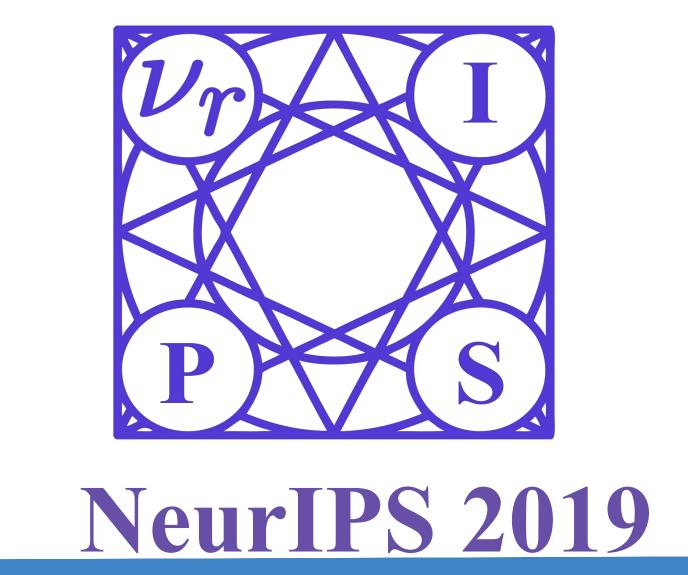




Quality Aware Generative Adversarial Networks

Parimala Kancharla, Sumohana S. Channappayya Department of Electrical Engineering, Indian Institute of Technology Hyderabad. India {ee15m17p100001,sumohana@iith.ac.in}



Objective and approach

- Goal: To design quality aware regularizers for training Generative Adversarial Networks.
- Approach: Using the full reference IQA algorithm (SSIM) and No reference IQA algorithm (NIQE).

Background

- Generative Adversarial Networks (GANs) [1] are generative models designed to learn the probability distribution of data that is aided by adversarial learning.
- A GAN is composed of two models: The generator model $G(z;\theta_G)$ the discriminator model $D(x;\theta_D)$
- Objective Function:

$$\min_{G} \max_{D} V(D,G) = E_{x \sim p_{data}(x)} [\log(D(x))] + E_{z \sim p_{z}(z)} [\log(1 - D(G(z)))] \quad \text{SSIM}(P_{(i,j)}, T_{(i,j)}) = L(P_{(i,j)}, T_{(i,j)}) \cdot C(P_{(i,j)}, T_{(i,j)}) \cdot S(P_{(i,j)}, T_{(i,j)})$$

Wasserstein Generative Adversarial Network

$$W(p_r, p_\theta) = \max_{w \in W} E_{x \sim p_r} [D_w(x)] - E_{z \sim p_z} [D_w(g_\theta(z))]$$

• Lipschitz constraint is enforced by weight clipping $w\epsilon[-c,c]$

WGAN-GP:

• Gradient penalty for discriminator loss to impose the lipschitz constraint.

$$|D(x) - D(y)| \le ||x - y||_2$$

$$L = E_{x \sim p_r} [D_w(x)] - E_{z \sim p_z} [D_w(g_\theta(z))] + \lambda E_{\hat{x}} (||\nabla D_w(\hat{x})||_2 - 1)^2$$

• Where the distribution of \hat{X} is taken to be the uniform distributions onlines connecting points drawn from p_r and $p_{g_{\theta}}(z)$

Structural Similarity Index (SSIM)

