Image Quality Assessment and Its Applications

Fei Gao

gaofei@hdu.edu.cn

http://camalab.hdu.edu.cn

Hangzhou Dianzi University

Contents

- Background
- Image Quality Assessment (IQA)
- Photo Quality Assessment (PQA)
- Biometric Quality Assessment (BQA)
- Discussions

Contents

- **Background**
- Image Quality Assessment (IQA)
- Photo Quality Assessment (PQA)
- Biometric Quality Assessment (BQA)
- Discussions

Background

- Dramatically increasing amount of images
  - **Devices**: computers, mobile phones, cameras, monitors, …
  - **Applications**: medias, websites, IM clients, …

Background

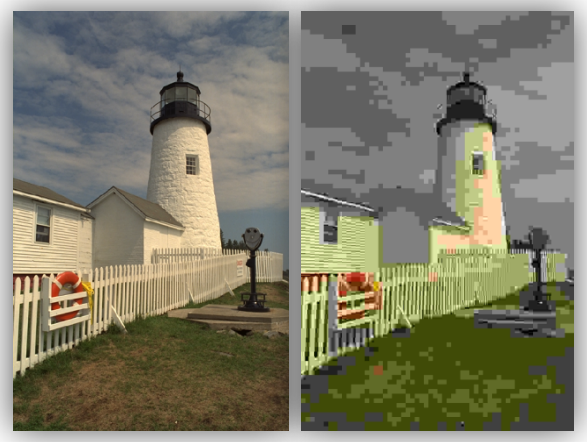
- Extensively existed distortions
  - **Processing**: acquisition, compression, transmission, reconstruction, …
  - **Distortions**: blurring, JPEG compression, Gaussian noise, …

What is Quality?

[Keelan, Handbook of Image Quality, 2002]
[Janssen and Blommaert, JIST, 1997]
[Janssen, Proc. IEEE, 2001]
[Halonen, et al., Proc. SPIE, 2011]

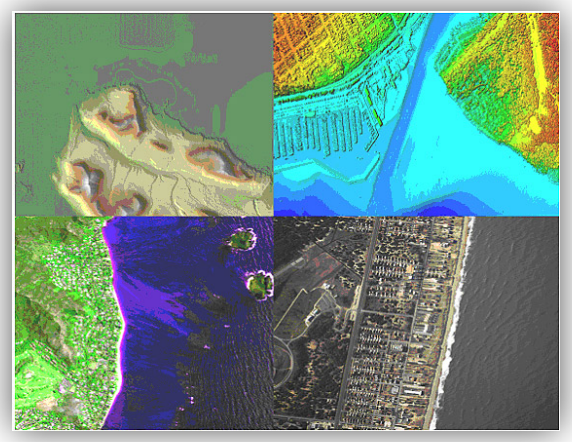
- Various aspects
  - **Athletics**: perceived beauty or image appeal
  - **Fidelity**: deviation from the undistorted version
  - **Intelligibility**: discriminability of image content

Athletics



Undistorted Distorted

Fidelity



Intelligibility

Background

- Demands for IQA metrics

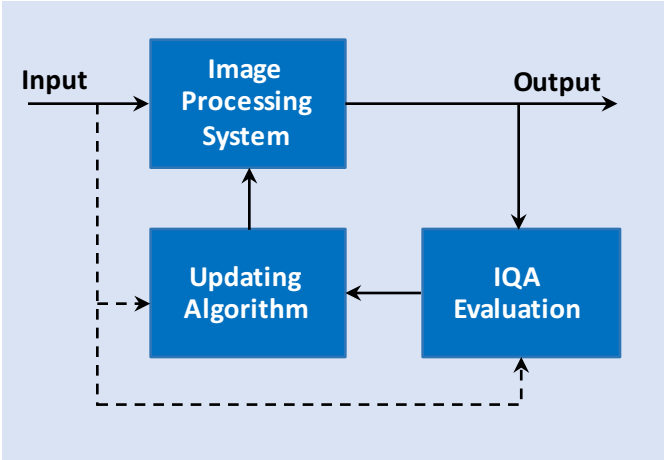


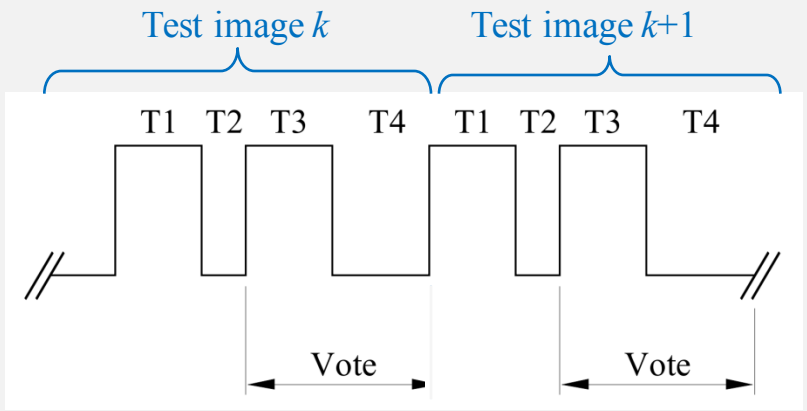
Diagram of IQA-based feedback optimization method. [Z. Wang, IEEE SPM'11]

Evaluation, control, and improve the perceptual quality of multimedia content, quality of service (QoS), image processing systems, …

Background

- Common Subjective IQA Method

[ITUR BT.500-13., 2012]

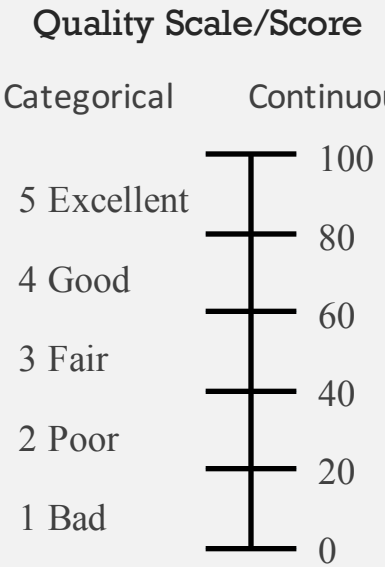


T1 = 10s Reference image

T2 = 3s Mid-gray image

T3 = 10s Test image

T4 = 10s Mid-gray image



Contents

- Background
- **Image Quality Assessment (IQA)**
- Photo Quality Assessment (PQA)
- Biometric Quality Assessment (BQA)
- Discussions

Image Quality Assessment (IQA)

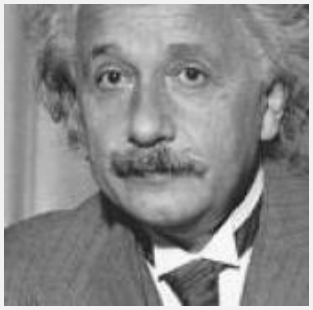
- **Traditional Objective Methods** [Wang & Bovik, IEEE SPM09]
  - Mean Squared Error (MSE)

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\left|I(i,j)-R(i,j)\right|^2$$

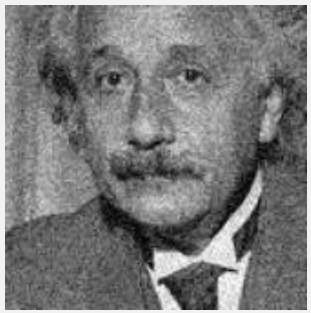
  - Peak Signal-to-Noise Ratio

$$PSNR = 10\cdot\log_{10}\left(\frac{I_{\max}^2}{MSE}\right)$$

  - Advantages
    - Mathematically conventional
    - Effective for white noise
  - Disadvantage
    - Lack of consideration of human visual property


Brightened (MSE=309)

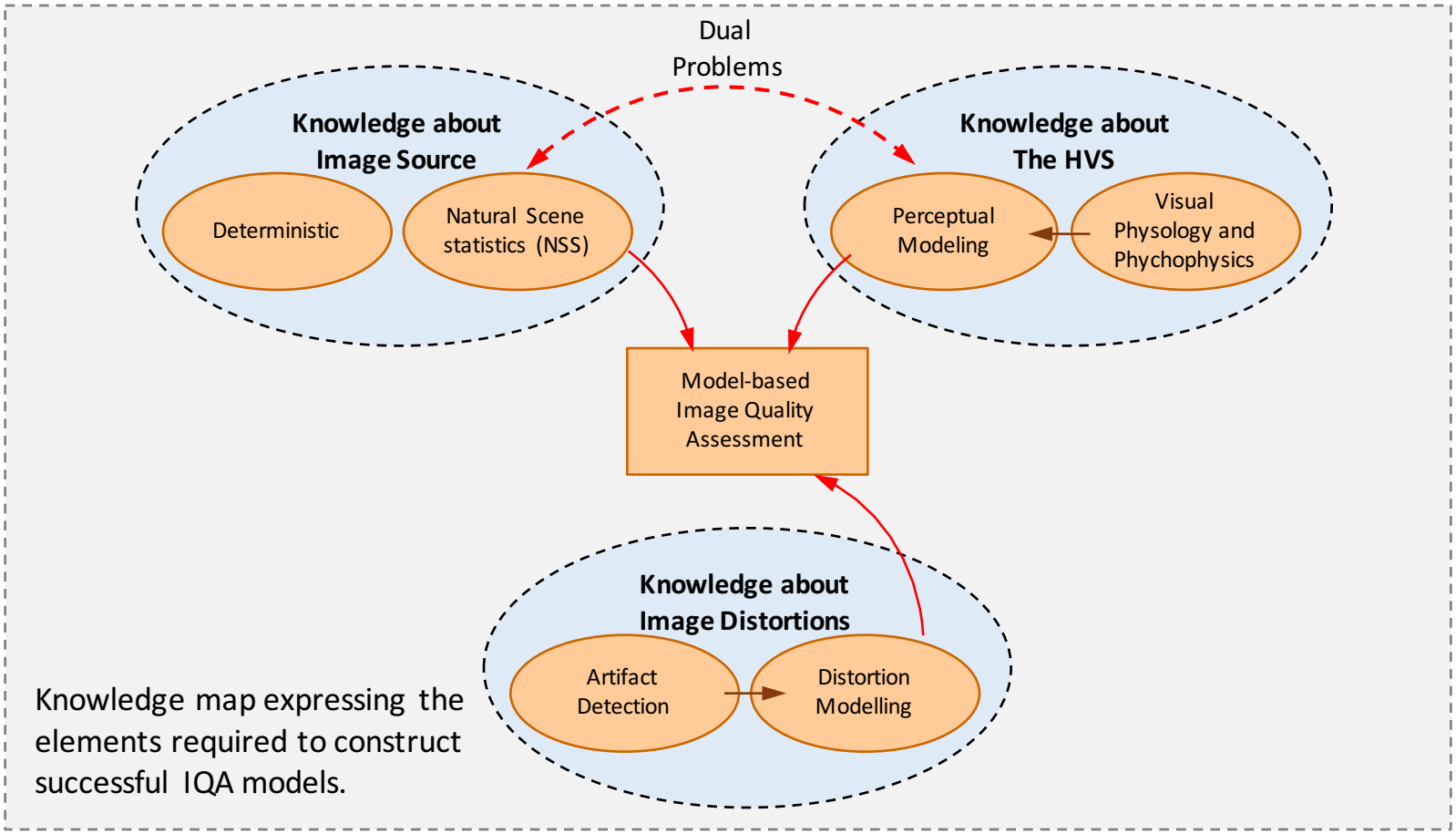

JPEG (MSE=309)


Gaussian noise(MSE=309)


Gaussian blur(MSE=309)

Image Quality Assessment (IQA)

- How to Construct Objective IQA Metrics?

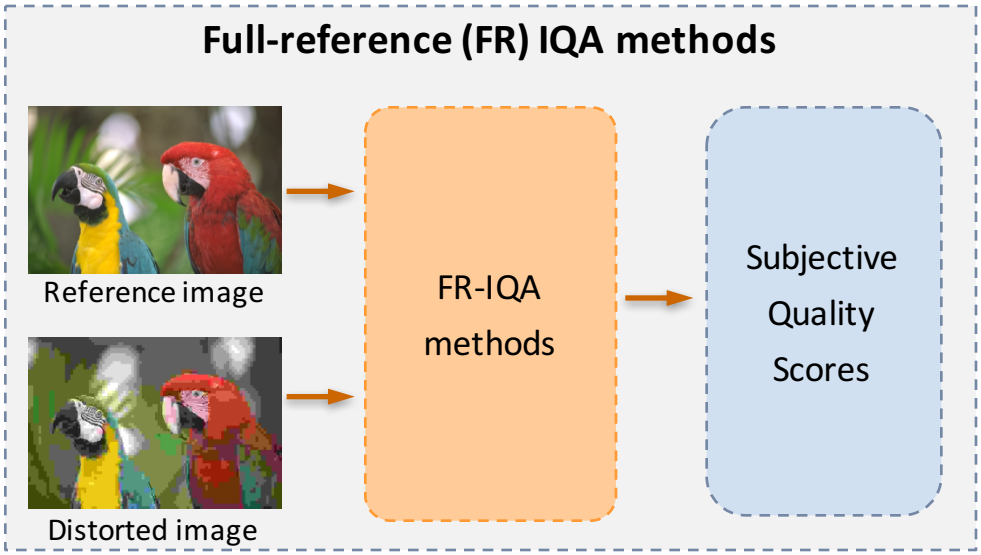


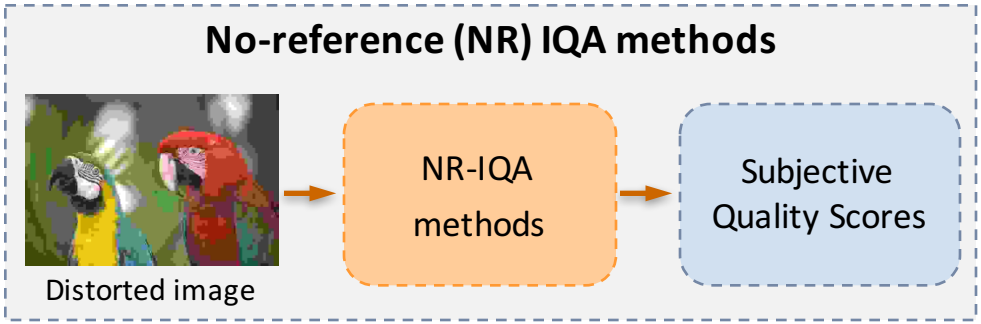
Knowledge map expressing the elements required to construct successful IQA models.

