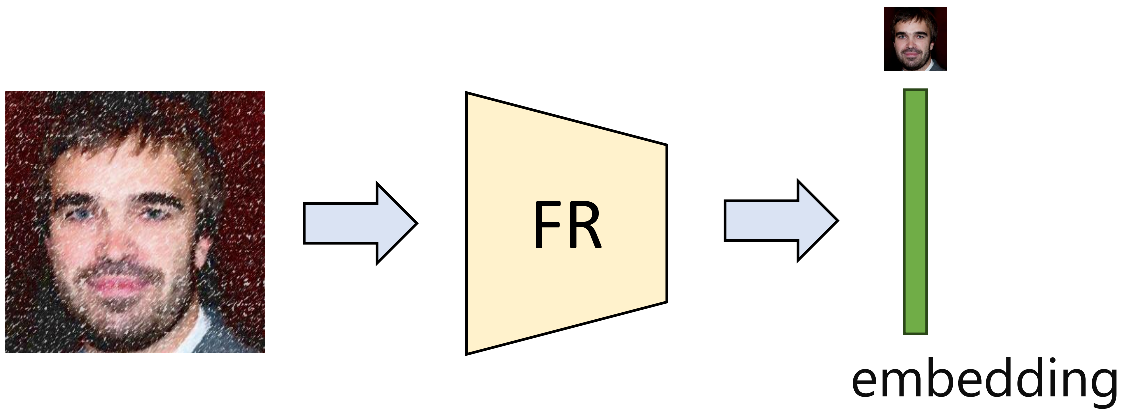


DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness

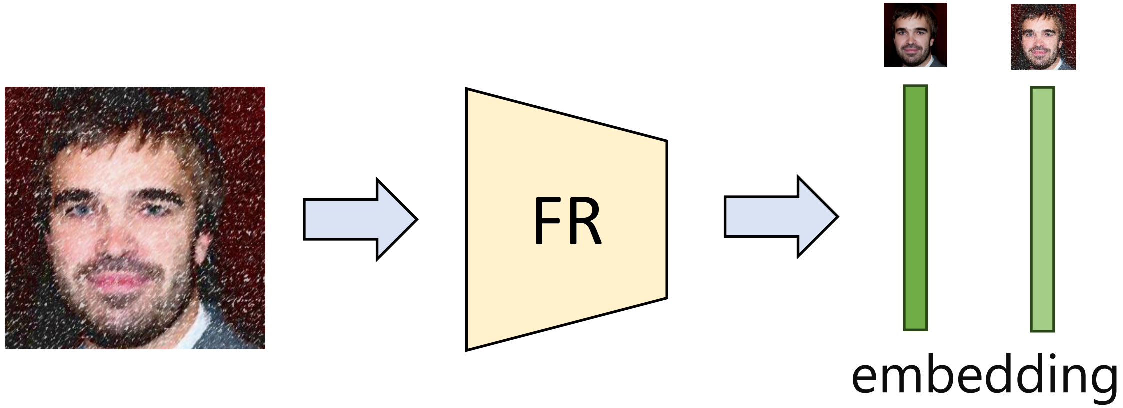
Reconstruction quality



DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness



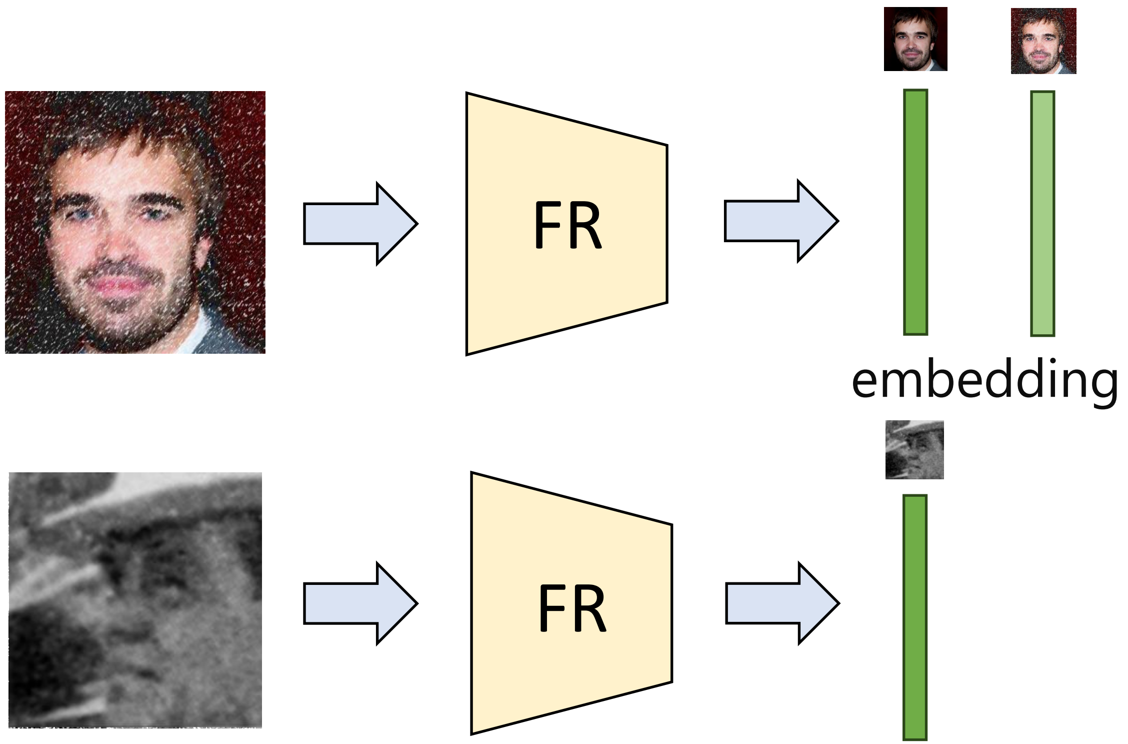
Reconstruction quality

DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness

Reconstruction quality

