

# Blind Image Quality Assessment

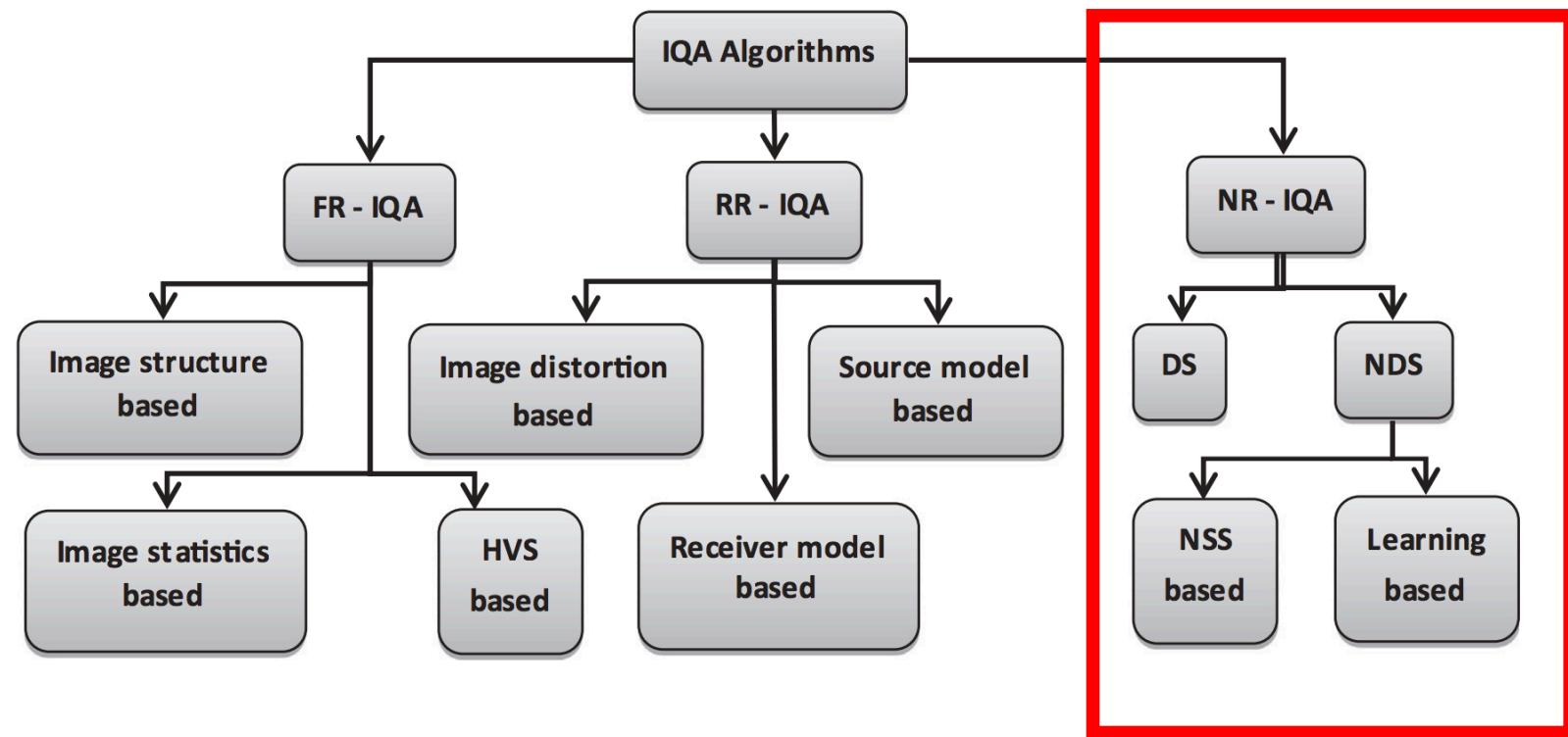
Оценка качества изображения без источника

# Постановка задачи



$$MOS = \frac{1}{n} \sum OS(I)$$

$$\textbf{DMOS} = \max(0, MOS(R) - MOS(I))$$



# Метрики качества методов

- LCC (Pearson's correlation coefficient):

$$\rho_{X,Y} = \frac{\text{cov}(X, Y)}{\sigma_X \sigma_Y}$$

- SROCC (Spearman's rank-order correlation coefficient):

$$r_s = \rho_{\text{rg}_X, \text{rg}_Y} = \frac{\text{cov}(\text{rg}_X, \text{rg}_Y)}{\sigma_{\text{rg}_X} \sigma_{\text{rg}_Y}}$$