[Wang & Bovik, SPM'11]

Image Quality Assessment (IQA)

- Classification of Objective IQA





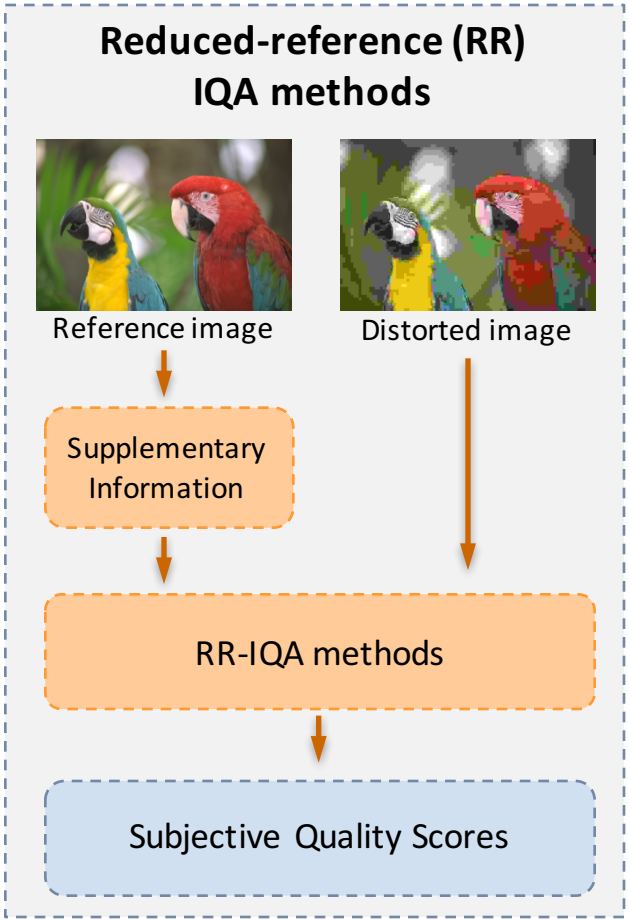


Image Quality Assessment (IQA)

- **FR-IQA:** Structural Similarity Index (SSIM) [Z. Wang, *et al*. TIP'04]

Reference image $\boldsymbol{x}$

Distorted image $\boldsymbol{y}$

Luminance Measure:
Mean intensity

$$\mu_I = \frac{1}{N}\sum_{i=1}^{N} I_i$$

Contrast Measure:
Standard deviation of intensity

$$\sigma_I = \left(\frac{1}{N-1}\sum_{i=1}^{N}(I_i - \mu_I)^2\right)^{\frac{1}{2}}$$

Structure Measure:
Normalized image

$$(I - \mu_I)/\sigma_I$$

$$l(\boldsymbol{x},\boldsymbol{y}) = \frac{2\mu_x\mu_y + C_1}{\mu_x{}^2 + \mu_y{}^2 + C_1}$$

$$c(\boldsymbol{x},\boldsymbol{y}) = \frac{2\sigma_x\sigma_y + C_2}{\sigma_x{}^2 + \sigma_y{}^2 + C_2}$$

$$s(\boldsymbol{x},\boldsymbol{y}) = \frac{2\sigma_{xy} + C_3}{\sigma_x\sigma_y + C_3}$$

$$SSIM(\boldsymbol{x},\boldsymbol{y}) = [l(\boldsymbol{x},\boldsymbol{y})]^{\alpha} \cdot [c(\boldsymbol{x},\boldsymbol{y})]^{\beta} \cdot [s(\boldsymbol{x},\boldsymbol{y})]^{\gamma}$$

- **Advantages**: efficient and effective
- **Extensions**: CBM [X. Gao et al., LNAI'05], IW-SSIM[W. Zhou and Q. Li, TIP'11], RR-SSIM [A. Rehman and Z. Wang, TIP'12], etc.

Image Quality Assessment (IQA)

- **FR-IQA:** Deep Similarity (DeepSim) [F. Gao, *et al.* NEUCOM'17]

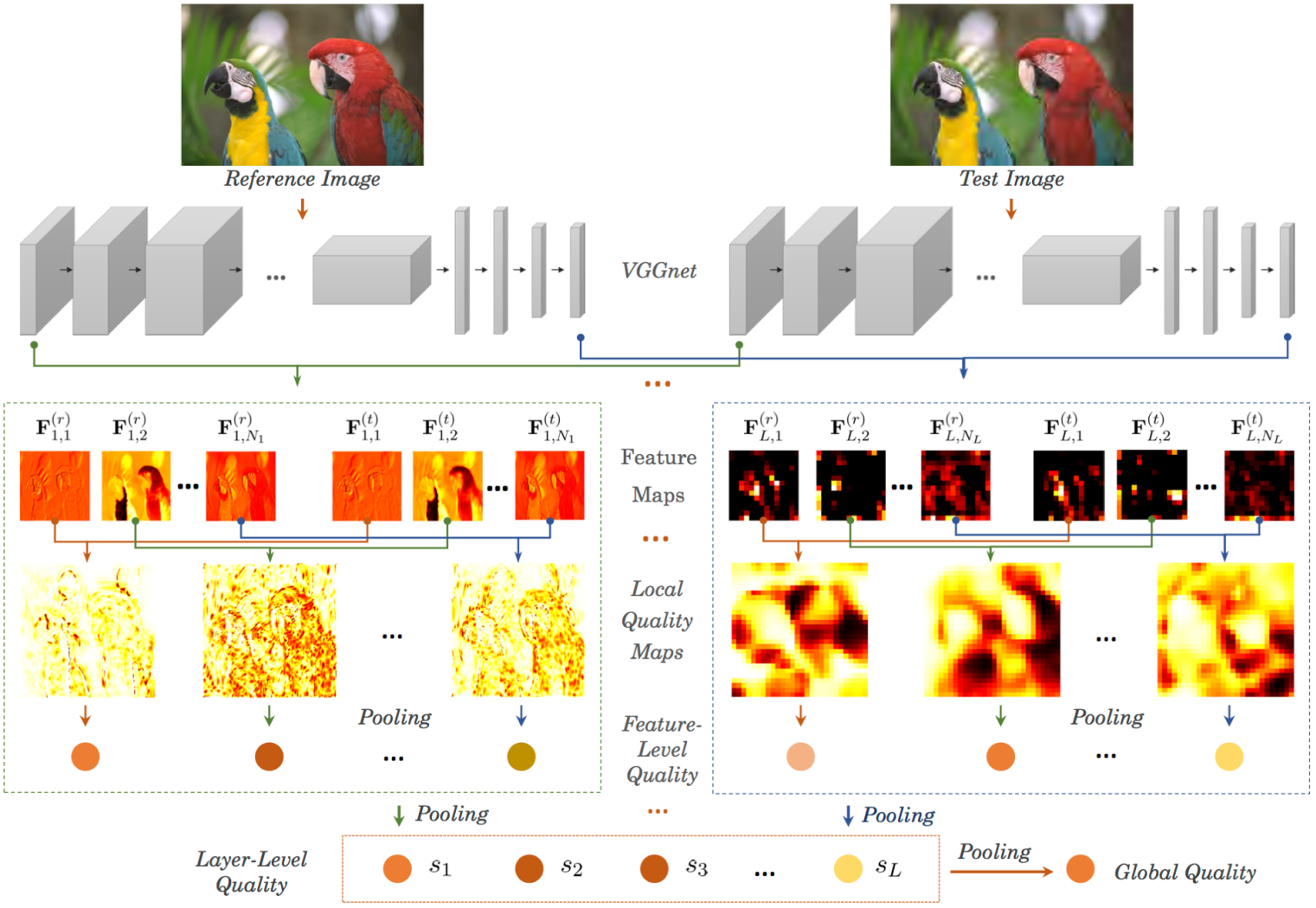


Image Quality Assessment (IQA)

- RR-IQA
  - Application: wireless communication scenario
  - Framework of RR-IQA System

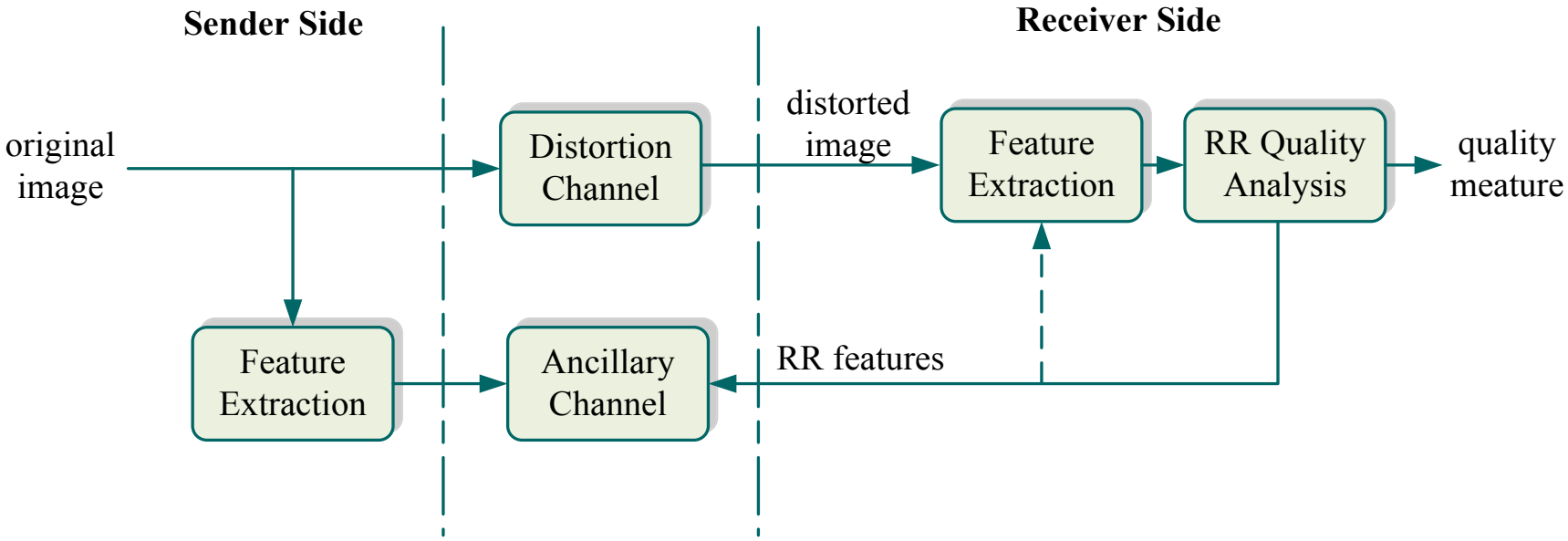
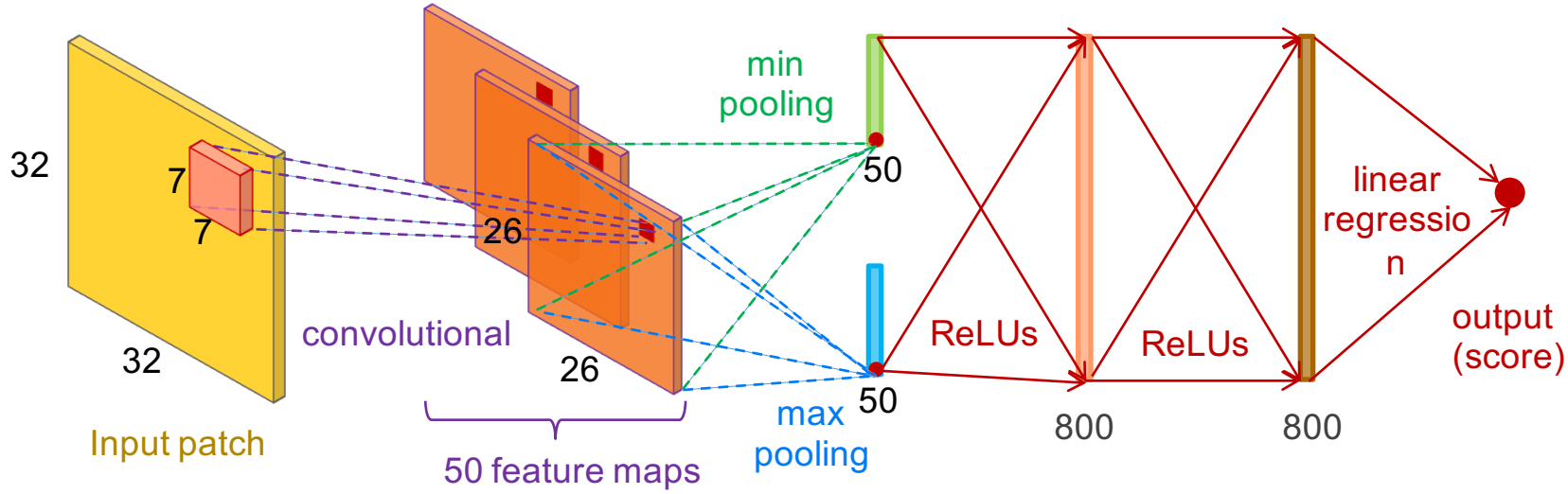


Image Quality Assessment (IQA)

- NR-IQA
  - Convolutional Neural Networks for BIQA (Kang *et al.* CVPR'14)



a) The input is locally normalized 32×32 image patches;

b) The convolutional layer produces 50 feature maps each of size 26×26, followed by a pooling operation that reduces each feature map to one max and one min;

c) The last layer is a simple linear regression with a one dimensional output that gives the score.

Image Quality Assessment (IQA)

- Performance Evaluation

[N. Ponomarenko, et al. EUVIP'13]

  - Color Image Database TID2013
    - 25 reference color images (512*368 pixels);
    - 120 distorted versions of each reference image;
    - 24 types of distortions, 125 images of each type;
    - Totally 3000 images;
    - MOS of each image is available.

Image Quality Assessment (IQA)

- Performance Evaluation
  - Scatter plots

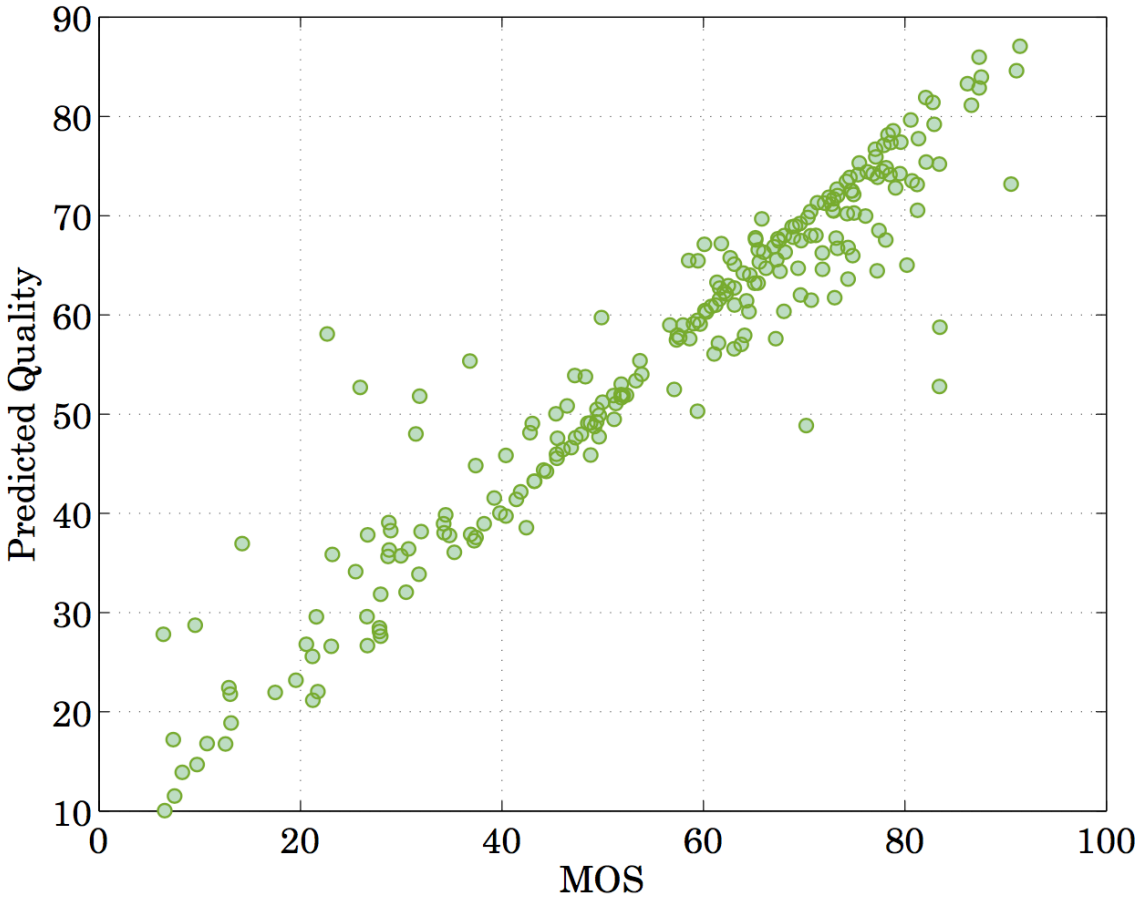


Image Quality Assessment (IQA)

- Performance Evaluation
  - Pearson linear correlation coefficient (PLCC),
  - Spearman's rank- order correlation coefficient (SRCC), and
  - Kendall rank-order correlation coefficient (KRCC)

SRCC	RMSE	MSSIM	FSIMc	GMSD	IGM	MAD	BIFS	DeepSim
CSIQ	0.805	0.839	0.917	**0.950**	0.932	0.937	0.935	0.919
LIVE	0.936	0.954	0.981	0.979	0.978	**0.982**	0.968	0.974
LIVEMD	0.677	0.646	0.864	0.845	0.856	0.865	0.855	**0.877**
TID2013	0.674	0.627	0.802	0.804	0.810	0.808	0.832	**0.846**
Avg.	0.773	0.767	0.891	0.895	0.894	0.898	0.898	**0.904**
Wgt. avg.	0.744	0.724	0.859	0.864	0.865	0.866	0.876	**0.884**