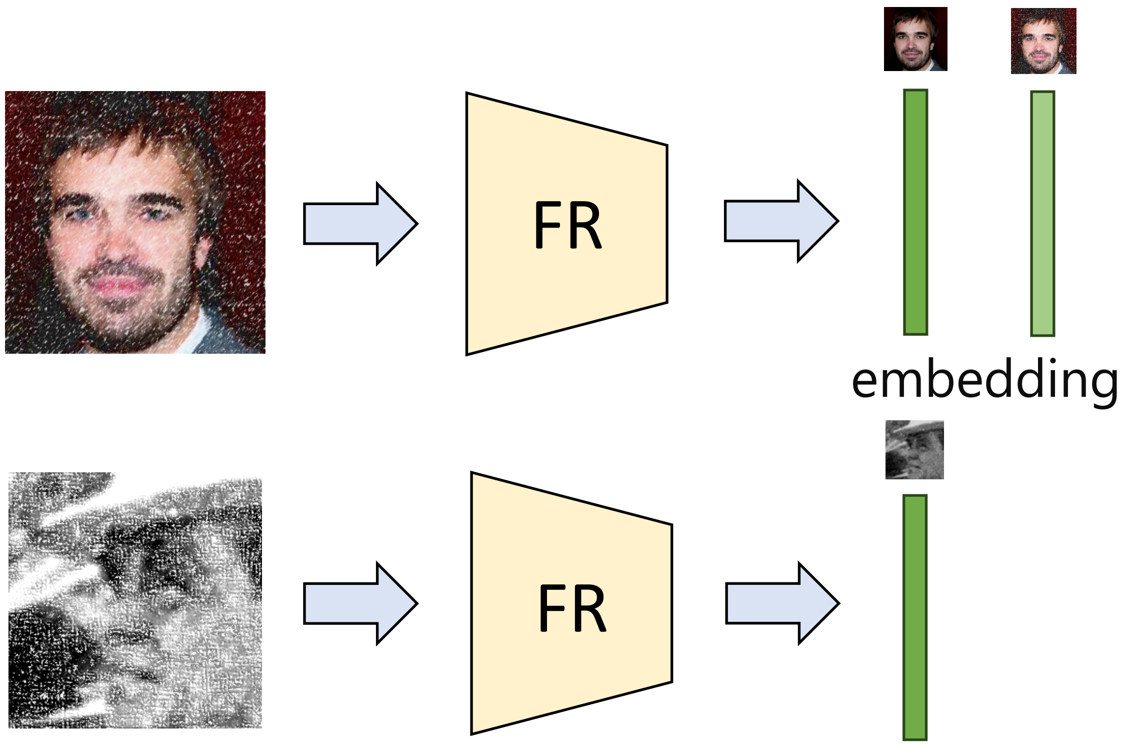


DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness

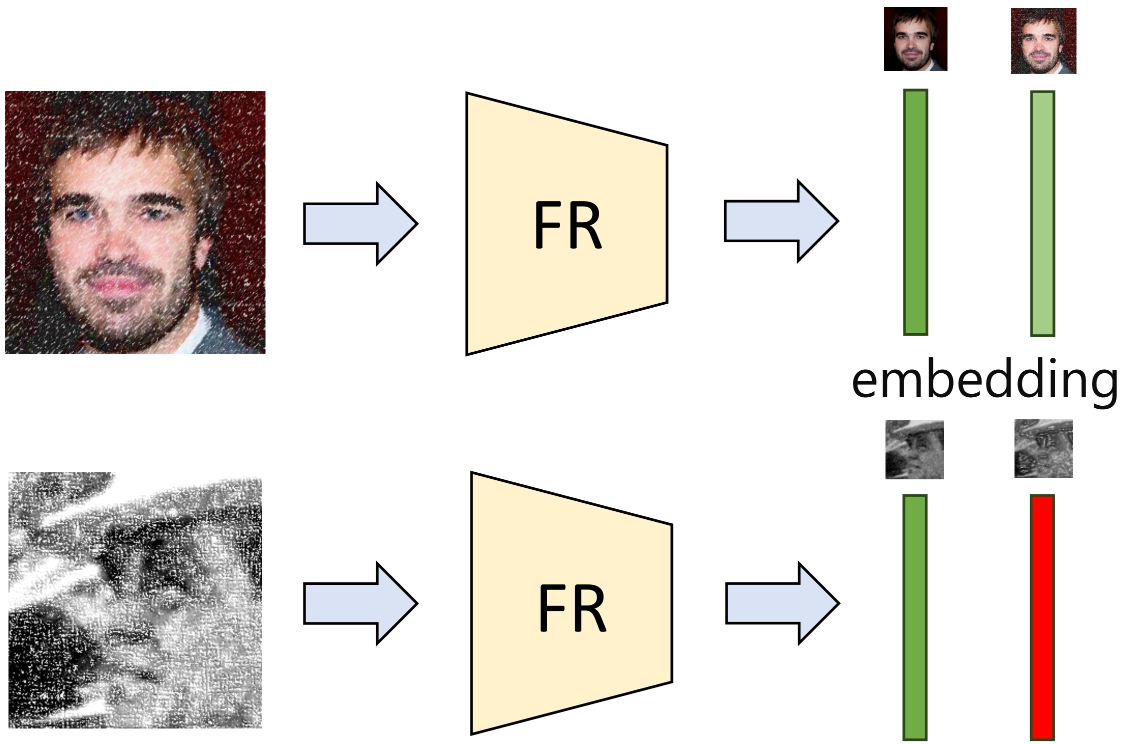
Reconstruction quality



DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness

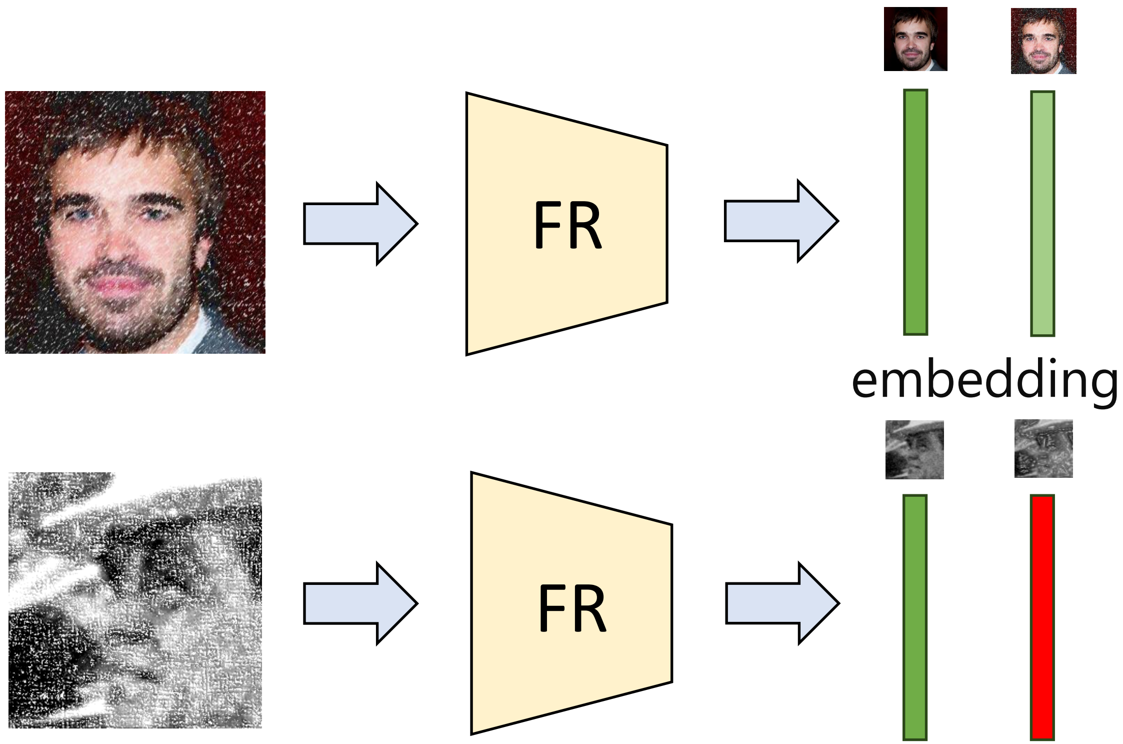


Reconstruction quality

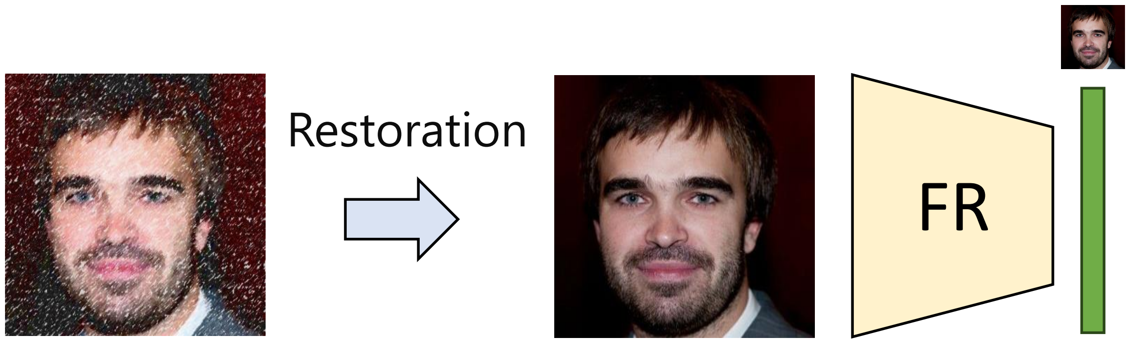
DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness



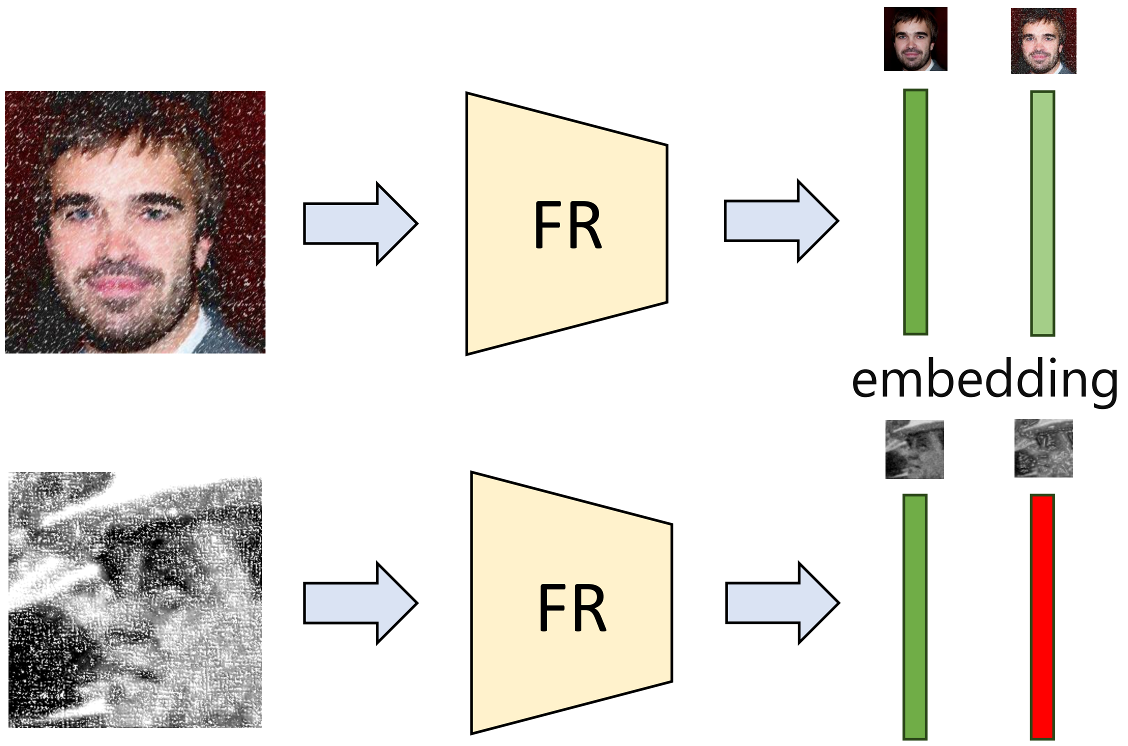
Reconstruction quality



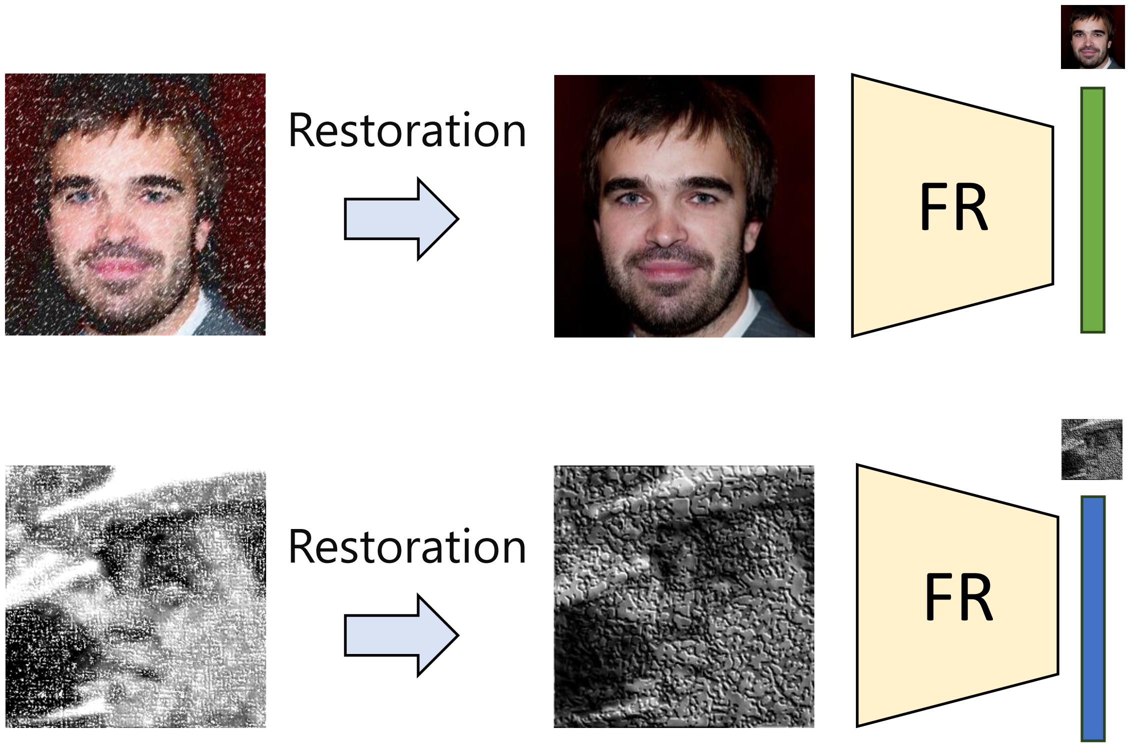
DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness



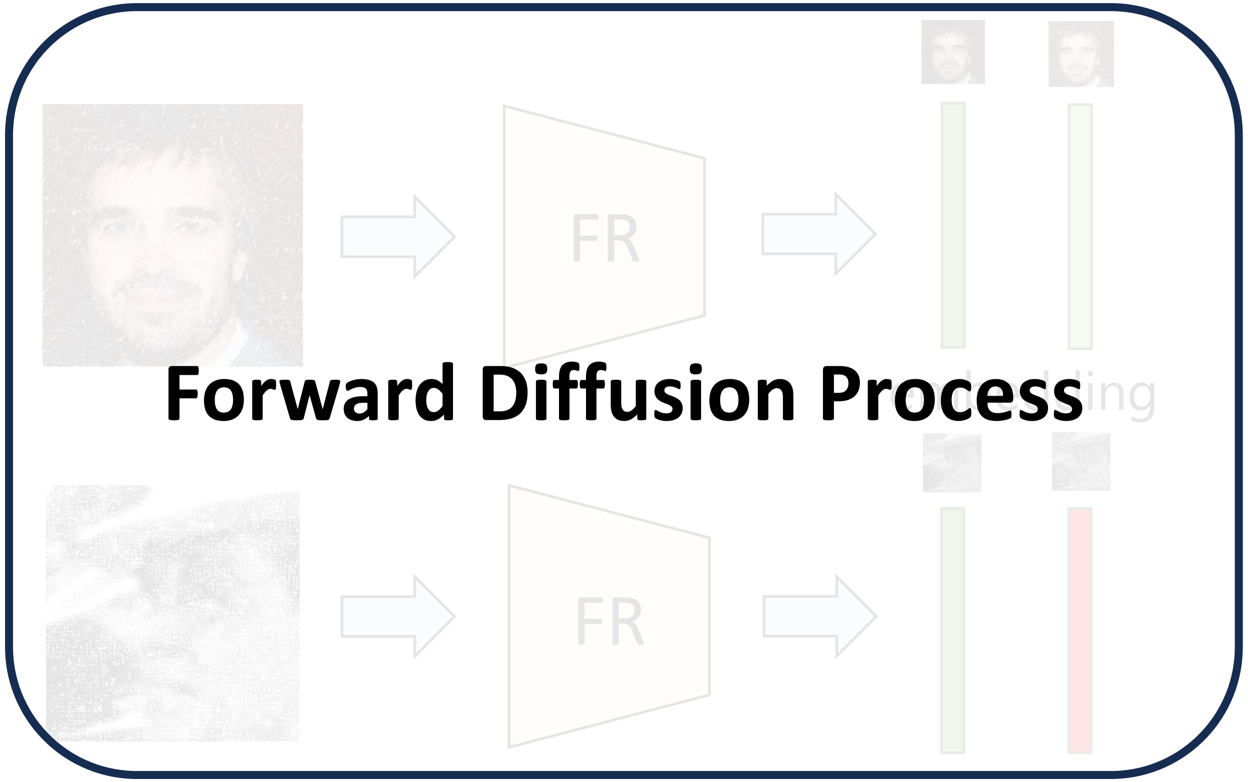
Reconstruction quality



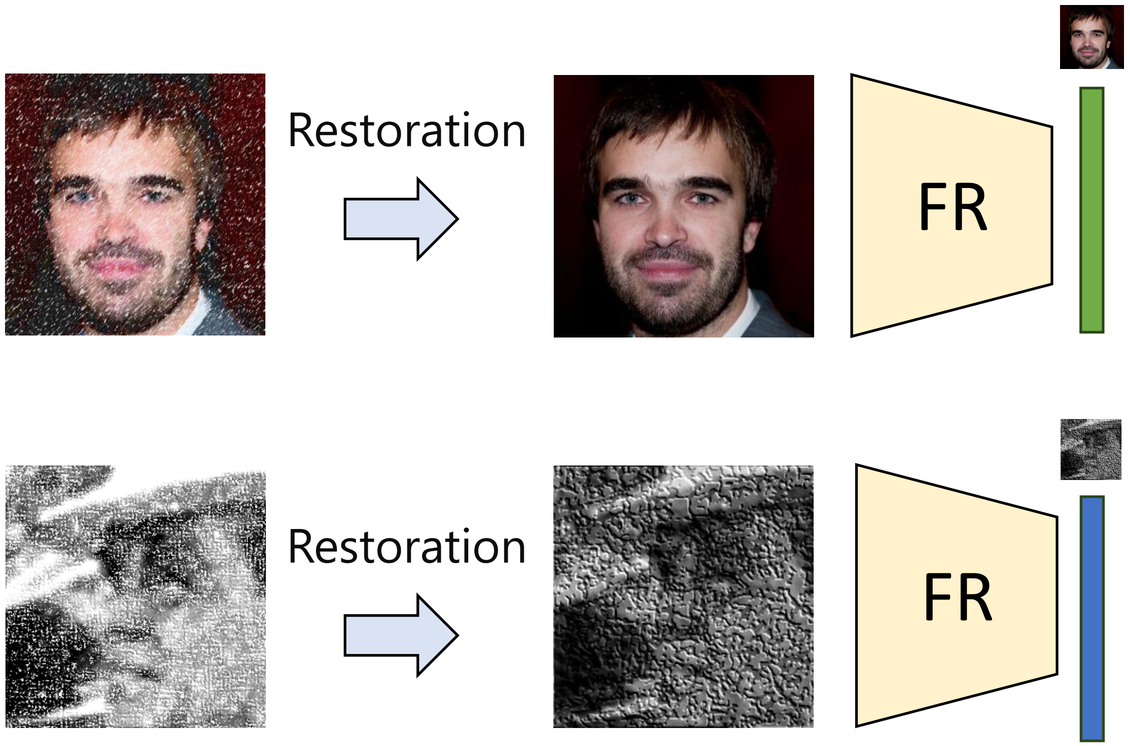
DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness



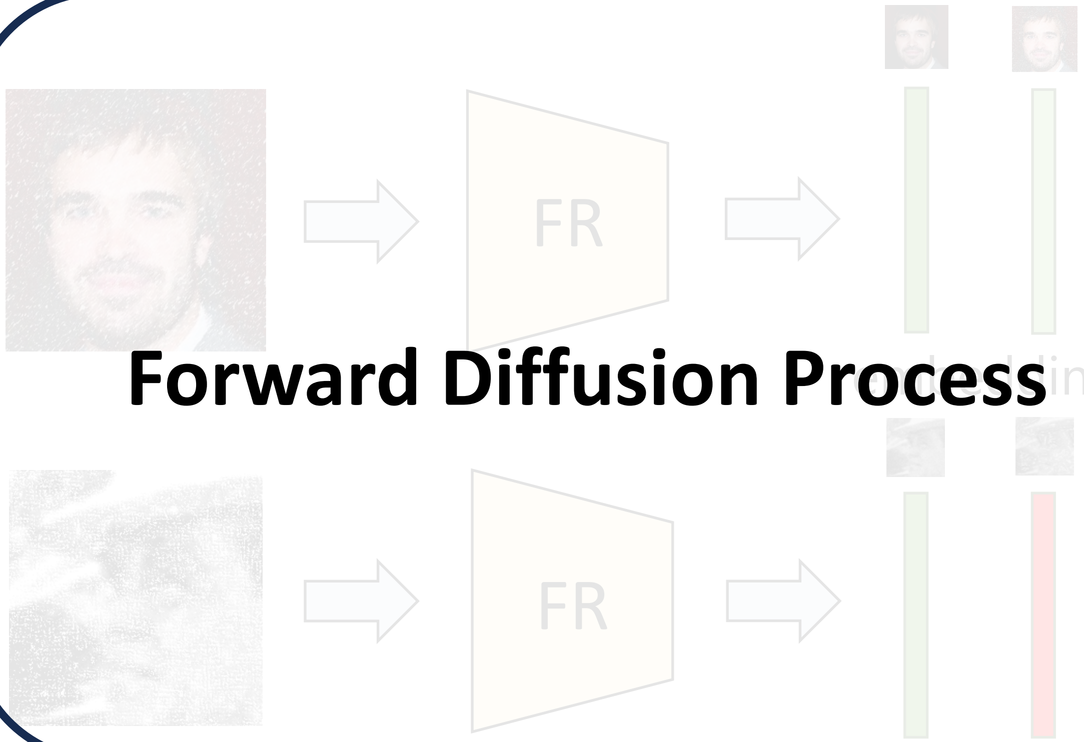
Reconstruction quality



DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Face Image Quality Assessment based on two concepts:

Perturbation robustness



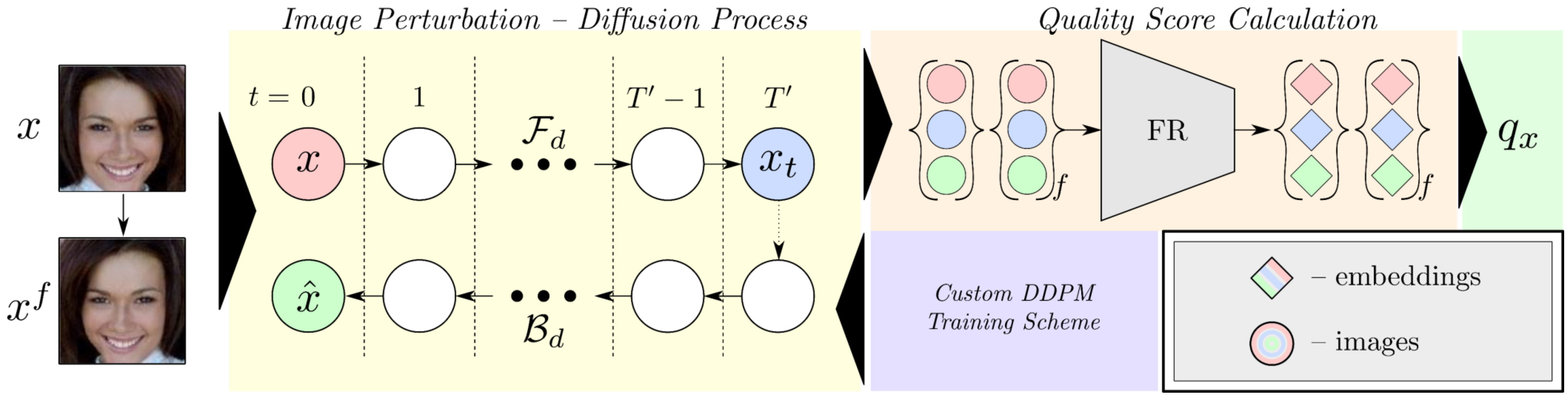
Forward Diffusion Process

Reconstruction quality

Backward Diffusion Process

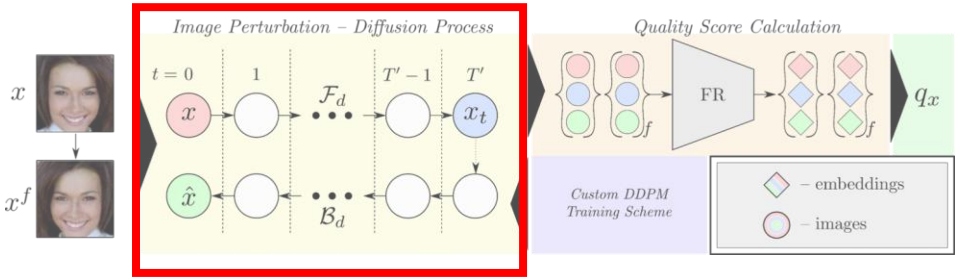
DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- DifFIQA (high-level) overview:
  - Step 1: Forward and backward diffusion (i.e., perturbations and reconstructions)
  - Step 2: Quality score calculation



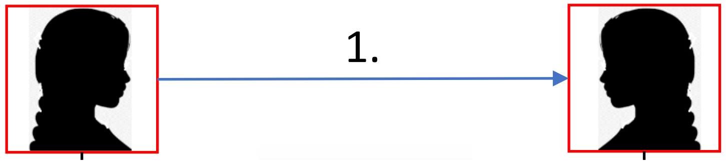
DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Step 1: Forward and backward diffusion

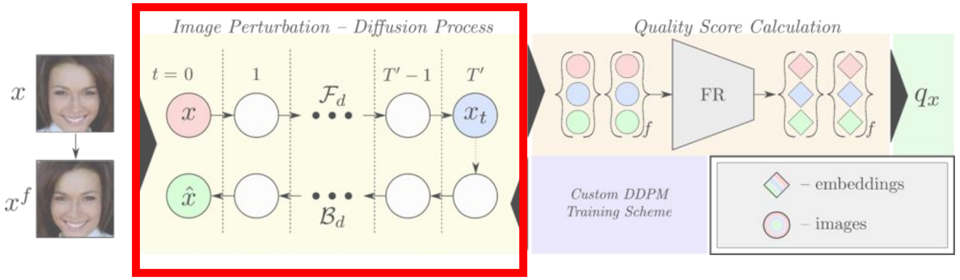


DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Step 1: Forward and backward diffusion

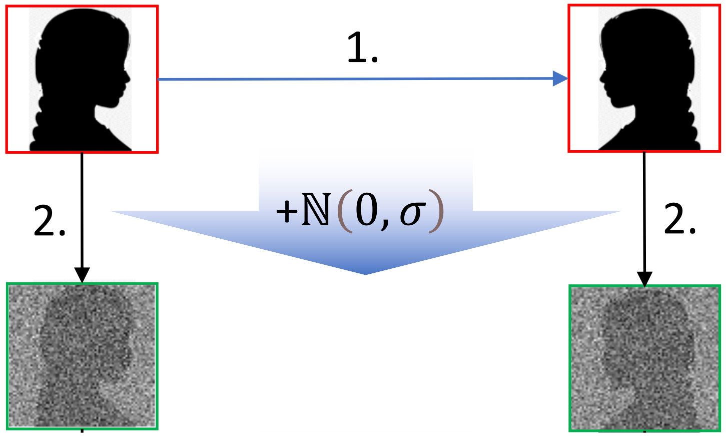


Flip image



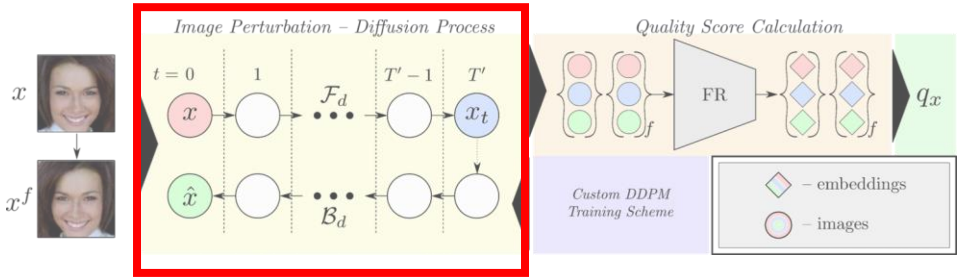
DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Step 1: Forward and backward diffusion