# NSS-based approach

- Естественные изображения имеют схожие статистические характеристики, отличные от неестественных:

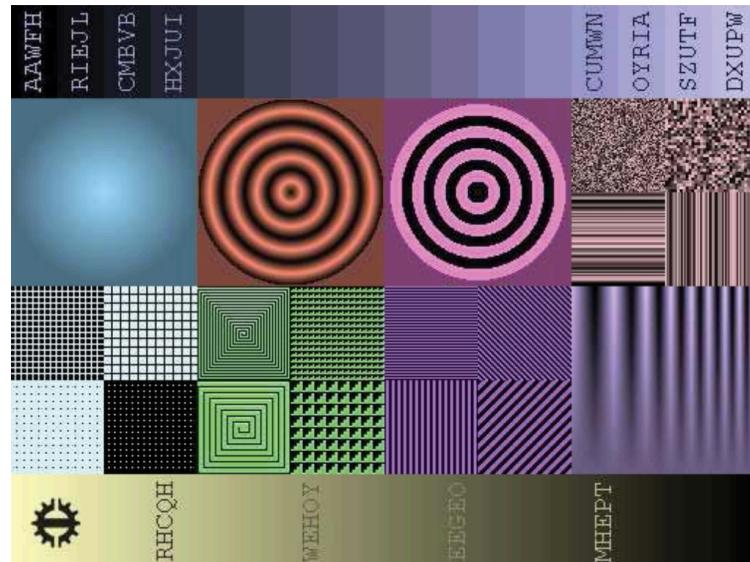
CONTRAST

STRUCTURE

ANISOTROPY

# NSS-based approach

- Естественные изображения имеют схожие статистические характеристики, отличные от неестественных:



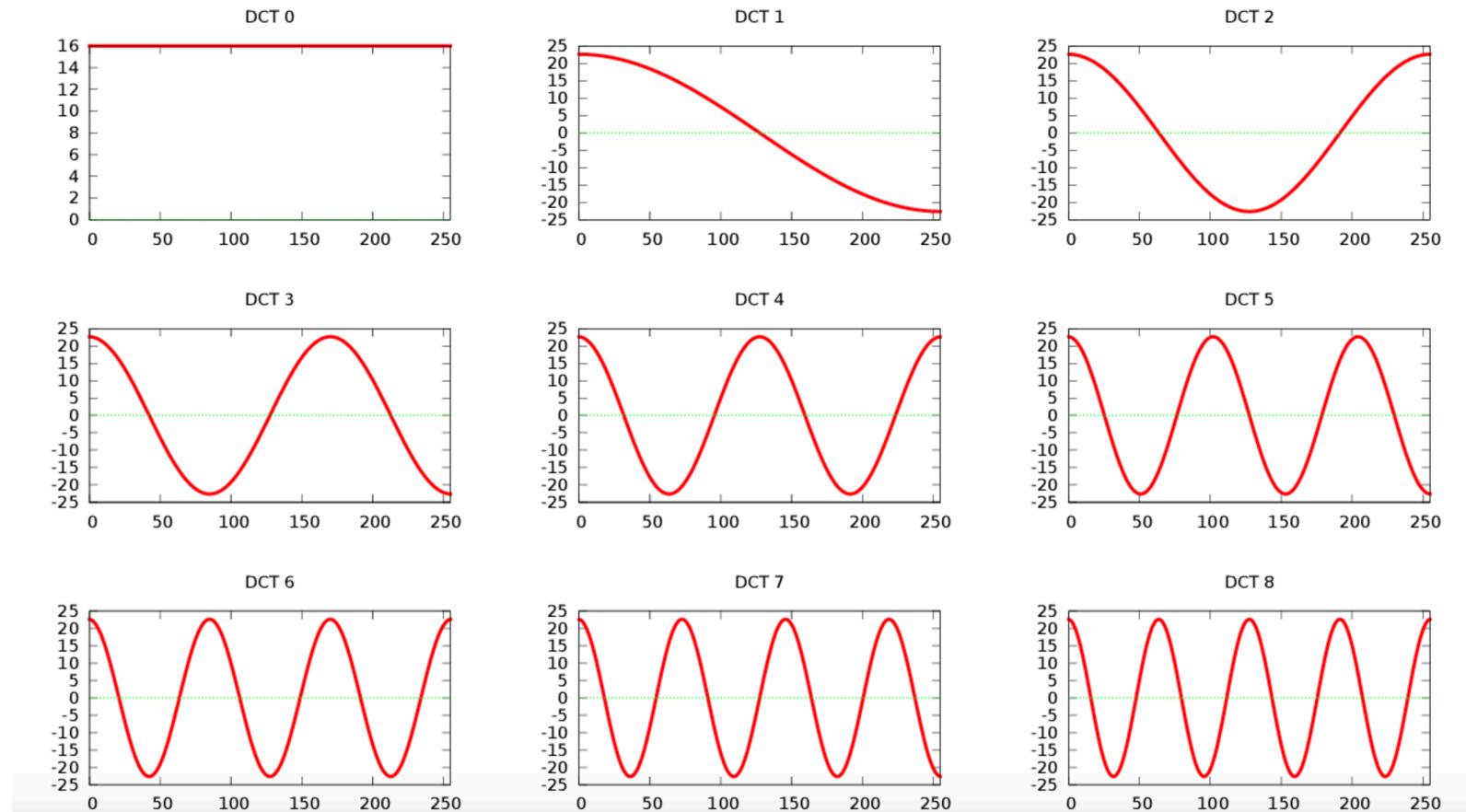
# Discrete Cosine Transform (DCT)