Image Quality Assessment (IQA)

- Applications: IQA Guided CNNs Training

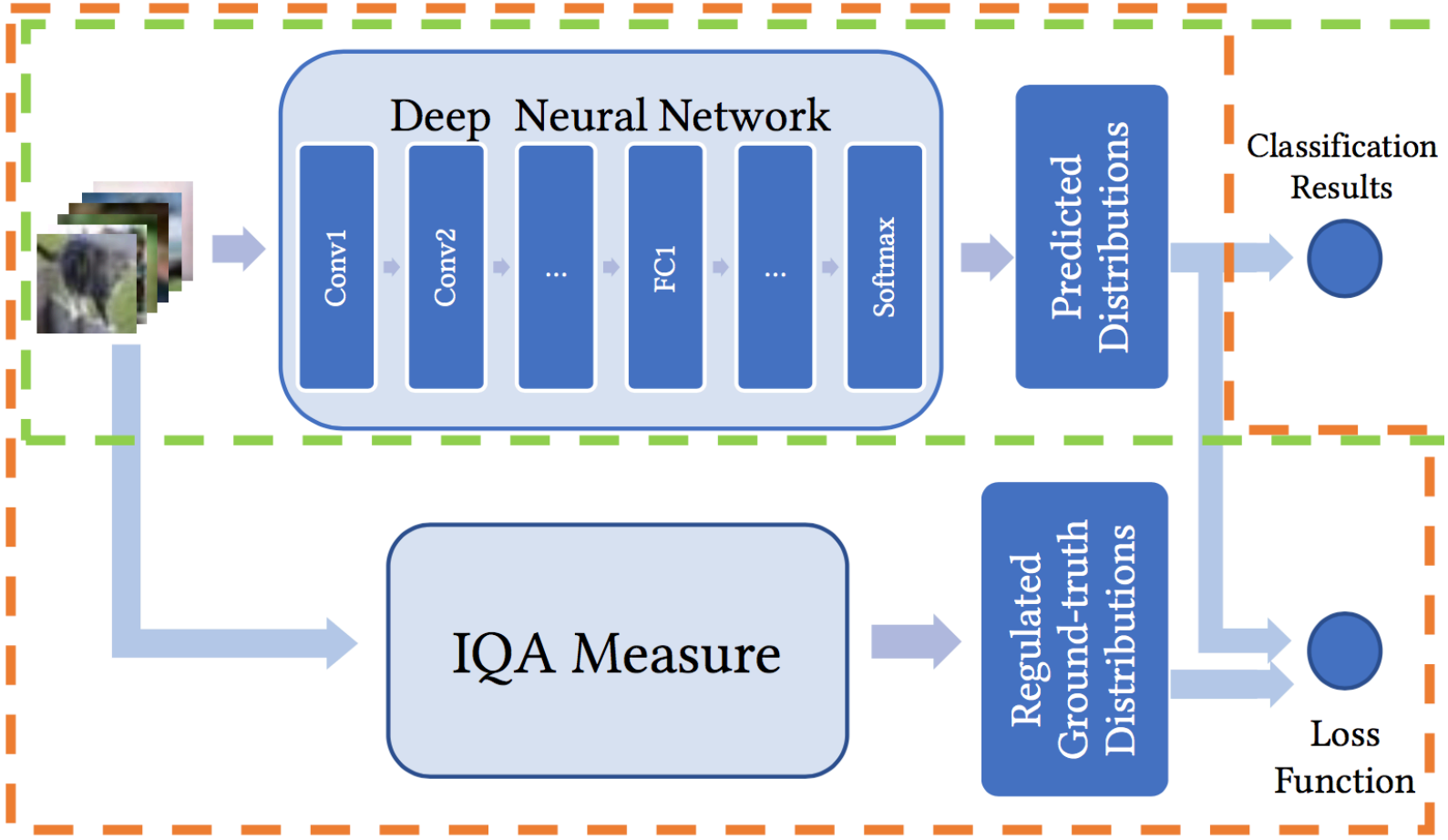
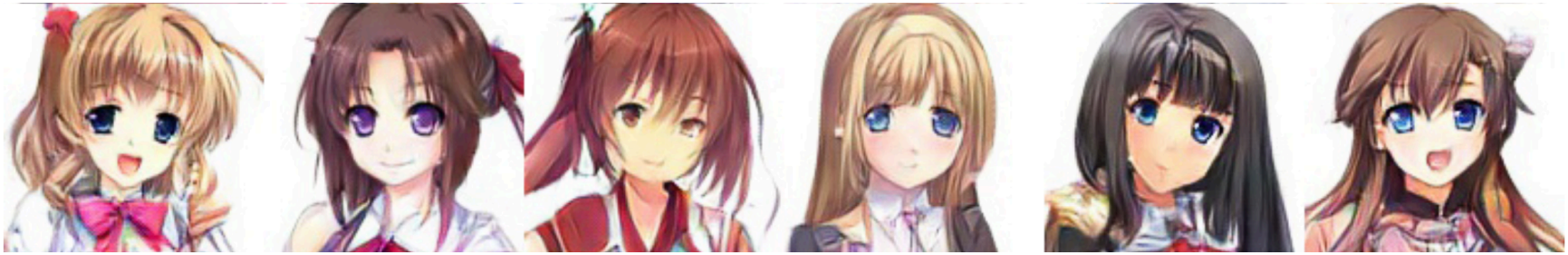


Image Quality Assessment (IQA)

- Applications: GAN



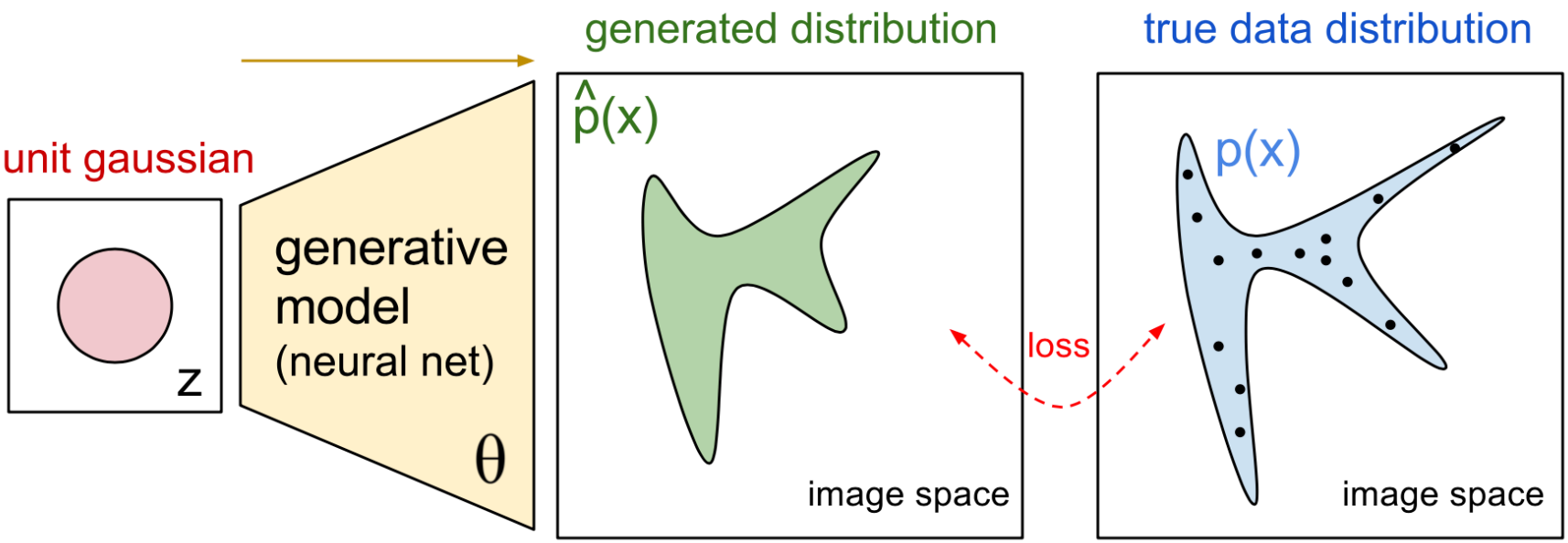
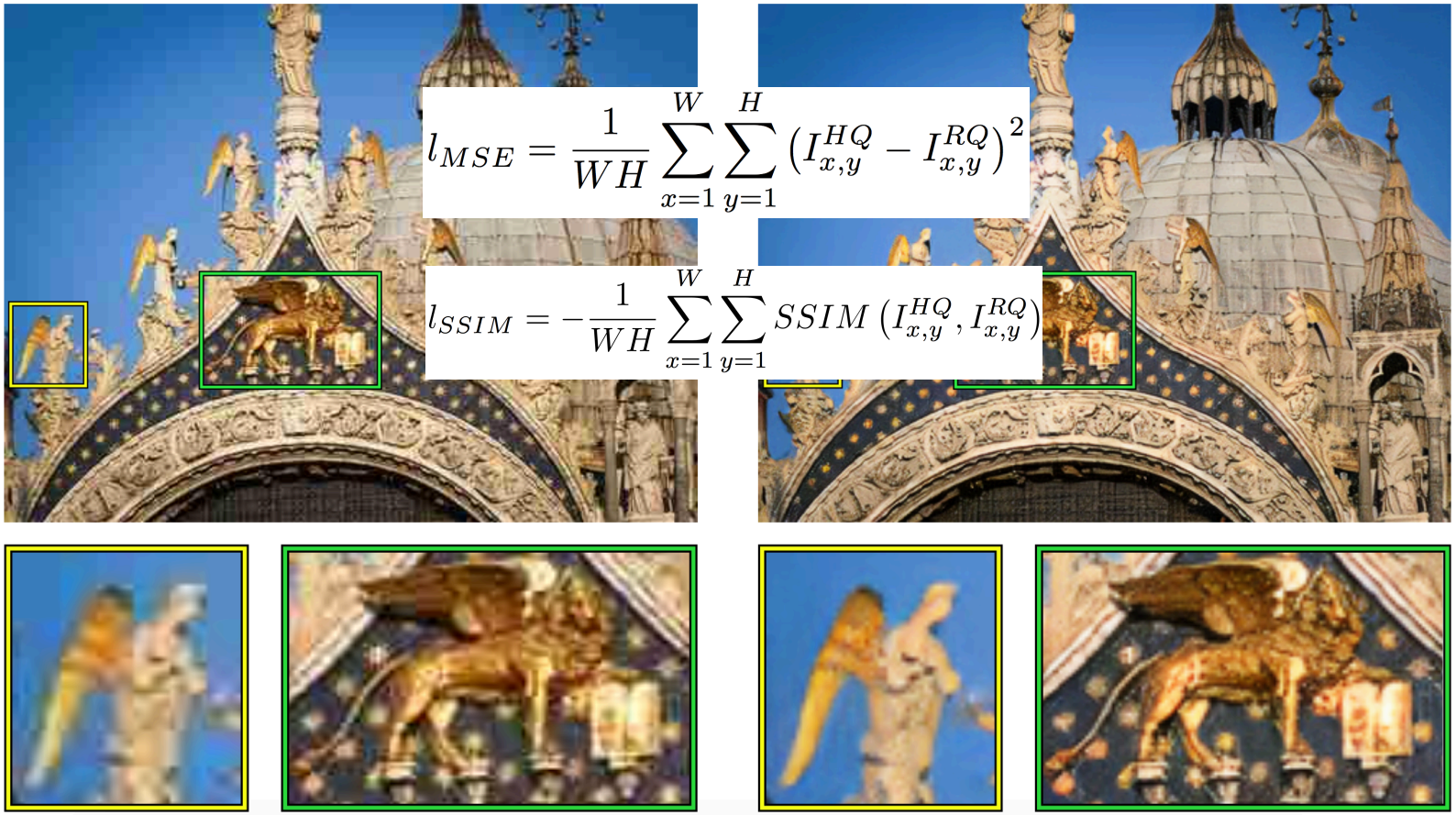


Image Quality Assessment (IQA)

- **Applications:** Compression Artifact Removal



$$l_{MSE} = \frac{1}{WH}\sum_{x=1}^{W}\sum_{y=1}^{H}\left(I_{x,y}^{HQ} - I_{x,y}^{RQ}\right)^2$$

$$l_{SSIM} = -\frac{1}{WH}\sum_{x=1}^{W}\sum_{y=1}^{H} SSIM\left(I_{x,y}^{HQ}, I_{x,y}^{RQ}\right)$$

Galteri, Leonardo, et al. "Deep Generative Adversarial Compression Artifact Removal." arXiv preprint arXiv:1704.02518 (2017).

Contents

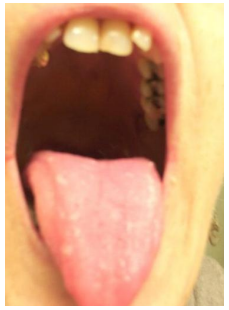
- Background
- Visual Quality Assessment (VQA)
- **Photo Quality Assessment (PQA)**
- Biometric Quality Assessment (BQA)
- Discussions

Photo Quality Assessment (PQA)

- What is Photo Aesthetic Quality? [Marchesotti et al. 2015]




Beautiful / Professional / Good







Ugly / Amateurish / Bad

Photo Quality Assessment (PQA)

- Challenges
  - Aesthetic Principles
  - Subjective PQA Mechanism
  - Personalized
  - Correlated with various image attributes (e.g. emotion, scene, semantic, style)

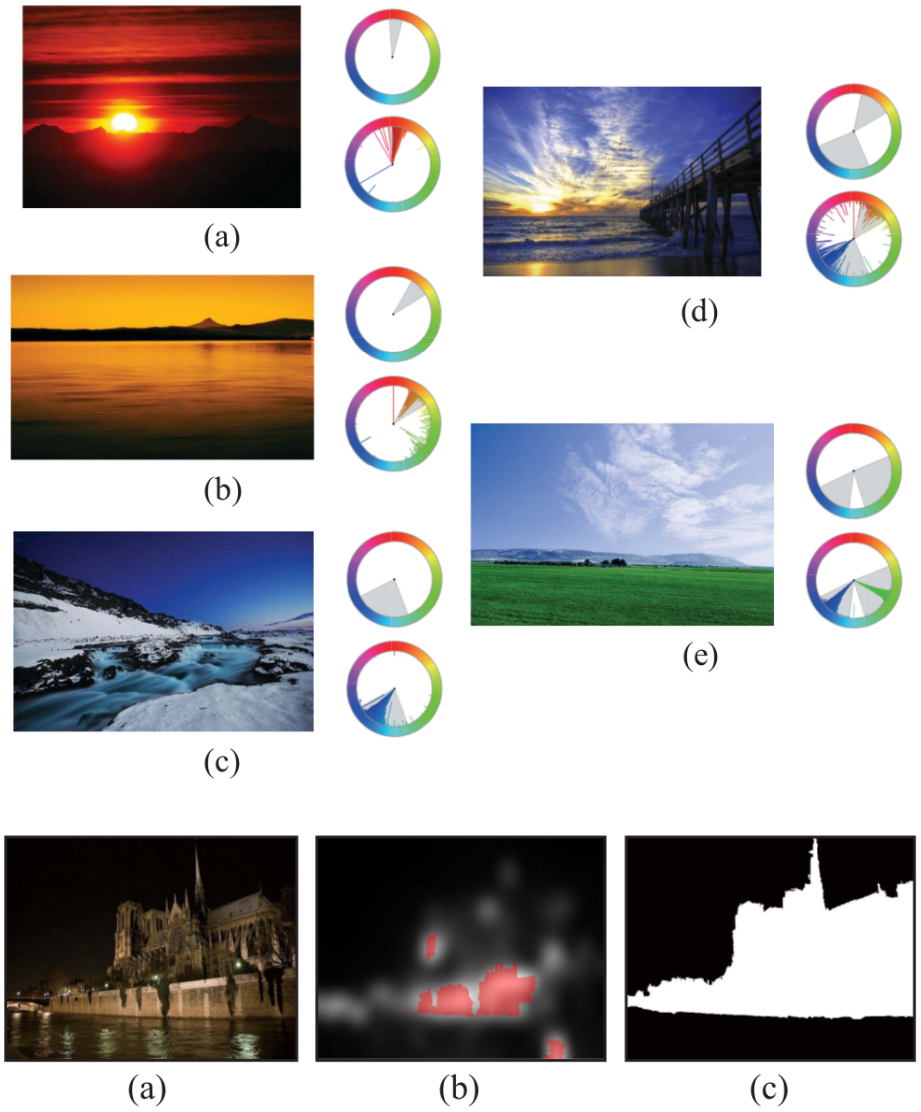
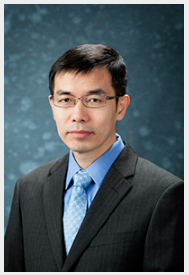