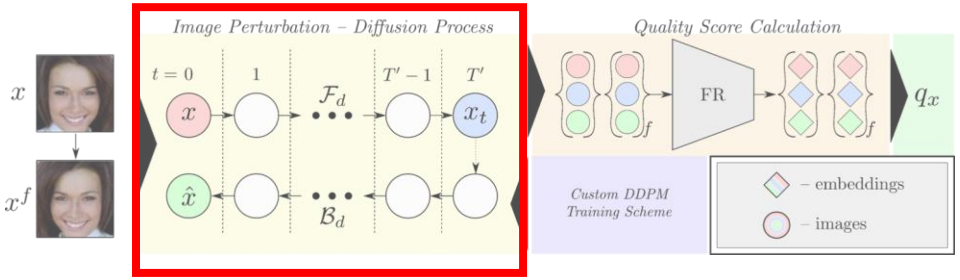
Flip image

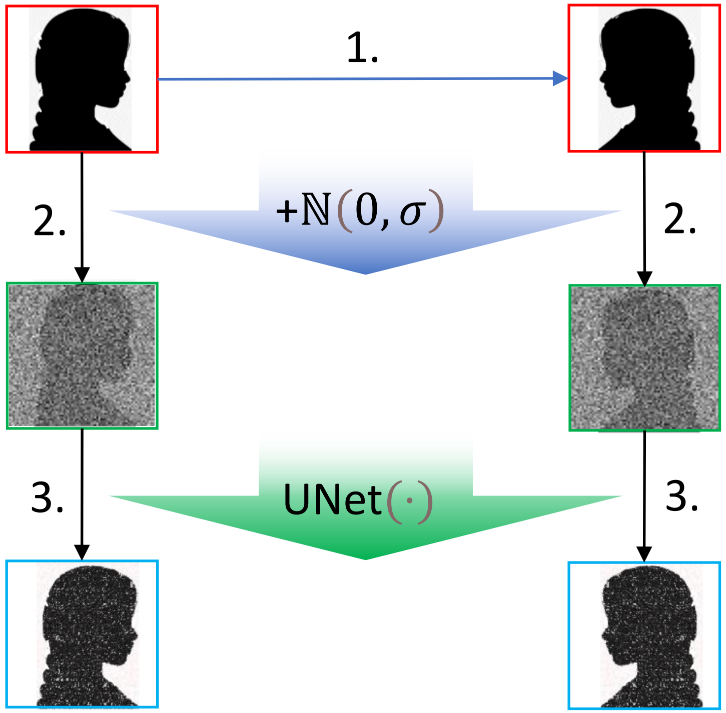
Forward diffusion – adds noise



DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Step 1: Forward and backward diffusion



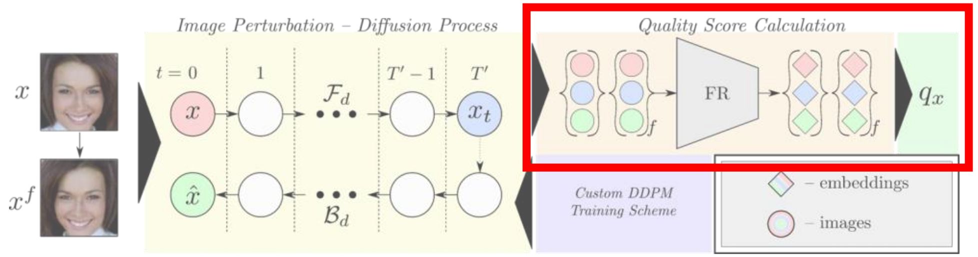


Flip image

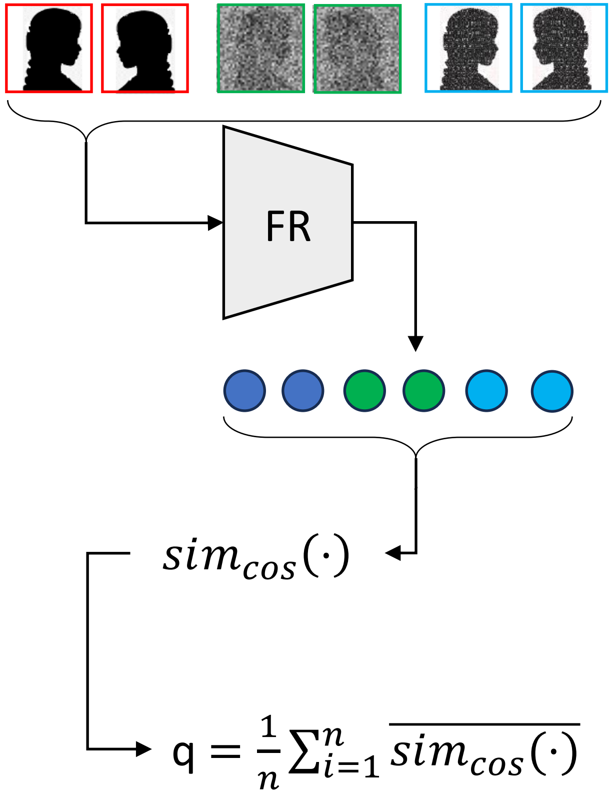
Forward diffusion – adds noise

Backwa

DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models



- Step 2: Quality score calculation



1. **Construct image embeddings:**
   - *using any target FR model,*
   - *for all three image pairs.*
2. **Calculate embedding similarity:**
   - *using cosine similarity,*
   - *comparing the input image embedding to all others.*
3. **Repeat process n-times and calculate average.**

DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

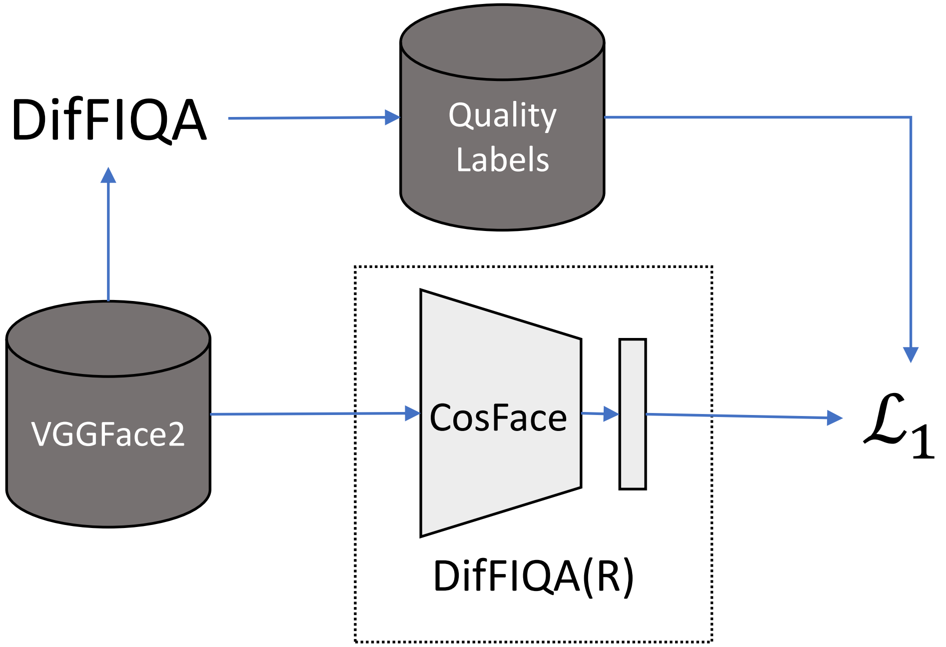
- Problem: Diffusion is slow!

DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

- Problem: Diffusion is slow!
- DifFIQA(R) - Knowledge distillation

DifFIQA: Quality Assessment Using Denoising Diffusion Probabilistic Models

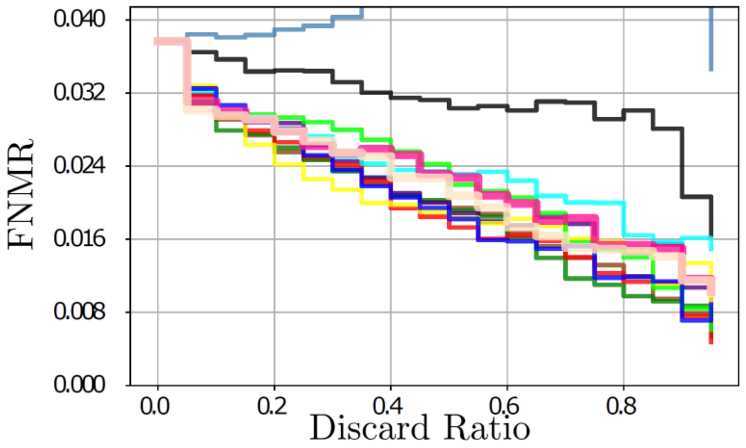
- Problem: Diffusion is slow!
- DifFIQA(R) - Knowledge distillation



Fine-tune a pretrained FR model using pseudo-quality labels extracted using DifFIQA.