$$X_k = C(k) \sum_{n=0}^{N-1} x_n \cos\left(\frac{\pi k(2n+1)}{2N}\right), \quad k = 0 : N-1$$

$$x_n = \sum_{k=1}^{N-1} C(k) X_k \cos\left(\frac{\pi k(2n+1)}{2N}\right), \quad k = 0 : N-1$$

$$C(x) = \begin{cases} 1/N, & x = 0 \\ \sqrt{2/N}, & x > 0 \end{cases}$$

# Discrete Cosine Transform (DCT)



# Discrete Cosine Transform (DCT)

$$U_{i,j} = \begin{cases} 1/N, & i = 0 \\ \sqrt{2/N} \cos\left(\frac{\pi k(2n+1)}{2N}\right), & i > 0 \end{cases}$$

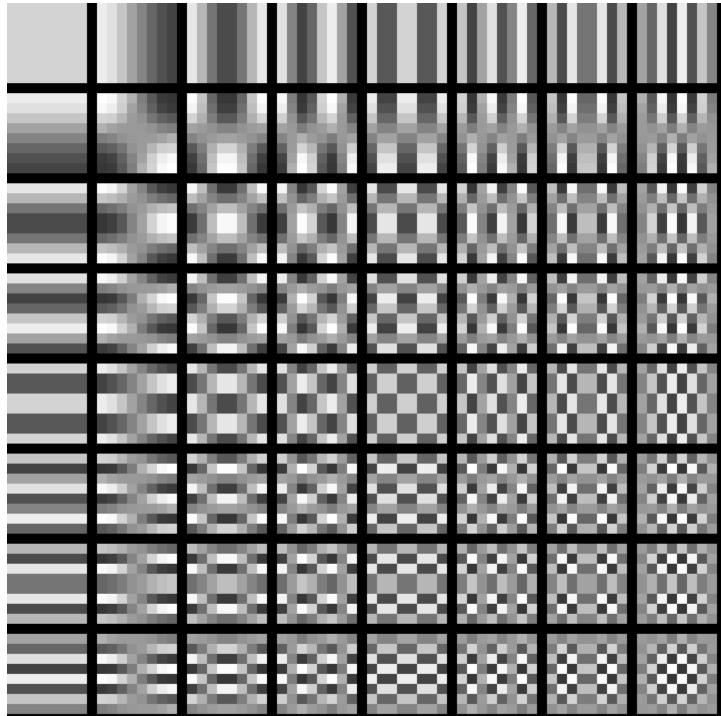
$$X = F(x) = Ux$$

$$x = F^{-1}(x) = U^T x$$

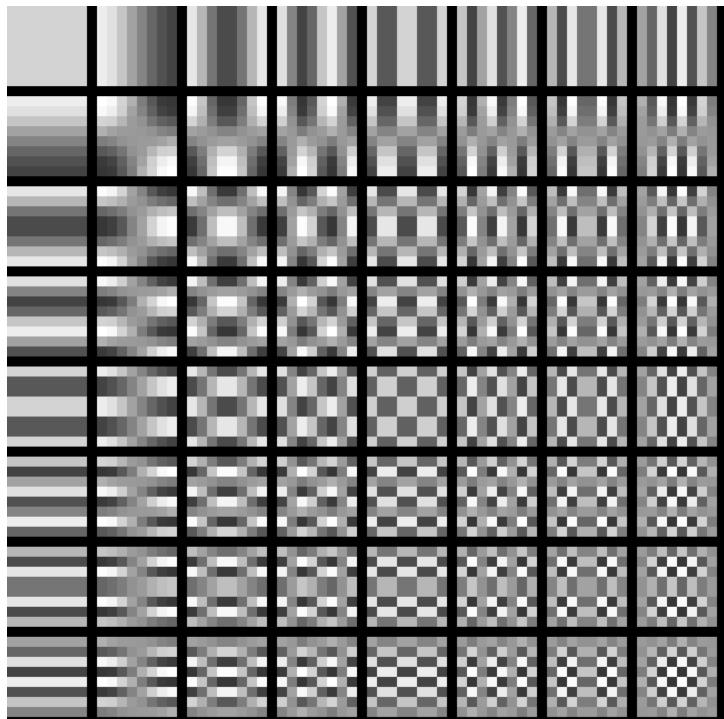
2D-Transform:  $X = F(x) = UxU^T$

$$D = \frac{1}{2} \begin{bmatrix} \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \\ \cos \frac{\pi}{16} & \cos \frac{3\pi}{16} & \cos \frac{5\pi}{16} & \cos \frac{7\pi}{16} & \cos \frac{9\pi}{16} & \cos \frac{11\pi}{16} & \cos \frac{13\pi}{16} & \cos \frac{15\pi}{16} \\ \cos \frac{2\pi}{16} & \cos \frac{6\pi}{16} & \cos \frac{10\pi}{16} & \cos \frac{14\pi}{16} & \cos \frac{18\pi}{16} & \cos \frac{22\pi}{16} & \cos \frac{26\pi}{16} & \cos \frac{30\pi}{16} \\ \cos \frac{3\pi}{16} & \cos \frac{9\pi}{16} & \cos \frac{15\pi}{16} & \cos \frac{21\pi}{16} & \cos \frac{27\pi}{16} & \cos \frac{33\pi}{16} & \cos \frac{39\pi}{16} & \cos \frac{45\pi}{16} \\ \cos \frac{4\pi}{16} & \cos \frac{12\pi}{16} & \cos \frac{20\pi}{16} & \cos \frac{28\pi}{16} & \cos \frac{36\pi}{16} & \cos \frac{44\pi}{16} & \cos \frac{52\pi}{16} & \cos \frac{60\pi}{16} \\ \cos \frac{5\pi}{16} & \cos \frac{15\pi}{16} & \cos \frac{25\pi}{16} & \cos \frac{35\pi}{16} & \cos \frac{45\pi}{16} & \cos \frac{55\pi}{16} & \cos \frac{65\pi}{16} & \cos \frac{75\pi}{16} \\ \cos \frac{6\pi}{16} & \cos \frac{18\pi}{16} & \cos \frac{30\pi}{16} & \cos \frac{42\pi}{16} & \cos \frac{54\pi}{16} & \cos \frac{66\pi}{16} & \cos \frac{78\pi}{16} & \cos \frac{90\pi}{16} \\ \cos \frac{7\pi}{16} & \cos \frac{21\pi}{16} & \cos \frac{35\pi}{16} & \cos \frac{49\pi}{16} & \cos \frac{63\pi}{16} & \cos \frac{77\pi}{16} & \cos \frac{91\pi}{16} & \cos \frac{105\pi}{16} \end{bmatrix}$$