Photo Quality Assessment (PQA)

- Research Groups



Prof. Tang Xiaoou, Sean

Fellow IEEE

Multimedia Laboratory

香港中文大學
The Chinese University of Hong Kong

SenseTime 商湯科技

Xin Lu

Penn
University of Pennsylvania

Xinmei Tian

Associate Professor

中国科学技术大学
University of Science and Technology of China

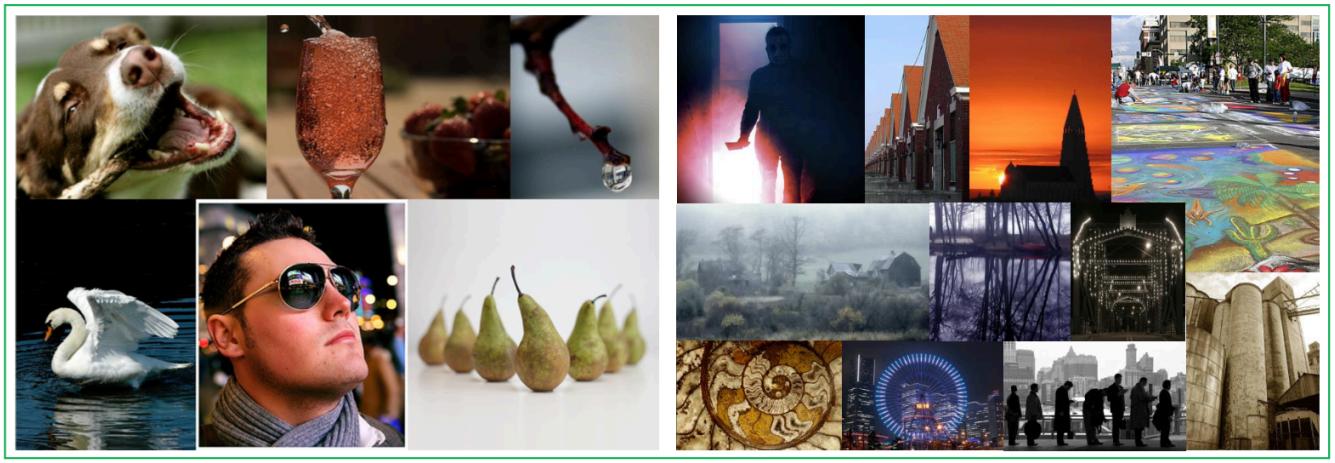
xerox

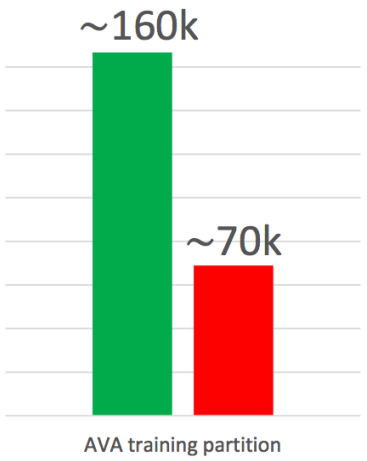
Google

Adobe®

Photo Quality Assessment (PQA)

- AVA database (250k images)
  - Ratings, Average ratings, Semantics, Styles





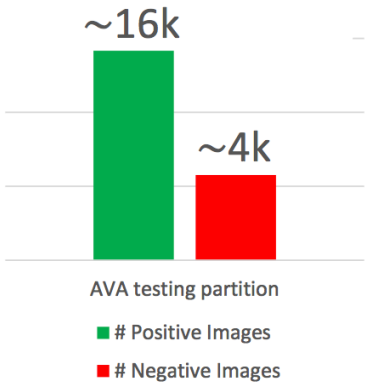
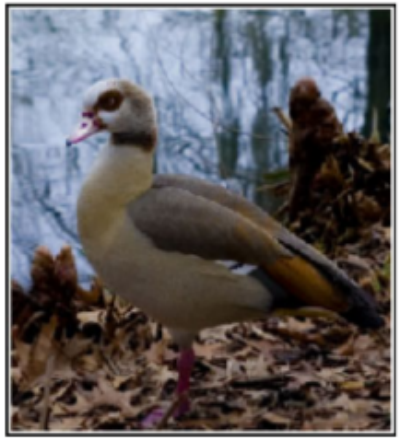


Photo Quality Assessment (PQA)

- Crowd Opinion

[Marchesotti et al. 2015]

low variance



high variance

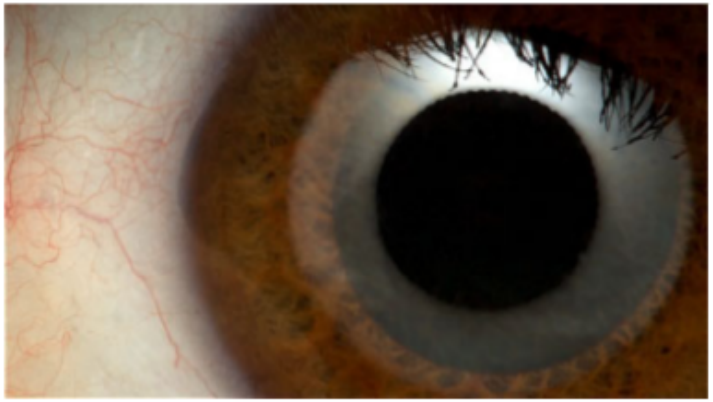
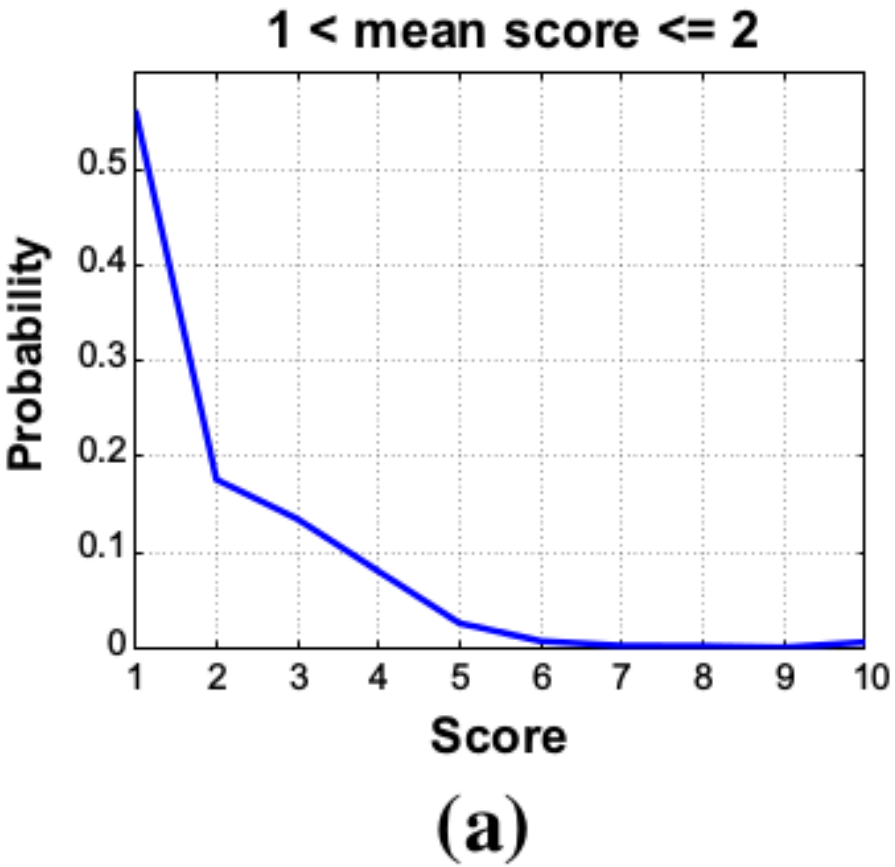


Photo Quality Assessment (PQA)

- Crowd Opinion

[Marchesotti et al. 2015]



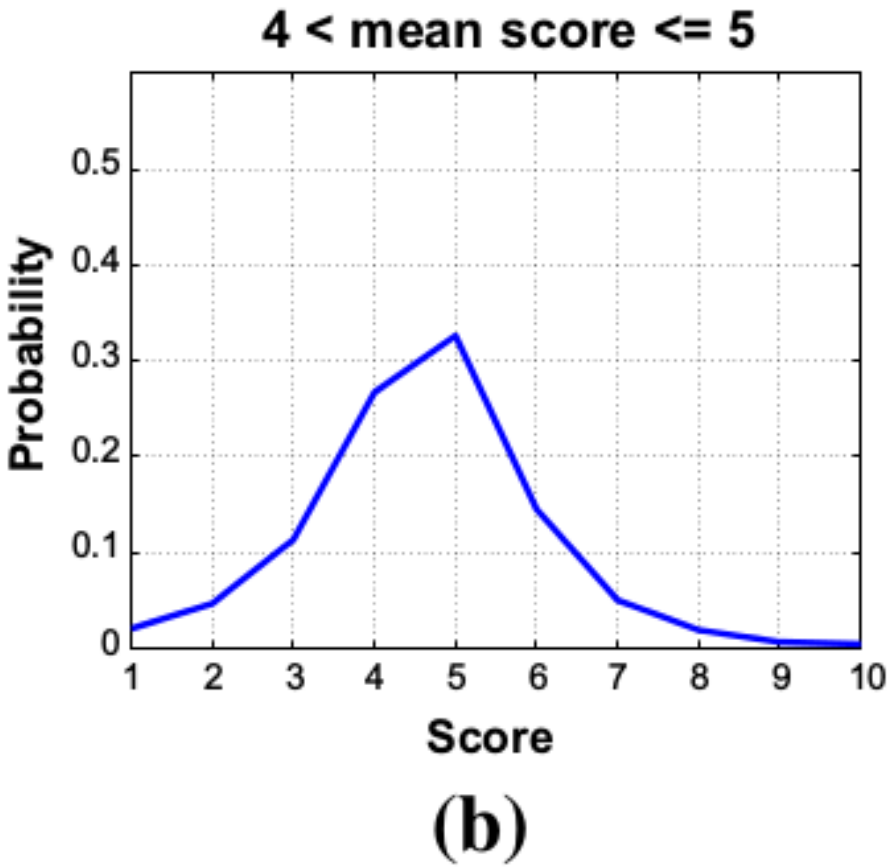
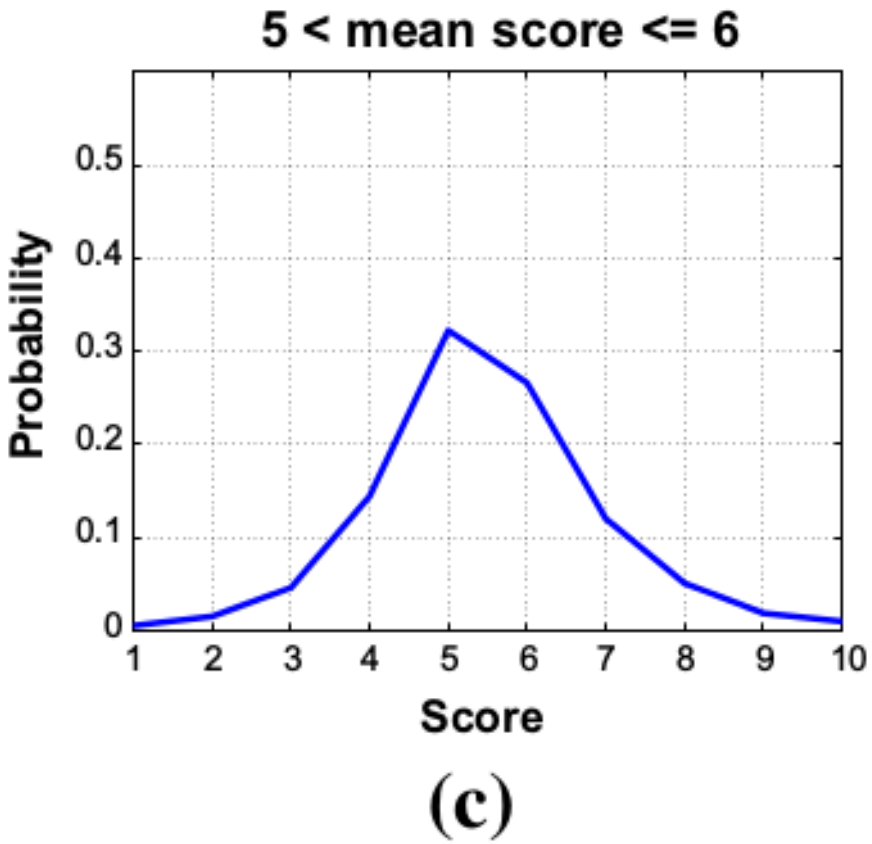


Photo Quality Assessment (PQA)

- Crowd Opinion

[Marchesotti et al. 2015]



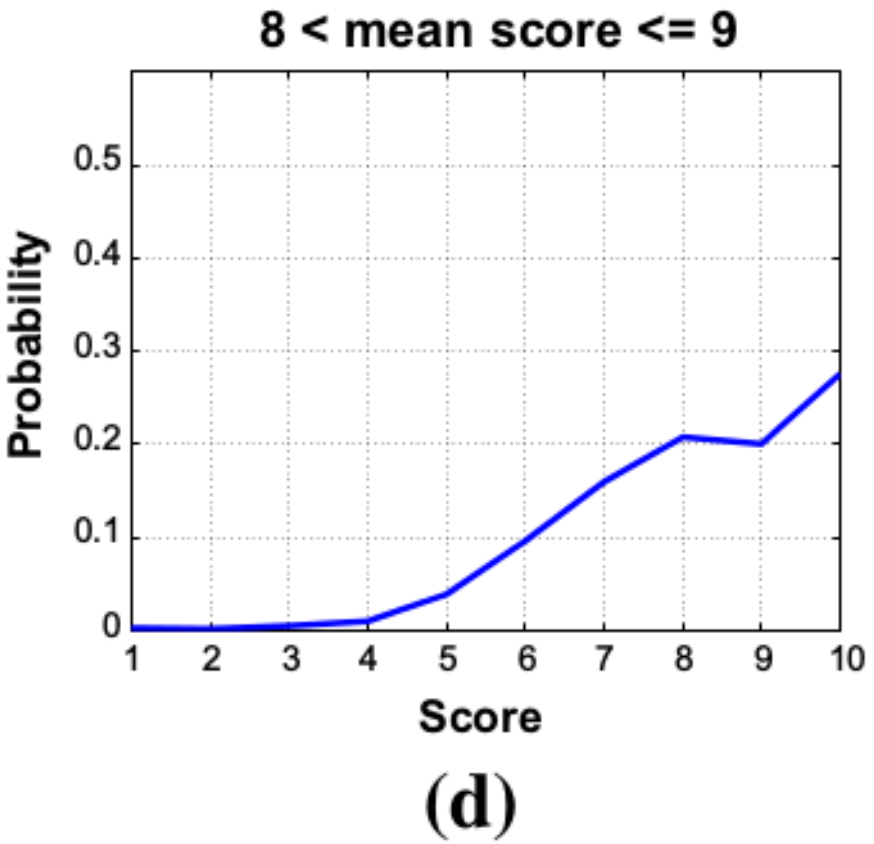


Photo Quality Assessment (PQA)