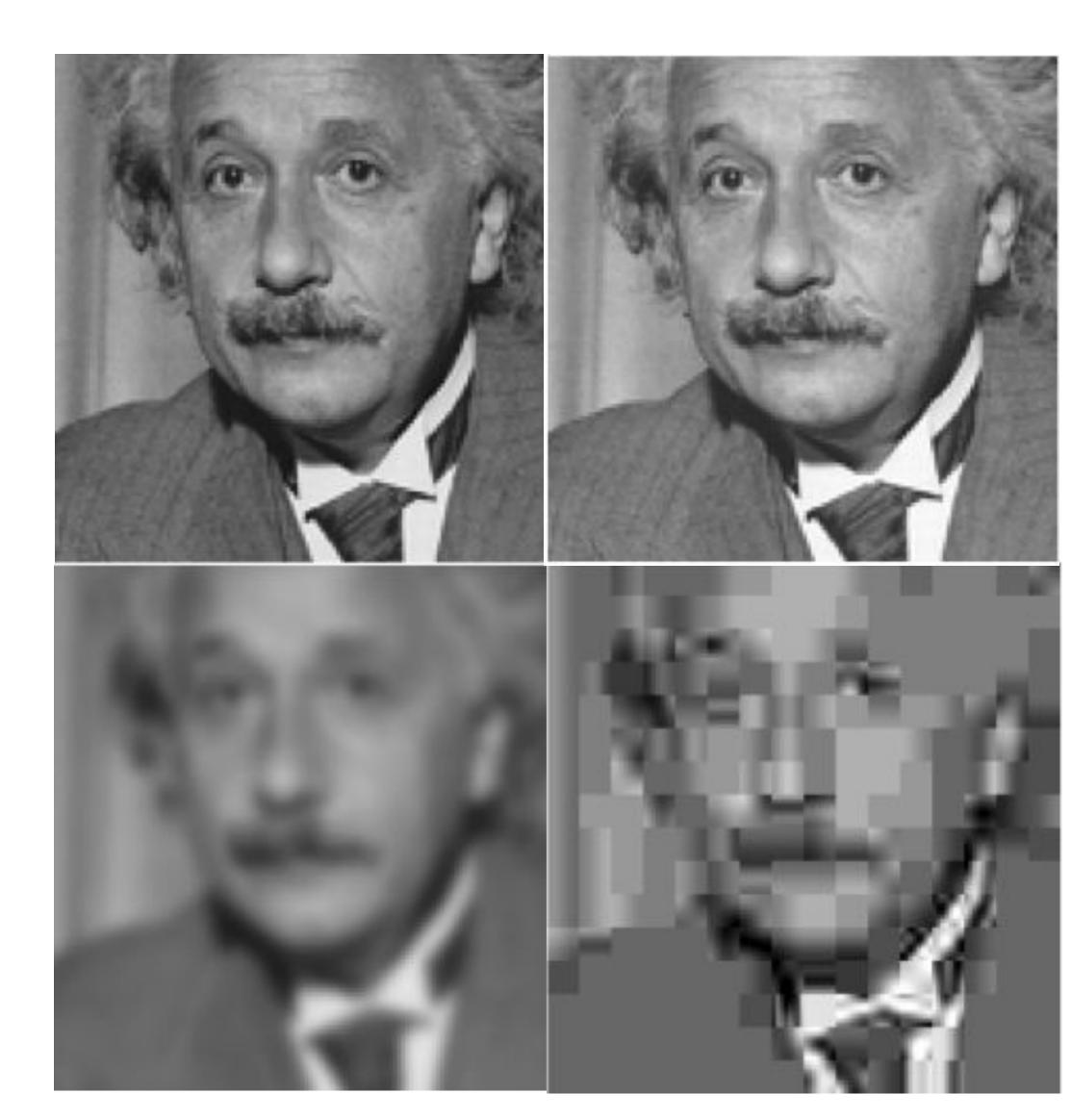


Figure: Same MSE! but different perceptual quality

OAGAN-SSIM

- Where P, T refers to the pristine and test images.
- $L(P_{(i,j)}, T_{(i,j)})$ $C(P_{(i,j)}, T_{(i,j)})$ $S(P_{(i,j)}, T_{(i,j)})$ and are the local luminance, contrast and structure scores at pixel (i, j) respectively. Further,

$$L(P_{(i,j)},T_{(i,j)}) = \frac{2\mu_P(i,j)\mu_T(i,j) + C_1}{\mu_P^2(i,j) + \mu_T^2(j) + C_1} \quad C(P_{(i,j)},T_{(i,j)}) = \frac{2\sigma_P(i,j)\sigma_T(i,j) + C_2}{\sigma_P^2(i,j) + \sigma_T^2(i,j) + C_2} \quad S(P_{(i,j)},T_{(i,j)}) = \frac{\sigma_{PT}(i,j) + C_3}{\sigma_P(i,j)\sigma_T(i,j) + C_3}$$

SSIM Metric:
$$d^Q(P_{(i,j)},T_{(i,j)}) = \sqrt{2 - L(P_{(i,j)},T_{(i,j)}) - CS(P_{(i,j)},T_{(i,j)})}$$
 $0 \le d^Q(x,y) \le \sqrt{2}$

• Discriminator should be lipstichtz with respect to $d^Q(X,Y)$.