Experimental Setup

- **Standard evaluation approach:**
  - **Error-Versus Discard Characteristic (EDC) curves**
    - *Show how the performance of FR models improves with increasing discard rates.*
  - **partial Area Under the Curve (pAUC)**
    - *Lower value indicates better performance.*
    - *Limit the discard ratio to (0.2) or (0.3).*
  - **Benchmarks:**
    - *Adience, CALFW, CFP-FP, CPLFW, IJB-C, LFW, XQLFW*
  - **FR models:**
    - *AdaFace, ArcFace, CurricularFace, CosFace*
  - **FIQA methods:**
    - *FaceQnet, SDD-FIQA, PFE, PCNet, MagFace, LightQNet, SER-FIQ, FaceQAN, CR-FIQA, FaceQgen*



Results (pAUC)

- **Average results over all benchmarks and FR models**

Results using discard ratio of (0.2).

FaceQnet [17]	SDD-FIQA [33]	PFE [39]	PCNet [44]	MagFace [31]	LightQNet [7]	SER-FIQ [40]	FaceQAN [3]	CR-FIQA [5]	FaceQgen [15]	DifFIQA	DifFIQA(R)
0.9458	0.8244	0.8197	0.8989	0.8253	0.8183	0.7985	**0.7519**	**0.7567**	0.8527	0.7591	**0.7518**

Results using discard ratio of (0.3).

FaceQnet [17]	SDD-FIQA [33]	PFE [39]	PCNet [44]	MagFace [31]	LightQNet [7]	SER-FIQ [40]	FaceQAN [3]	CR-FIQA [5]	FaceQgen [15]	DifFIQA	DifFIQA(R)
0.9315	0.7483	0.7497	0.8691	0.7635	0.7412	0.7292	0.6847	**0.6800**	0.7954	**0.6822**	**0.6768**

- Knowledge distilation improves the results of the base approach
- DifFIQA(R) outperforms SOTA methods.

Ablation Study

- **Showcase performance changes when:**
  - *(A1) Removing image flipping.*
  - *(A2) Include only perturbations from the backward diffusion pass.*
  - *(A3) Use a different number of timesteps for noise generation.*

Model variant	**LFW**	**CPLFW**	**CALFW**	**XQLFW**	$\overline{\text{pAUC}}$
(A1): w/o Image Flipping	0.702	0.727	0.888	0.535	0.713
(A2): w/o Forward Pass	0.730	0.684	0.897	0.531	0.710
(A3): DifFIQA ($t = 20$)	0.657	0.694	0.945	0.628	0.731
DifFIQA (complete)	0.695	0.669	0.900	0.546	**0.702**

<u>DifFIQA best overall performance on a varied set of benchmarks.</u>

Run-time

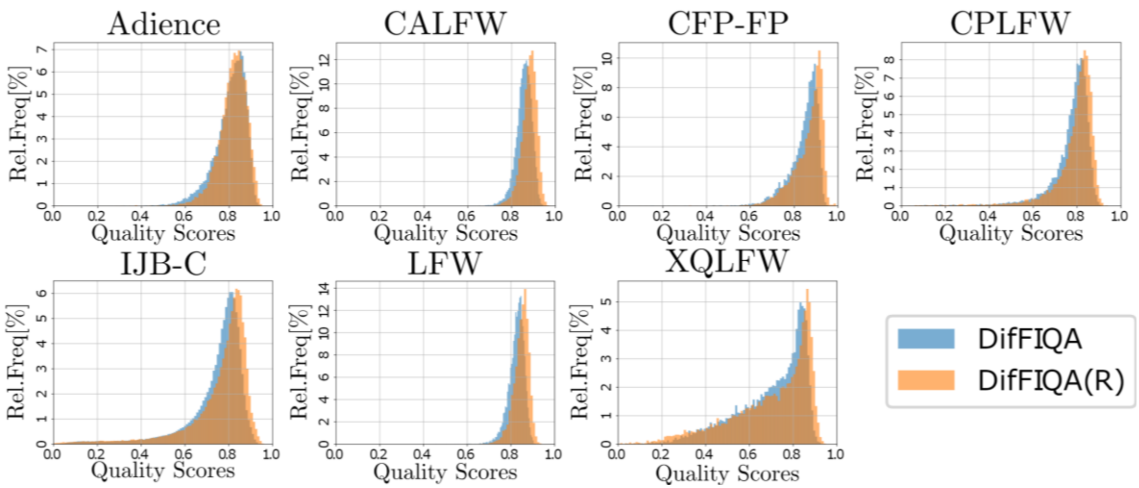
- **Hardware: Intel i9-10900KF CPU, 64 GB RAM in Nvidia 3090 GPU**

FIQA model	**Ours**	
	DifFIQA	**DifFIQA(R)**
Runtime ($\mu \pm \sigma$)	1074.62 ± 11.45	1.24 ± 0.36