- Style

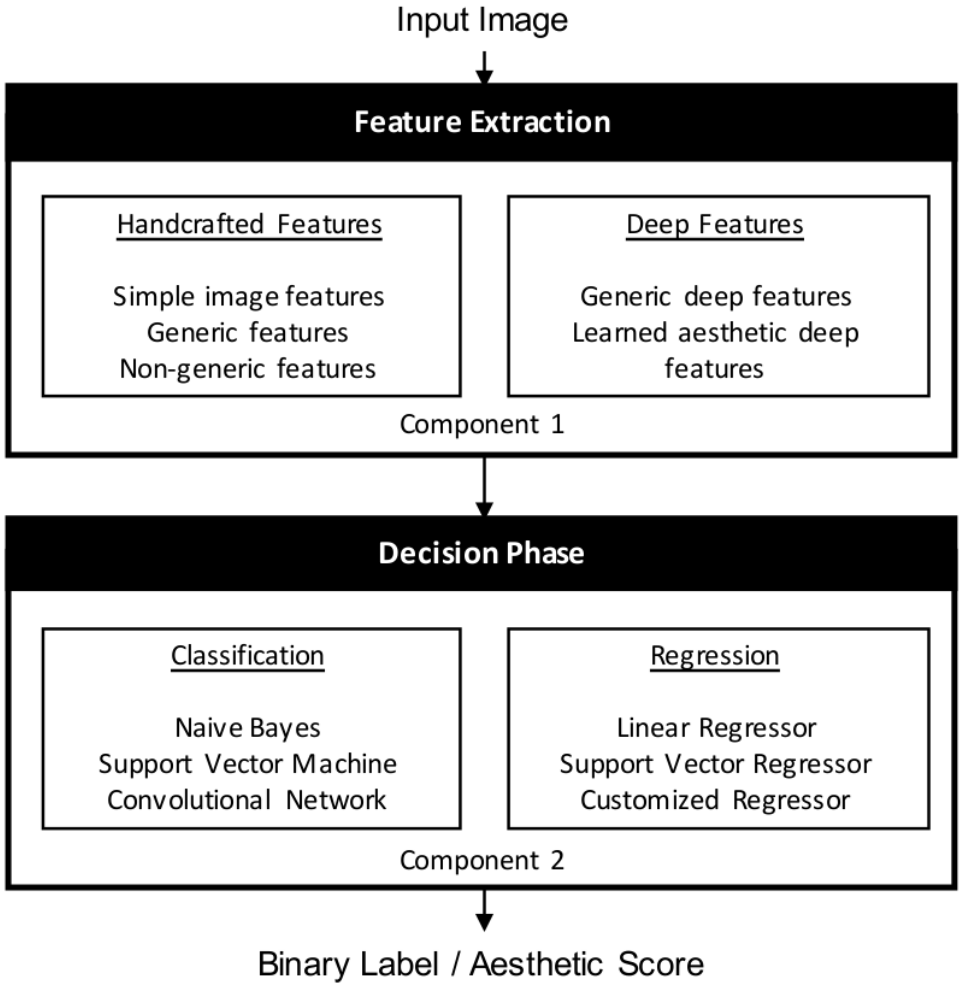
[Marchesotti et al. 2015]

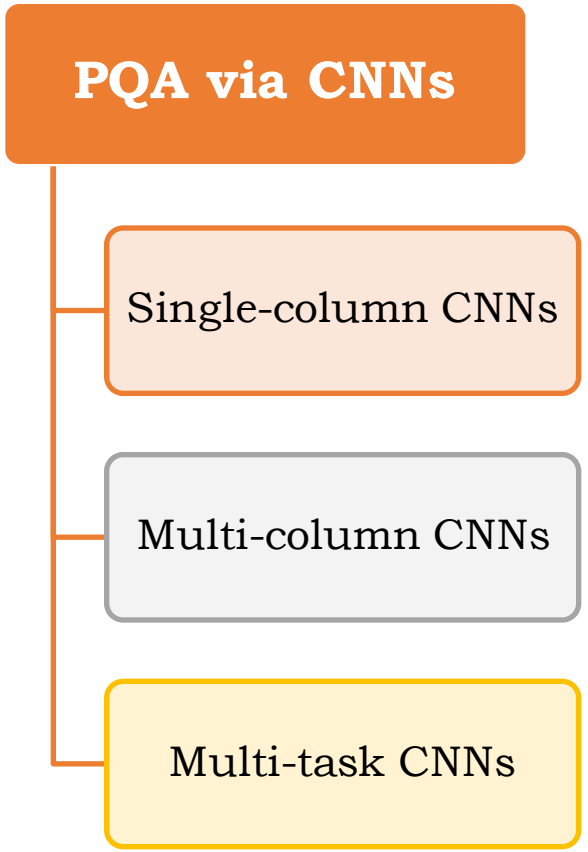
black and white

low depth-of-field, single salient object and rule-of-thirds

PQA via Deep Learning

- Methodology



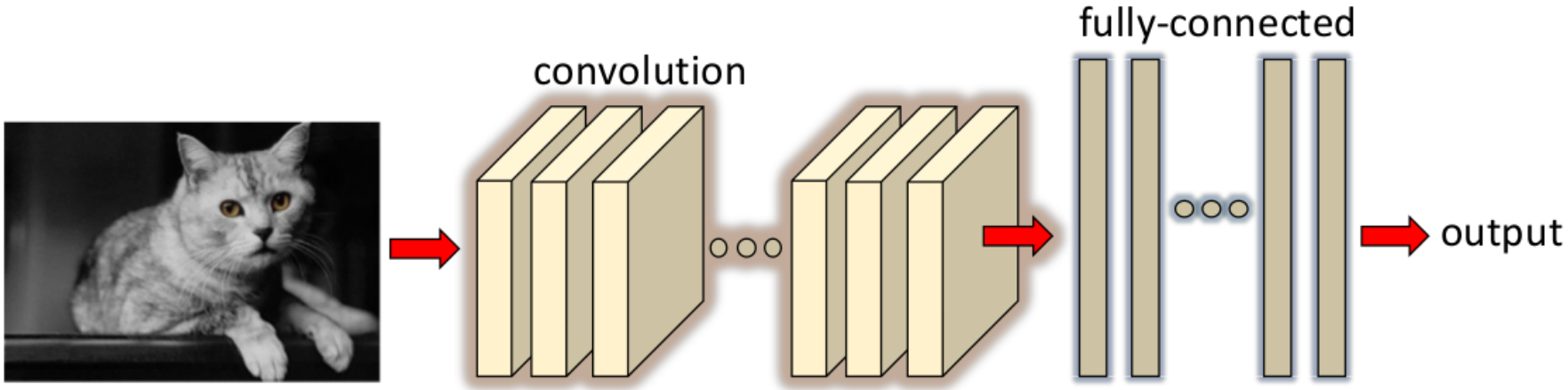


Y. Deng, C.-L. Chen, and X. Tang, "Image aesthetic assessment: An experimental survey," 2016.

PQA via Deep Learning

- Single-column CNNs
  - CNNs trained on ImageNet
  - Transferred CNNs
    - Pretrain in the PQA task
    - Fine-tuning in the binary classification task of photo aesthetic (good or bad)

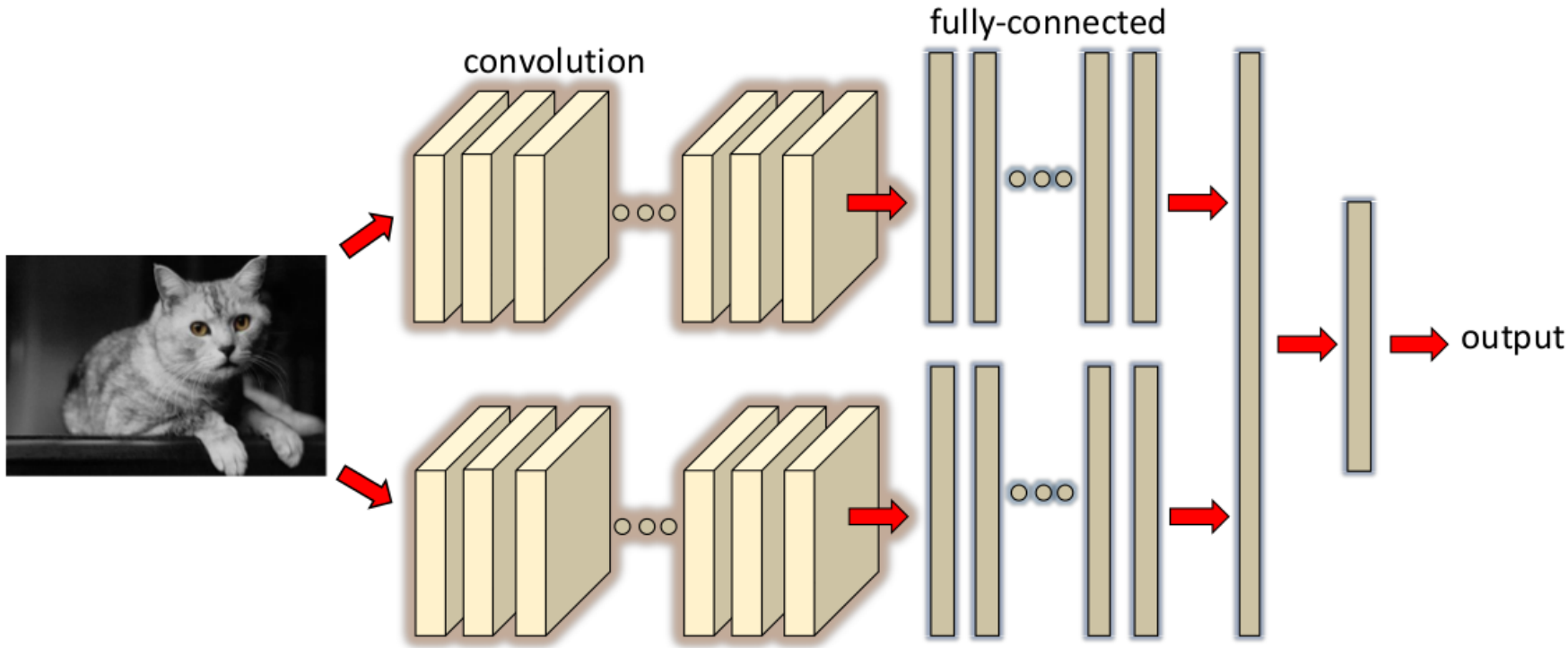
Y. Deng, C.-L. Chen, and X. Tang, "Image aesthetic assessment: An experimental survey," 2016.



PQA via Deep Learning

- Multi-column CNNs
  - global features + local features
  - global features + attribute features

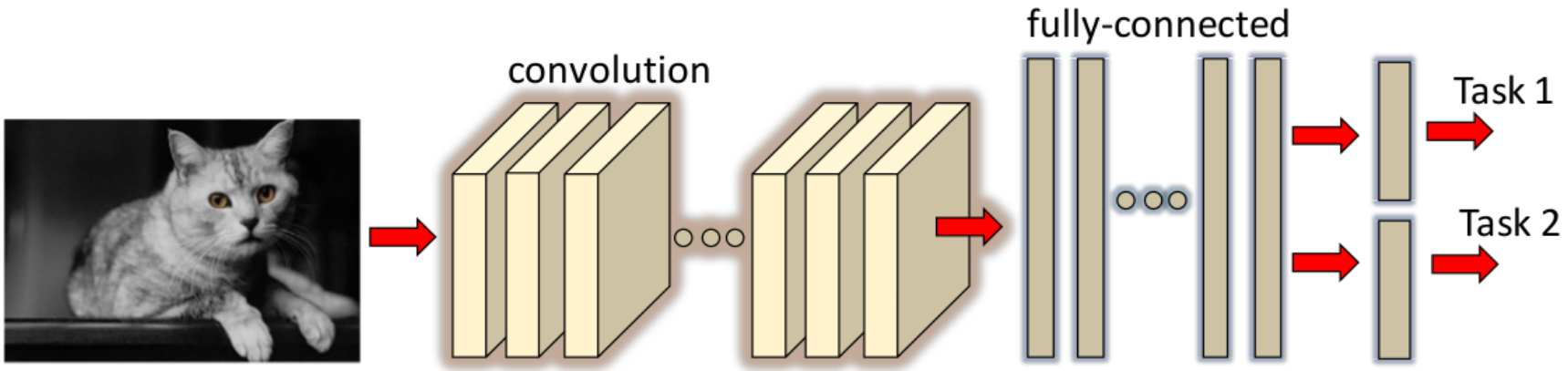
Y. Deng, C.-L. Chen, and X. Tang, "Image aesthetic assessment: An experimental survey," 2016.



PQA via Deep Learning

- Multi-task CNNs
  - Correlated with various image attributes (e.g. emotion, scene, semantic, style)
    - Task 1: Aesthetic prediction
    - Task 2: Semantic prediction
    - Task n: …

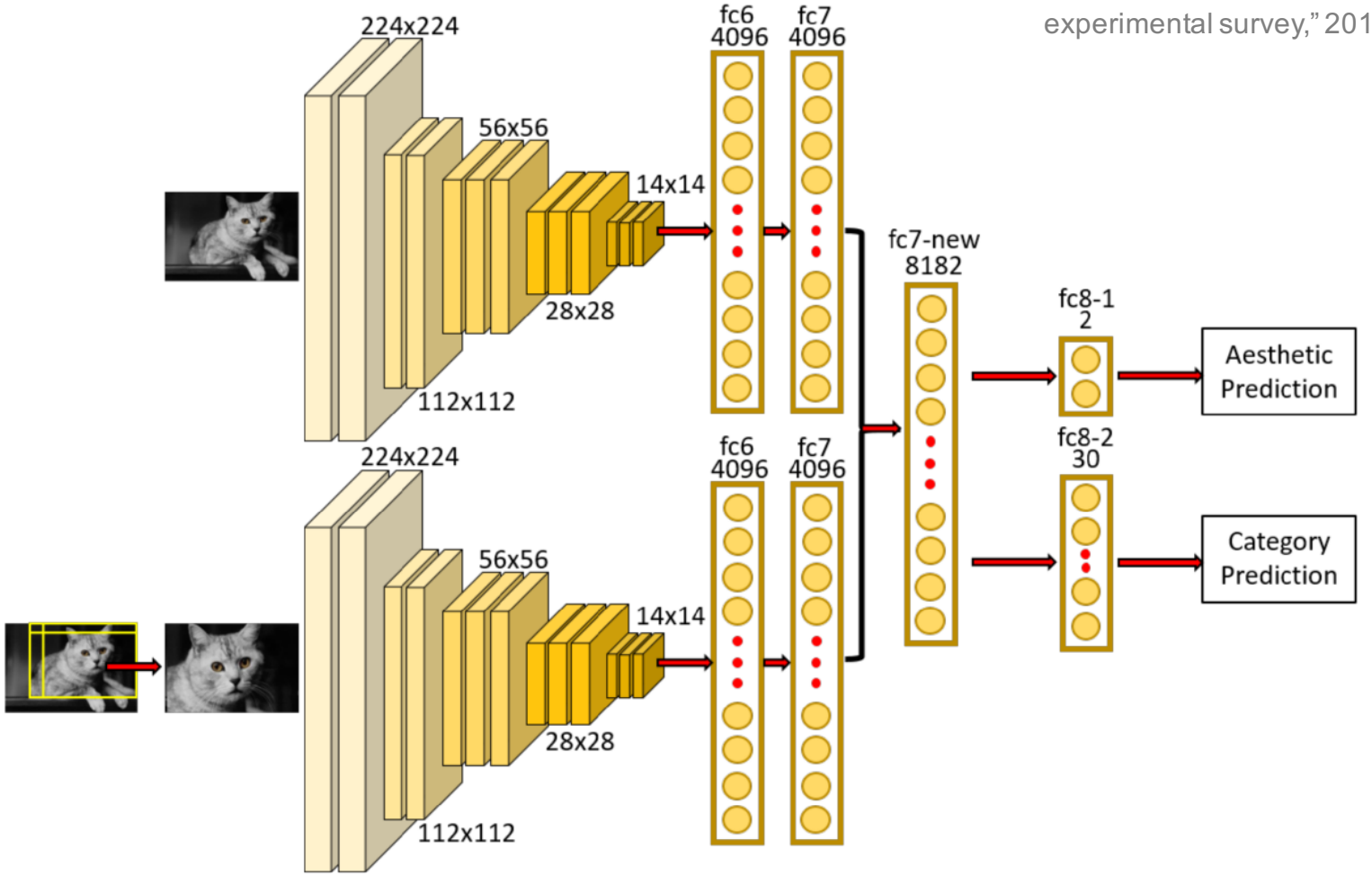
Y. Deng, C.-L. Chen, and X. Tang, "Image aesthetic assessment: An experimental survey," 2016.