SSIM GP =
$$E_{X \sim P_r, Y \sim P_G} \left[\left(\frac{|D(X) - D(Y)|}{d^Q(X, Y)} \right) - 1 \right]^2$$

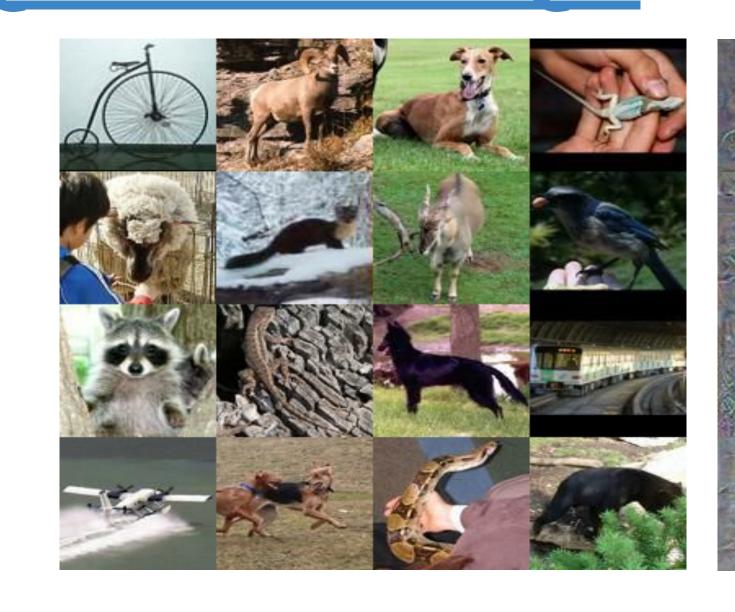
$$L_{d} = \min_{D \in \mathcal{D}} \left(E_{z \sim P_{z}} D(G(z)) - E_{X \sim P_{r}} D(X) \right) + \lambda_{1} E_{\hat{x} \sim P_{\hat{x}}} (||\nabla_{\hat{x}} D(\hat{x})||_{2} - 1)^{2} + \lambda_{2} E_{X \sim P_{r}, G(z) \sim P_{G}} \left[\left(\frac{|D(X) - D(G(z))|}{d^{Q}(X, G(z))} \right) - 1 \right]^{2}$$

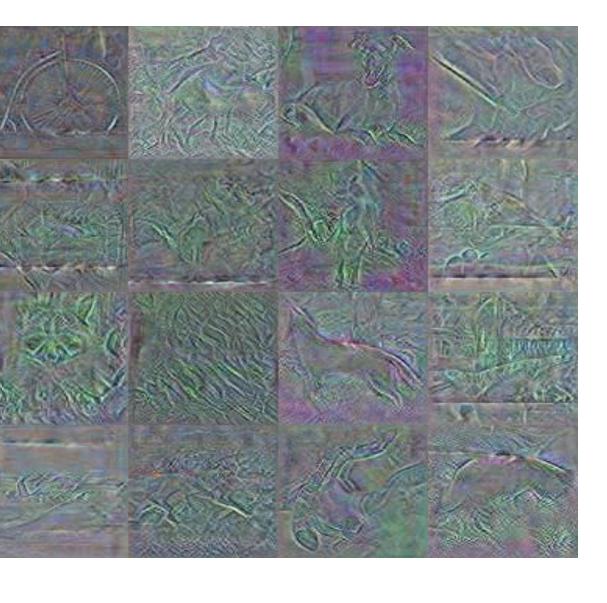
Natural Image Quality Evaluator (NIQE)

- NIQE builds a statistical model for the class of pristine natural scenes.
- Mean subtracted contrast normalization:
- The parameters of these GGD and AGGD models are in turn modeled using a Multivariate Gaussian (MVG) distribution.
- NIQE score: the "distance" of its MVG parameters from the pristine MVG parameters.

$$D(\mu_P, \mu_T, \Sigma_P, \Sigma_T) = \sqrt{(\mu_P - \mu_T)^T \left(\frac{\Sigma_P + \Sigma_T}{2}\right)^{-1} (\mu_P - \mu_T)}$$