- Speed-up due to knowledge distilation is around 1000x

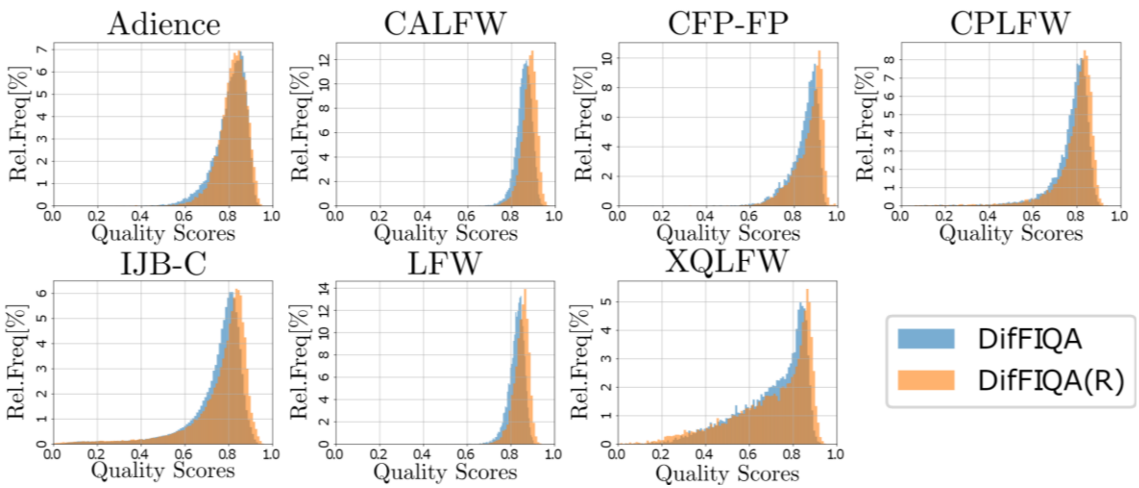
DifFIQA and DifFIQA(R) Comparison

Comparison of quality score distributions

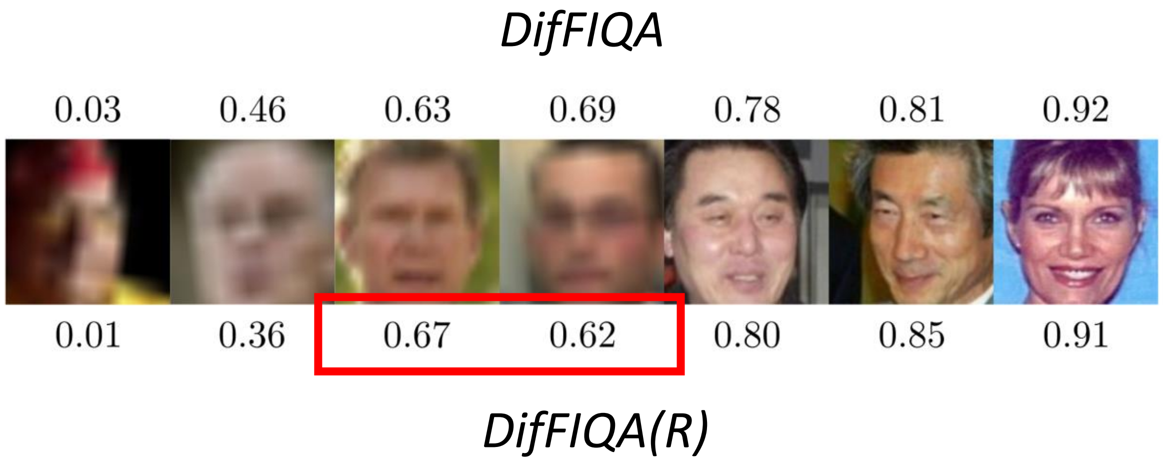


DifFIQA and DifFIQA(R) Comparison

Comparison of quality score distributions



Visual comparison



Conclusions

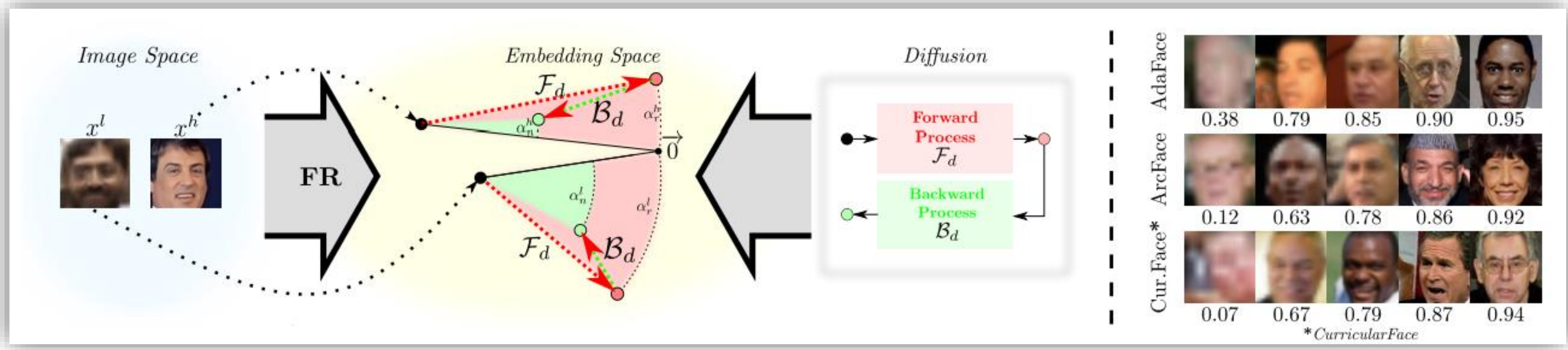
- DifFIQA: a new FIQA approach based on DDPMs
- DifFIQA(R): distilled version for fact prediction
- State-of-the-art performance across multiple datasets and face recognition models

- Outlook and future work
  - Distillation with lighter models
  - Distillation with score-optimization for fine-grained FIQA
  - Incroporating detector variability
  - FIQA for videos

Javna agencija za znanstvenoraziskovalno
in inovacijsko dejavnost Republike Slovenije

European Association for Biometrics
eab
Human Identity in Europe

LMI



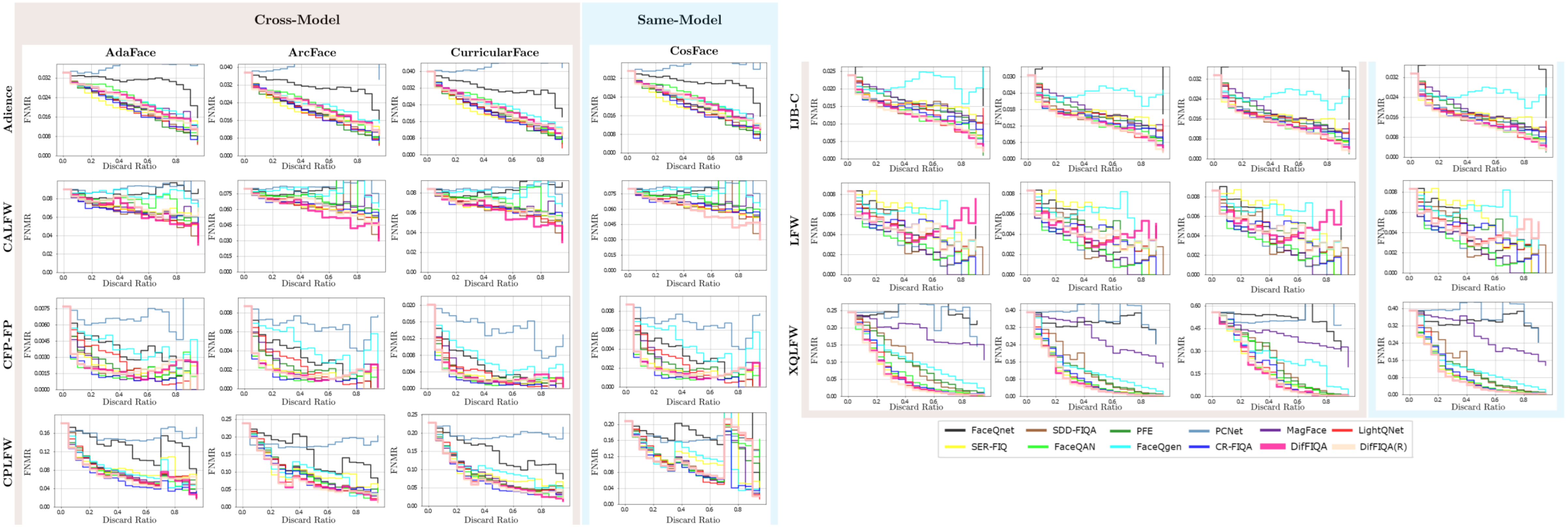
Paper

Thank You!

Code

ziga.babnik@fe.uni-lj.si, peter.peer@fri.uni-lj.si,
vitomir.struc@fe.uni-lj.si

EDC curves



Cross-Model
Same-Model
AdaFace
ArcFace
CurricularFace
CosFace
Adience
CALFW
CFP-FP
CPLFW
IJB-C
LFW
XQLFW
FNMR
Discard Ratio
FaceQnet
SDD-FIQA
PFE
PCNet
MagFace
LightQNet
SER-FIQ
FaceQAN
FaceQgen
CR-FIQA
DifFIQA
DifFIQA(R)