PQA via Deep Learning

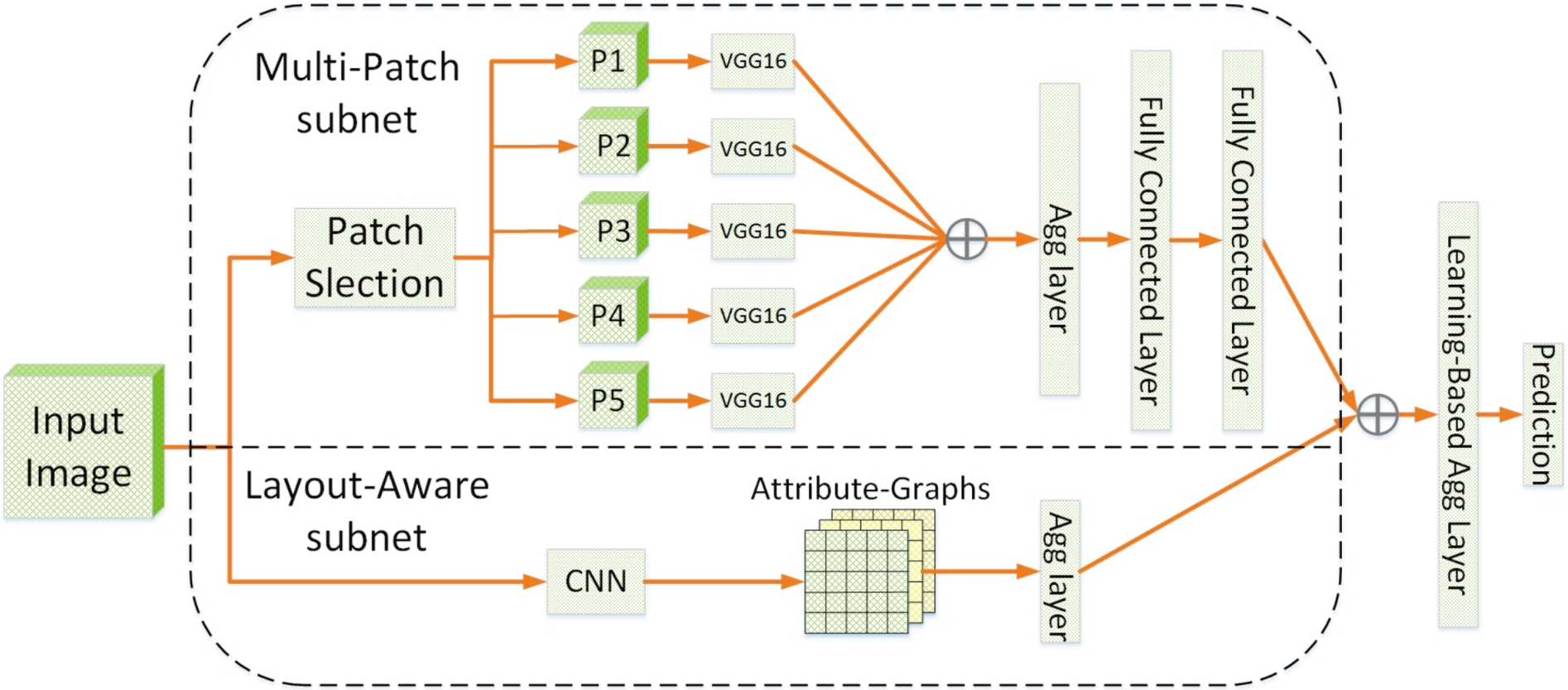
- Multi-task Multi-column CNNs

Y. Deng, C.-L. Chen, and X. Tang, "Image aesthetic assessment: An experimental survey," 2016.



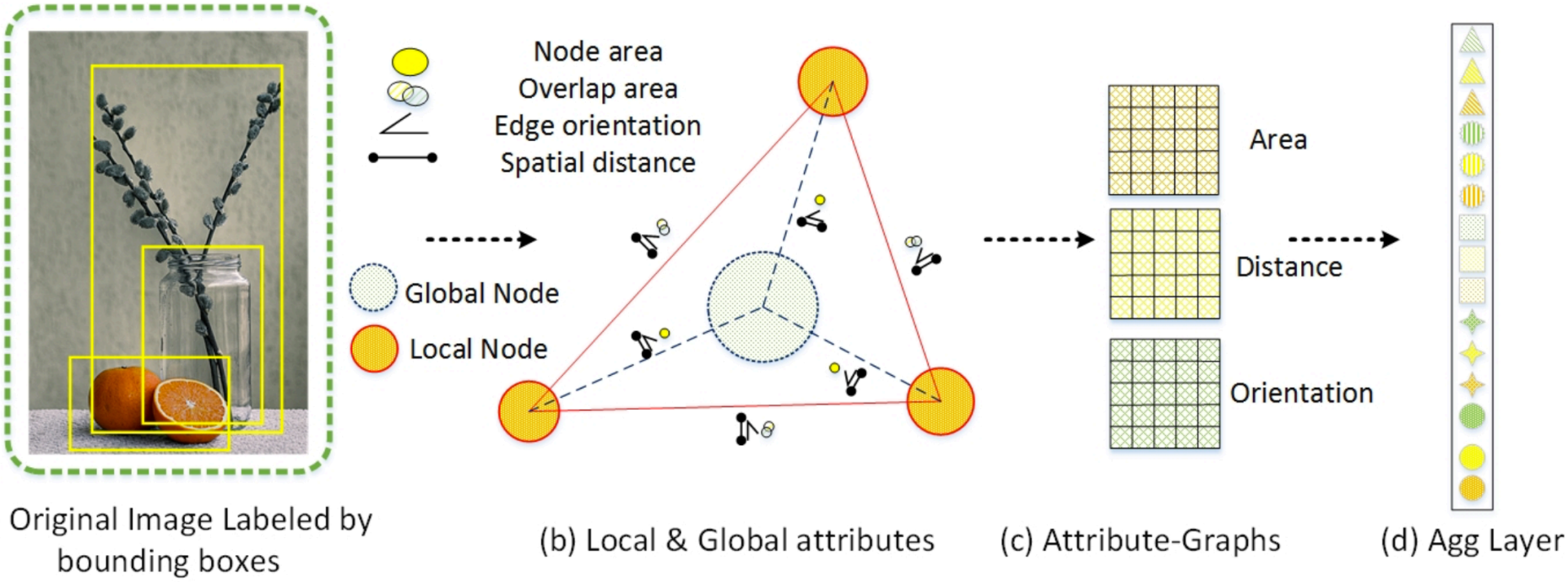
PQA via Deep Learning

- A-lamp
  - Adaptive Layout-Aware Multi-Patch



PQA via Deep Learning

- A-lamp



Pipeline of attribute-graphs construction. (a) Salient objects (labeled by yellow bounding boxes) are first detected by a trained CNN, and regarded as local nodes. The dashed green bounding box denote the overall scene, which served as a global node. (b) Local and global attributes are extracted from these nodes to capture the object topology and the image layout. (c) Attribute-graphs are constructed and (d) concatenated into an aggregation layer.

PQA via Deep Learning

- Performance

Method	Year	Accuracy
RAPID [10]	2014	75.42
SPP [21]	2015	72.85
DMA net [21]	2015	75.41
Peng et al. [35]	2016	74.50
Kao et al. [19]	2016	74.51
Kao et al. [25]	2016	76.15
Wang et al. [36]	2016	76.94
MNA-CNN [20]	2016	77.10
Kong et al. [9]	2016	77.33
BDN [24]	2016	78.08
Two-column DAN-2 [27]	2016	78.72
MTRLCNN [26]	2017	79.08
Lee et al. [37]	2017	81.02
A-Lamp [22]	2017	82.50
Proposed ($T_q = 5$)	2017	78.16
Proposed ($T_q = 4.8$)	2017	79.20

Y. Deng, C.-L. Chen, and X. Tang, "Image aesthetic assessment: An experimental survey," 2016.

PQA via Deep Learning

- Applications
  - Enhancement
  - Retargeting
  - Retrieval
  - Mobile APPs

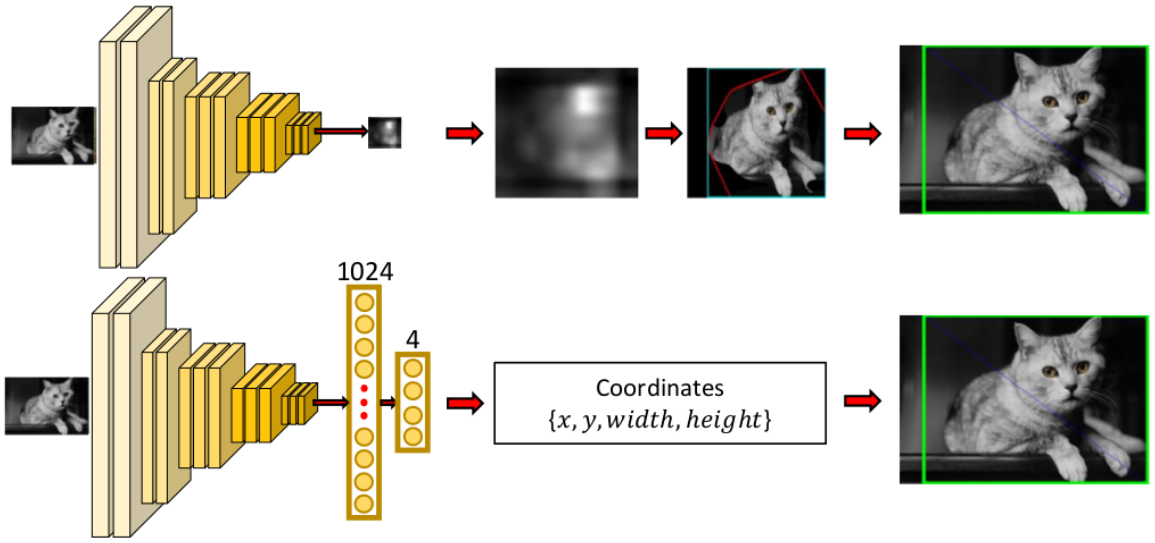
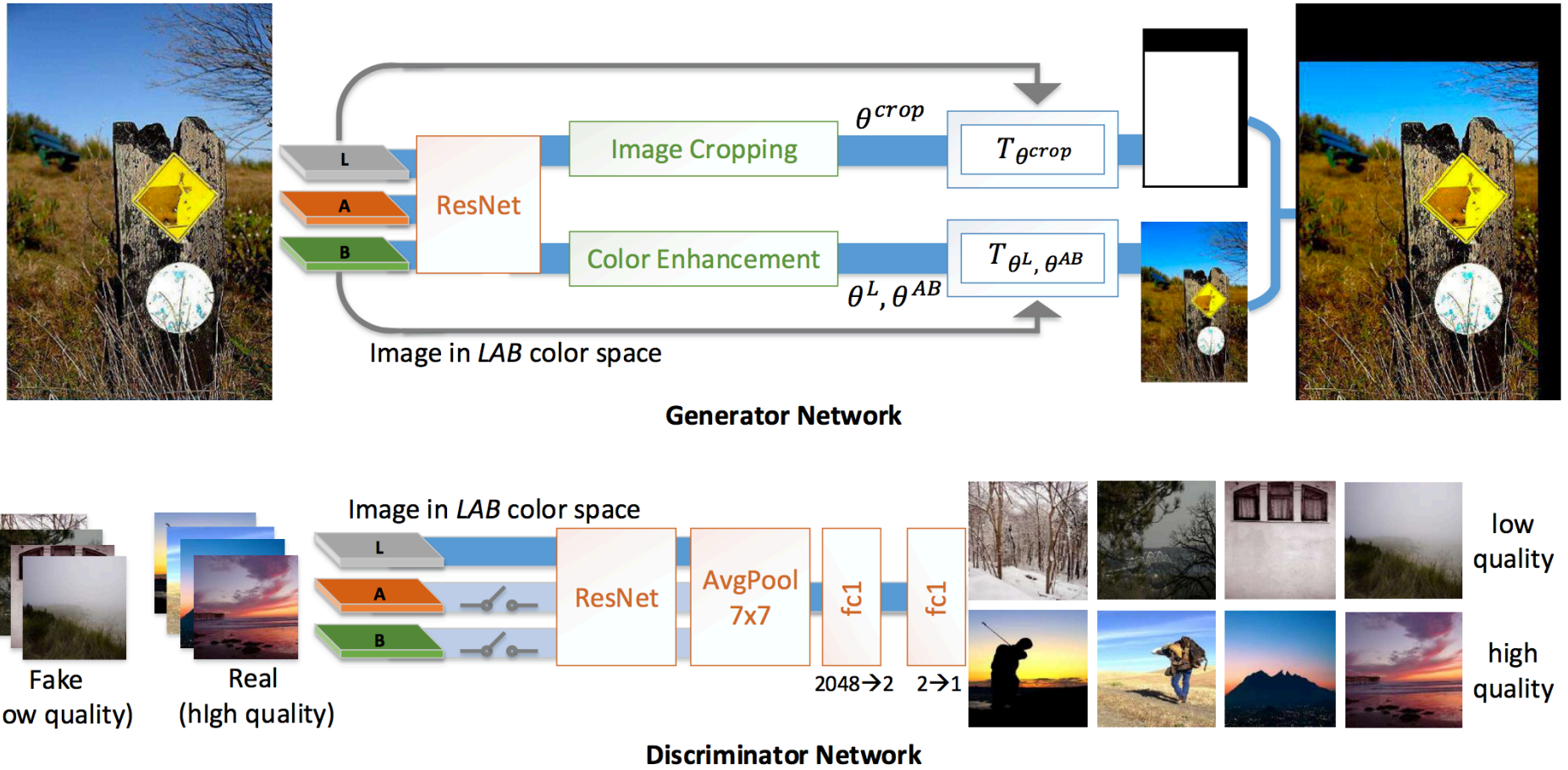


Image Enhancement

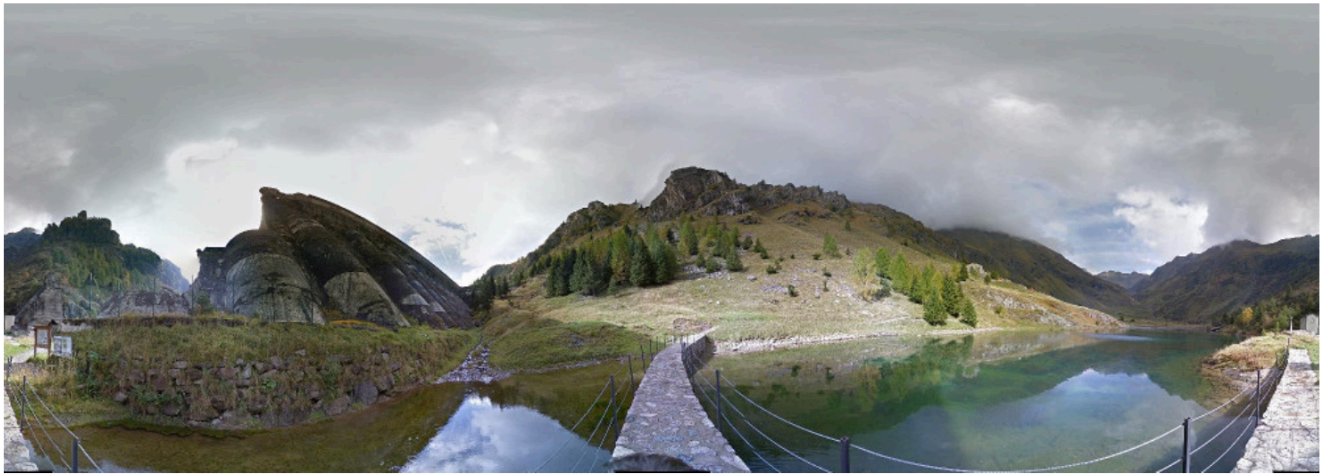
- EnhanceGAN



- Deng, Yubin, Chen Change Loy, and Xiaoou Tang. "Aesthetic-Driven Image Enhancement by Adversarial Learning." *arXiv preprint arXiv:1707.05251*(2017).