OAGAN - NIOE





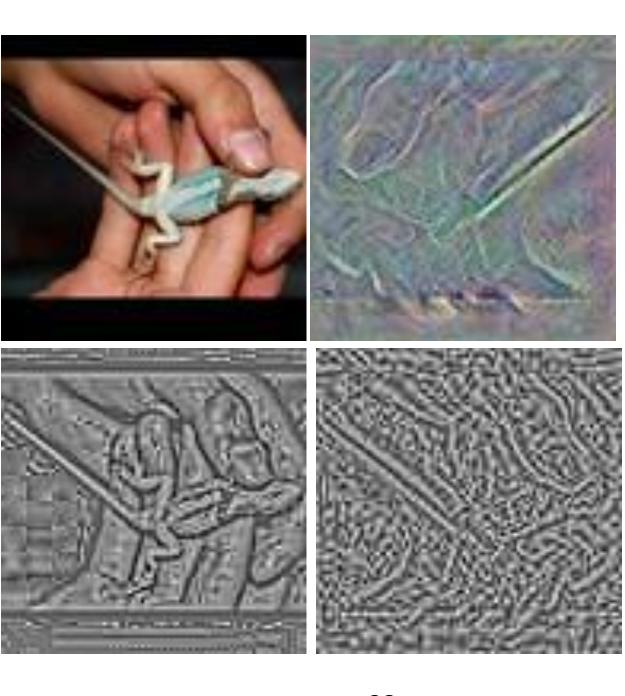
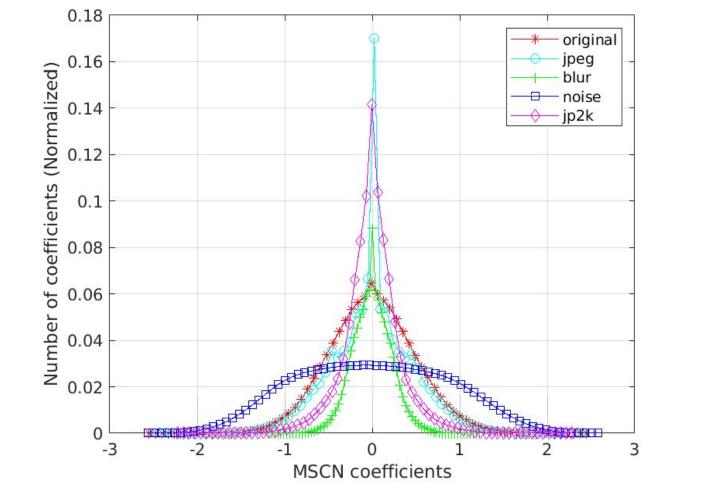
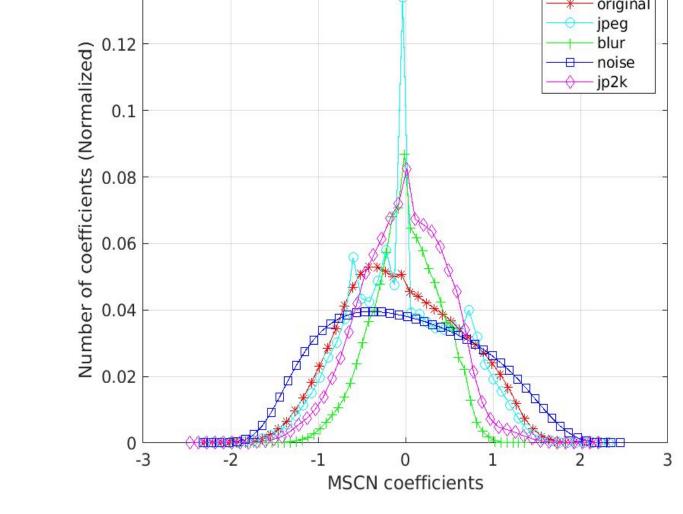


Figure: Real images and corresponding discriminator gradient maps.

Figure: MSCN coeffiecients.





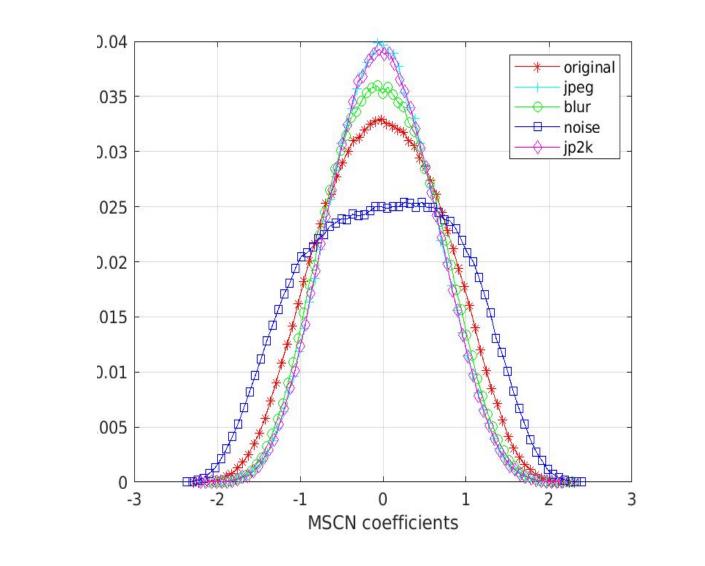


Figure: The empirical histograms of MSCN coefficients

- Motivation: To preserve the MSCN coefficients of the discriminator gradient map.
- The naturalness of a test discriminator gradient image T is computed to be its "distance" from the pristine image gradient class.

$$L_{d} = \min_{D \in \mathcal{D}} \left(E_{z \sim P_{z}} D(G(z)) - E_{X \sim P_{r}} D(X) \right) + \lambda_{1} E_{\hat{x} \sim P_{\hat{x}}} (||\nabla_{\hat{x}} D(\hat{x})||_{2} - 1)^{2} + \lambda_{2} E_{\hat{x} \sim P_{\hat{x}}} (||(\nabla_{\hat{x}} D(\hat{x})|\mu_{P}, \Sigma_{P})||_{\text{NIQE}})$$

 $\lambda_2 E_{X \sim P_r, G(z) \sim P_G} \left[\left(\frac{|D(X) - D(G(z))|}{d^Q(X, G(z))} \right) - 1 \right]^2$ • where λ 's are hyper parameters and those are chosen empirically.

Evaluation



Figure: Randomly generated images using QAGANs for CelebA, STL10 datasets. Right: QAGAN-SSIM, Left: QAGAN-NIQE.

• FID and IS scores on CelebA, STL10 and CIFAR10 datasets.

Model	FID	Model	IS	FID	Model	IS	FID
Faces (CelebA)	1.09	Real Data (48×48)	26.08 ± 0.26	7.9	Real data	11.24 ± 0.12	7.80
WGAN-GP	12.89	WGAN-GP	9.05 ± 0.12	55.1 ± 0.0	DCGAN	6.16 ± 0.07	-
The state of the s		SNGAN	9.10 ± 0.04	40.10 ± 0.50	WGAN-GP	7.86 ± 0.10	40.2 ± 0.0
anach WGAN	10.5				CTGAN	8.12 ± 0.12	-
ID GAN-rep-b	6.79	MMD GAN-rep	9.36 ± 0.0	36.67 ± 0.0	SNGAN	8.12 ± 0.12	21.5 ± 0.23
GAN (SSIM)	6.421	QAGAN (SSIM)	9.29 ± 0.05	19.77 ± 0.0091	$W^{-\frac{3}{2},2}$ - Banach WGAN	8.26 ± 0.07	-
GAN (NIQE)	6.504	QAGAN (NIQE)	9.1720 ± 0.08	$\boxed{19.45 \pm 0.0013}$	L^{10} - Banach WGAN	8.31 ± 0.07	-
GAIT (ITTQL)	0.504				MMD GAN-rep-b	8.29 ± 0.0	16.21 ± 0.0
					QAGAN (SSIM)	$\textbf{8.37} \pm \textbf{0.04}$	$\textbf{13.91} \pm \textbf{0.1}$

Conclusions:

- Based on insights from both FR and NR IQA metrics, we have proposed two novel regularization approaches for the WGAN-GP framework.
- The key takeaway from our work is that the unique local structural and statistical signature of pristine natural images must be preserved in the generated images.

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