Image Enhancement

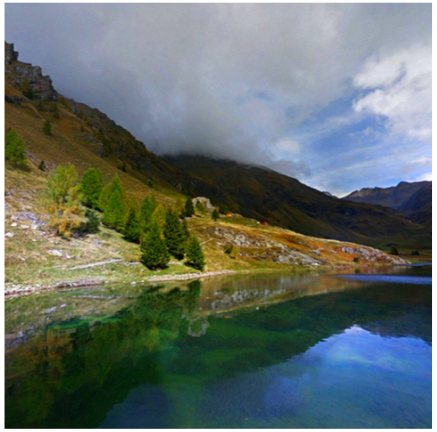
- Creatism



(a)

(b)

(c)



(d)

A panorama (a) is cropped into (b), with saturation and HDR strength enhanced in (c), and with dramatic mask applied in (d).

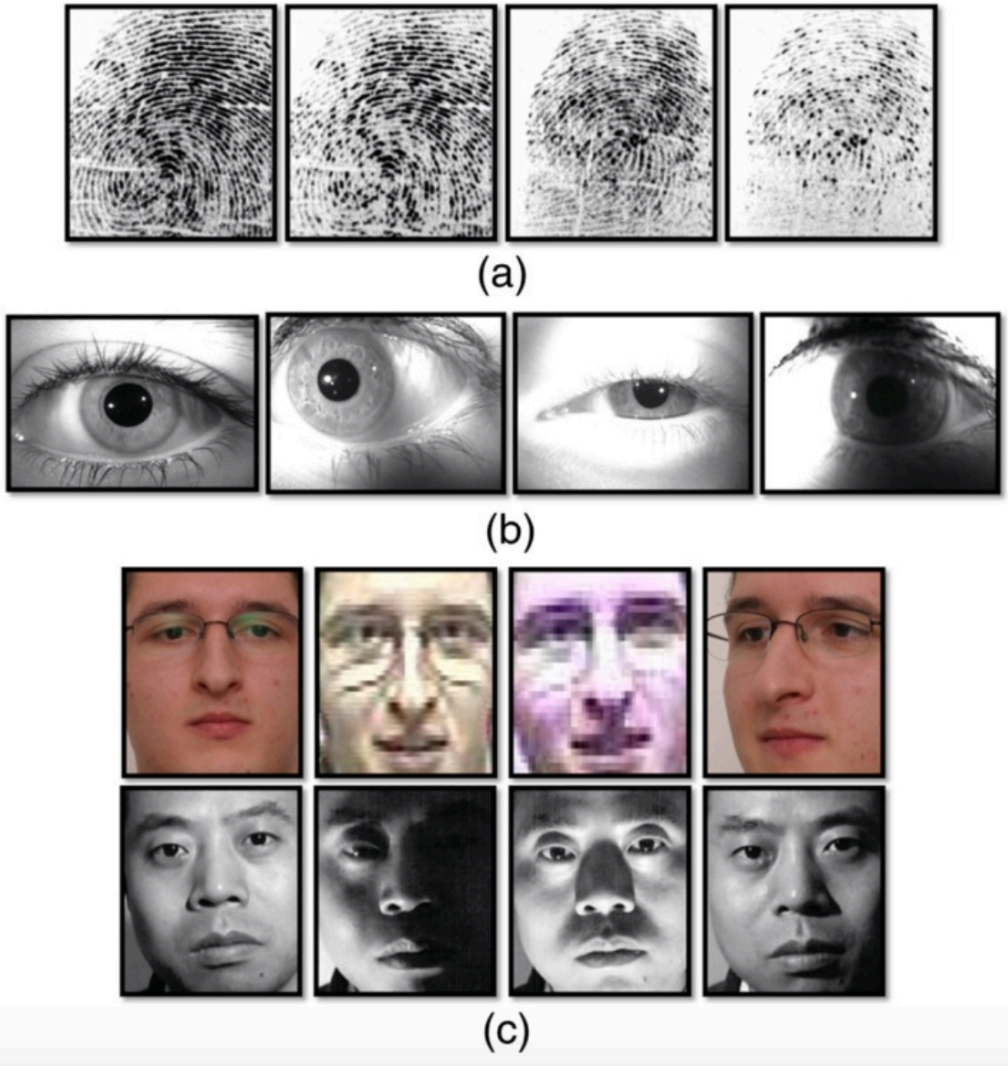
- Fang, Hui, and Meng Zhang. "Creatism: A deep-learning photographer capable of creating professional work." *arXiv preprint arXiv:1707.03491*(2017).

Contents

- Background
- Image Quality Assessment (IQA)
- Photo Quality Assessment (PQA)
- **Biometric Quality Assessment (BQA)**
- Discussions

Biometric Quality Assessment (BQA)

- Definition
  - *Quality of a biometric sample is a measure of its efficiency in aiding recognition of an individual, ideally, irrespective of the recognition system in use.*

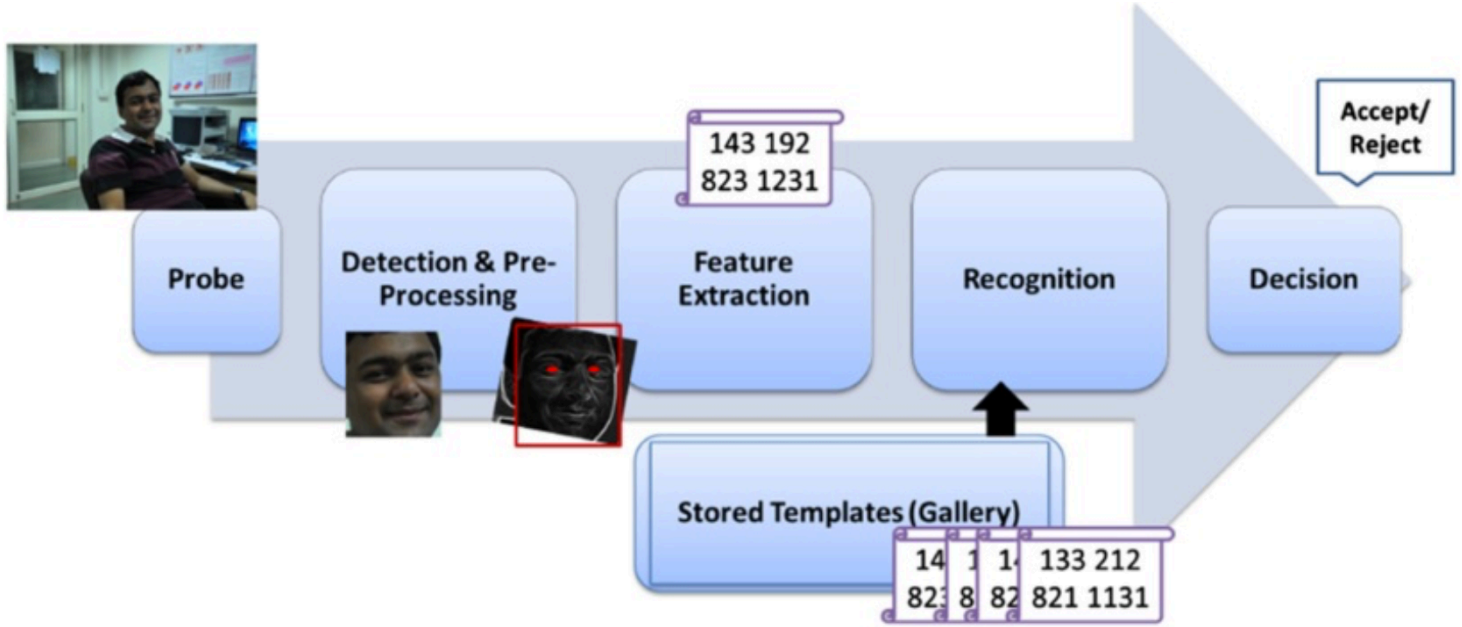


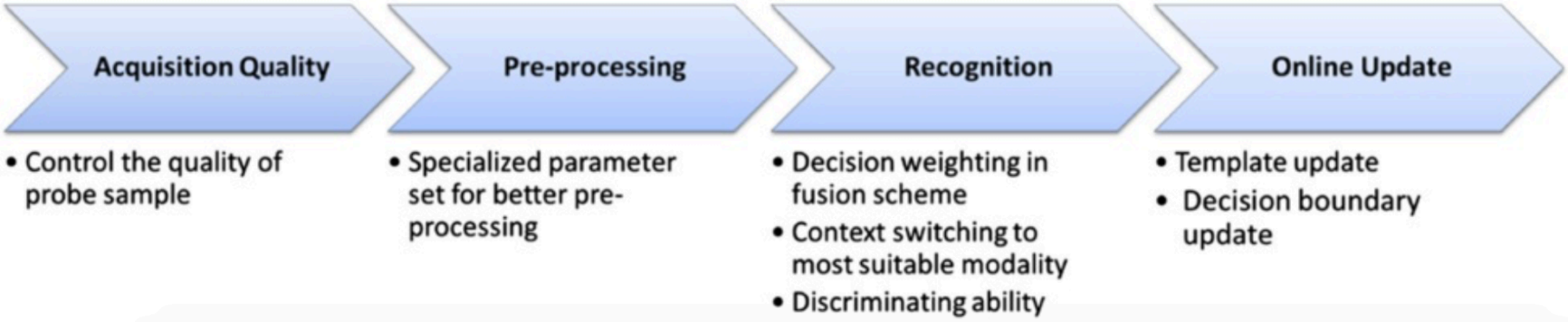
Sample images of varying quality.

(a) Fingerprint, (b) iris (from WVU multimodal database), and (c) face (from SCface and CAS-PEAL face databases)

Biometric Quality Assessment (BQA)

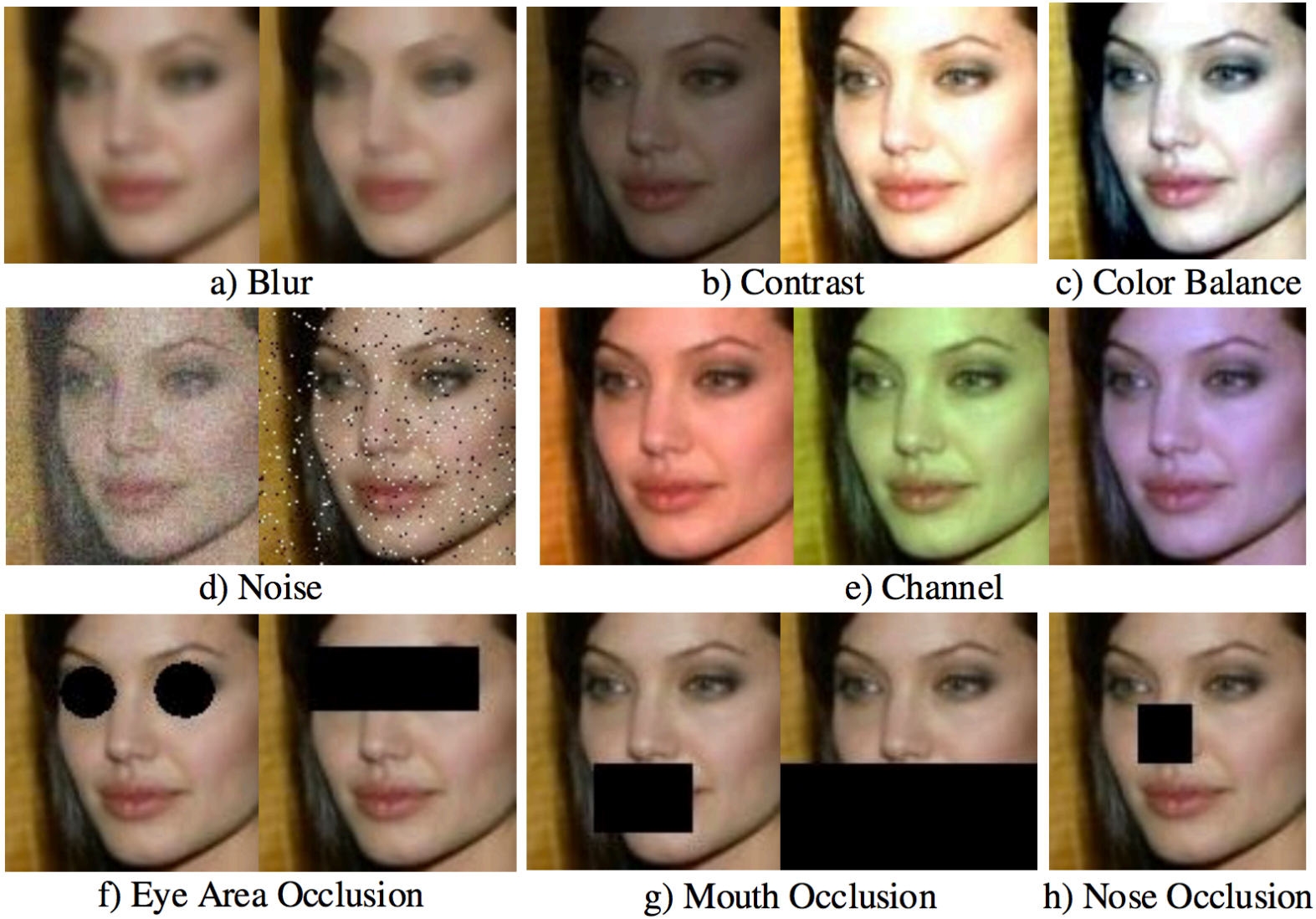
- Pipeline of a typical biometric system.





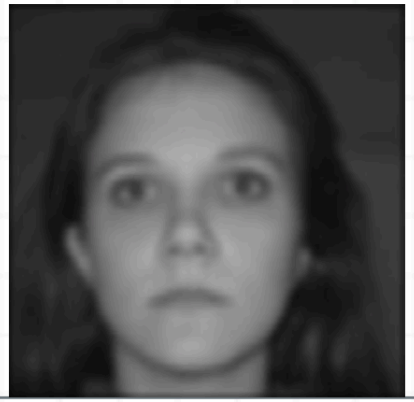
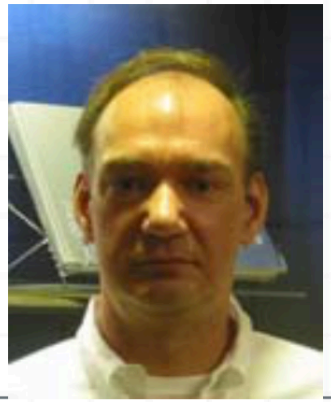
Biometric Quality Assessment (BQA)

- Face



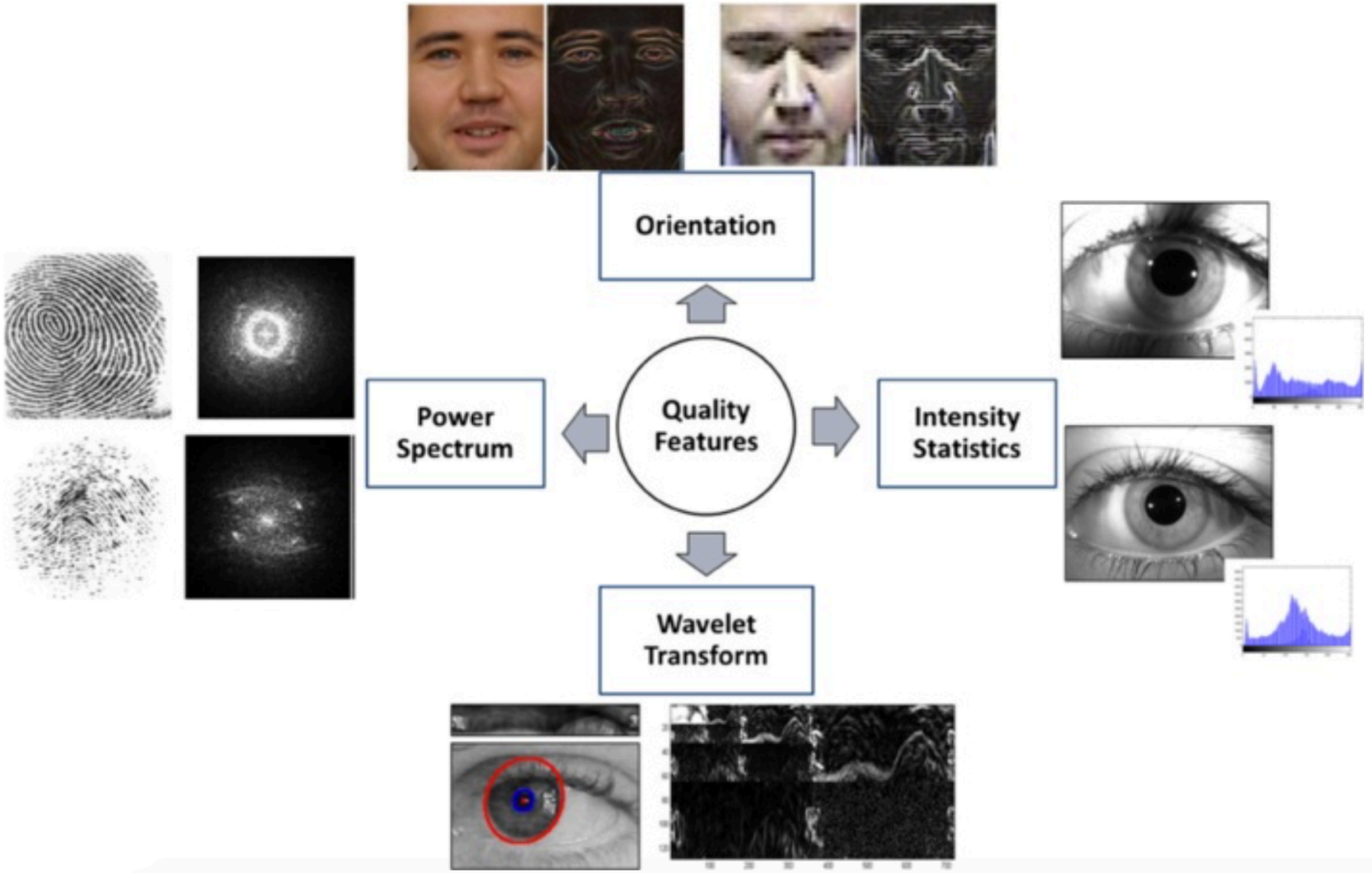
Biometric Quality Assessment (BQA)

- Face: ID

Metric / Quality	Compression Artifacts	Contrast	Focus	Facial Shadows
Good				
Poor				

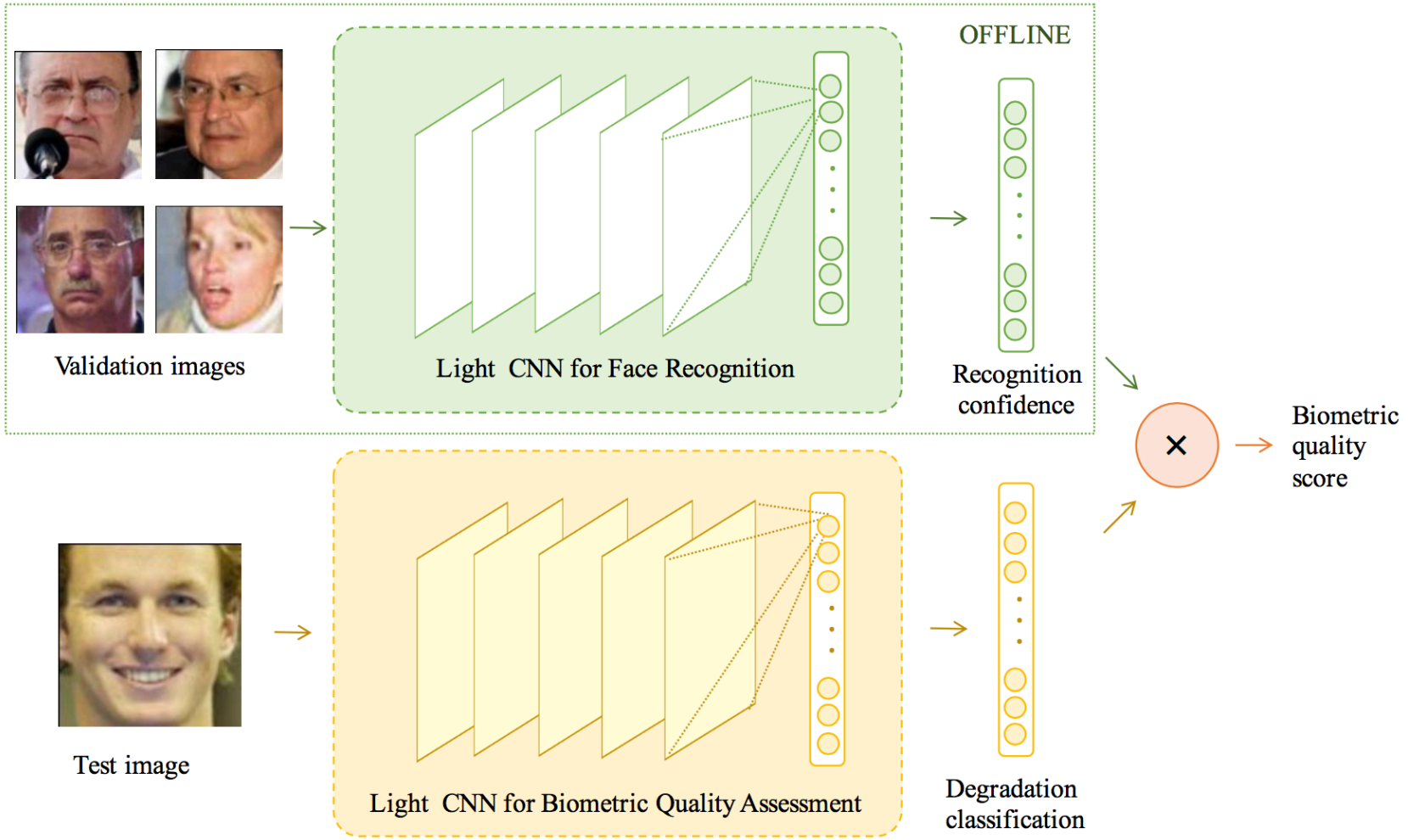
Biometric Quality Assessment (BQA)

- Four primary image features for BQA



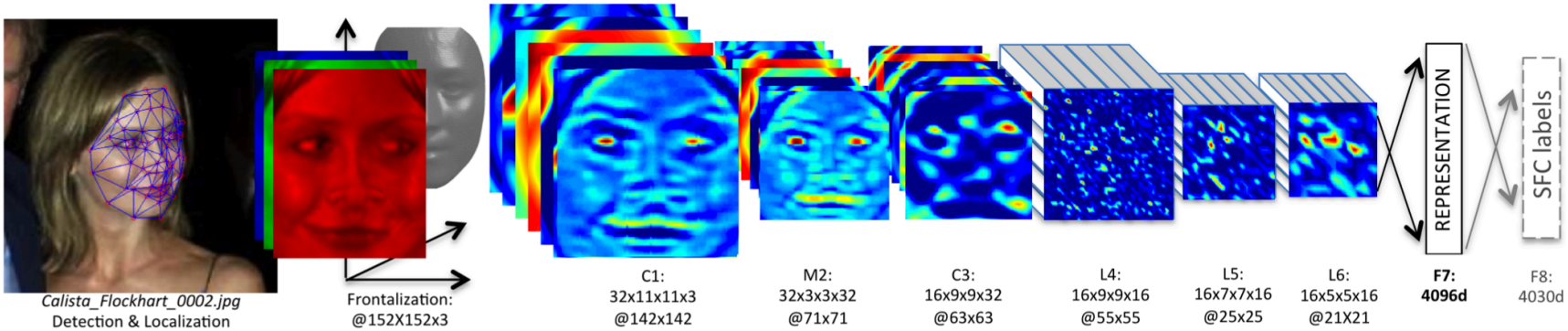
Biometric Quality Assessment (BQA)

- BQA via LightCNN



Biometric Quality Assessment (BQA)

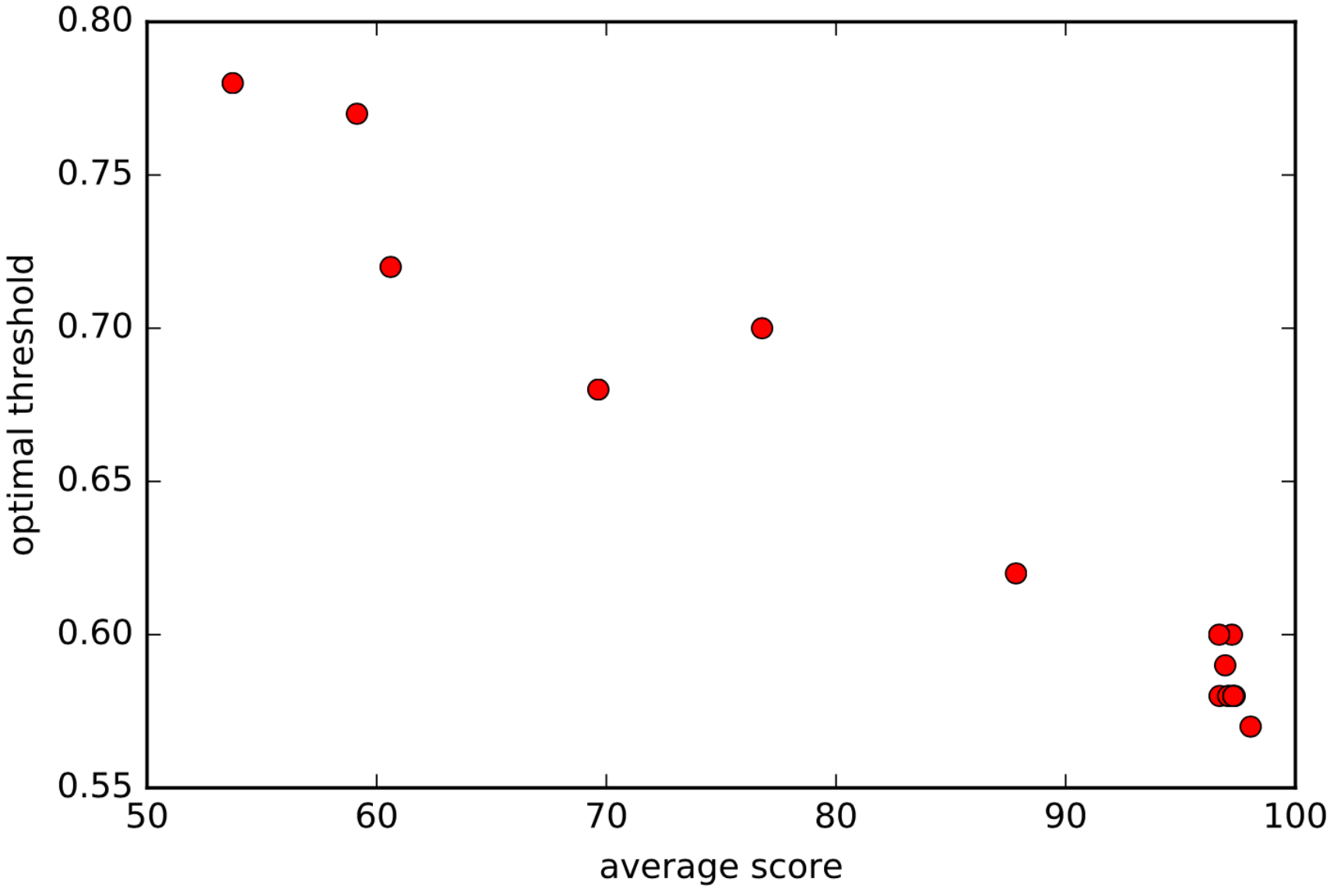
- Face recognition/identification/verification



Outline of the *DeepFace* architecture.

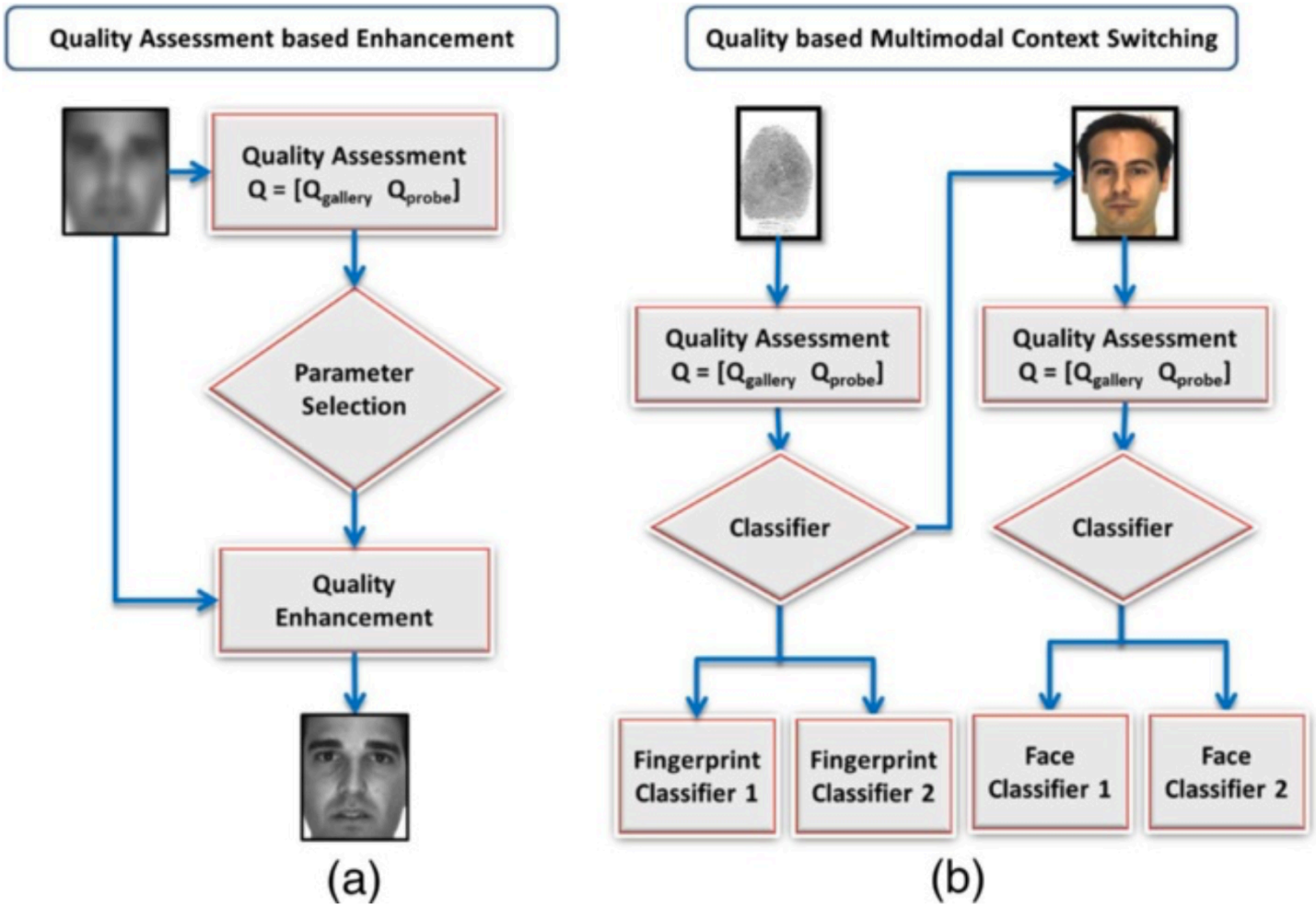
Cosine Sim.	Sigma	0	10	20	30	40	50
	VGG-Face	0.79	0.74	0.62	0.43	0.28	0.22
	AlexNet	0.61	0.54	0.33	0.22	0.16	0.13
	GoogLeNet	0.78	0.77	0.57	0.42	0.28	0.18

Biometric Quality Assessment (BQA)



Biometric Quality Assessment (BQA)

- **Applications:** Utilizing BQA for context switching



Contents

- Background
- Image Quality Assessment (IQA)
- Photo Quality Assessment (PQA)
- Biometric Quality Assessment (BQA)
- Discussions

Q & A

Thank You !