# Discrete Cosine Transform (DCT)



# Discrete Cosine Transform (DCT)

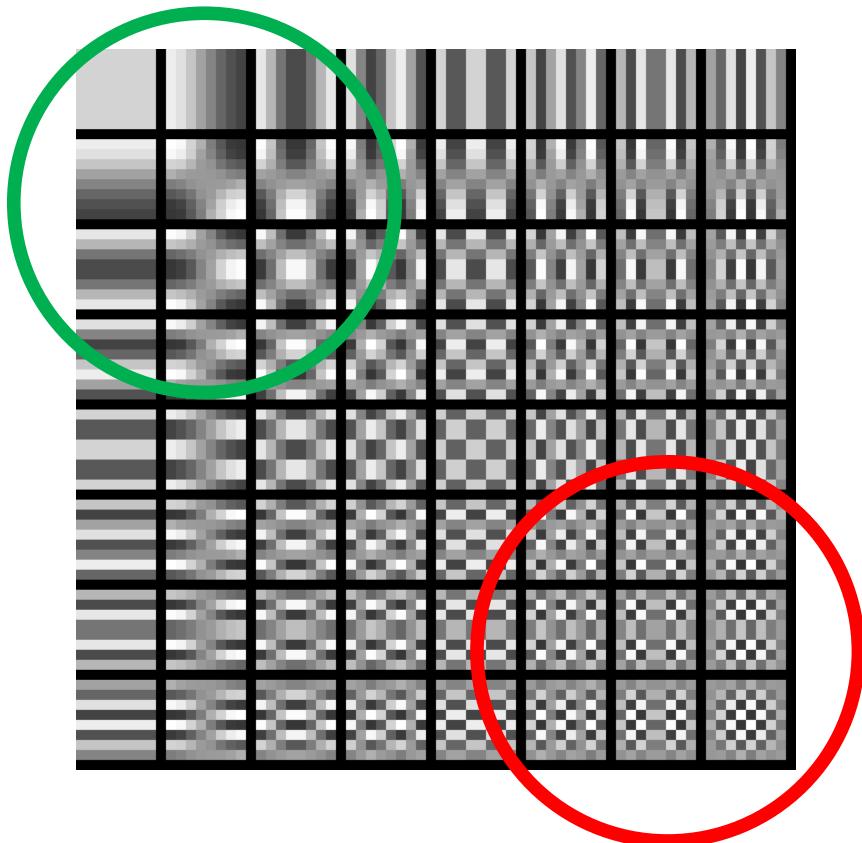


$$\begin{bmatrix} 51 & 52 & 51 & 50 & 50 & 52 & 50 & 52 \\ 51 & 52 & 51 & 51 & 50 & 52 & 52 & 51 \\ 50 & 50 & 51 & 52 & 52 & 51 & 51 & 51 \\ 51 & 50 & 50 & 50 & 52 & 50 & 50 & 51 \\ 51 & 50 & 50 & 51 & 50 & 50 & 51 & 50 \\ 50 & 51 & 52 & 52 & 51 & 50 & 50 & 50 \\ 51 & 52 & 51 & 50 & 52 & 50 & 52 & 50 \\ 50 & 51 & 52 & 52 & 50 & 51 & 52 & 51 \end{bmatrix}$$



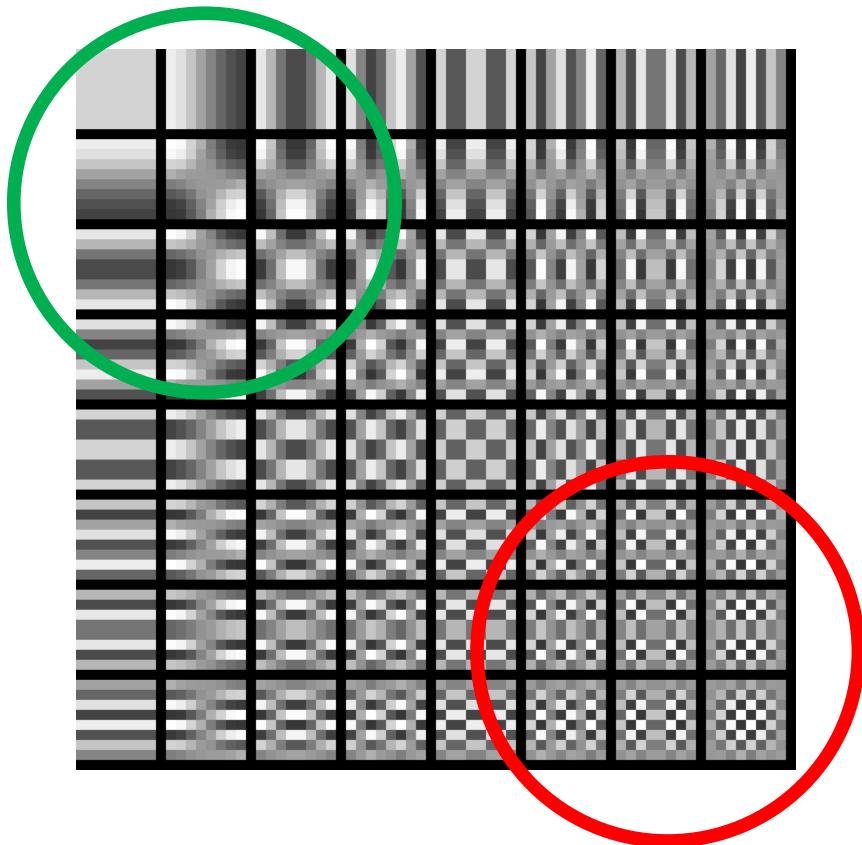
$$\begin{bmatrix} 407 & 0.058 & -0.518 & -0.592 & -0.5 & 0.118 & -0.597 & 0.086 \\ 0.352 & -0.654 & 1.019 & 0.818 & 0.179 & -1.074 & 1.190 & -1.194 \\ 1.904 & -0.116 & 1. & -0.598 & -2.174 & -0.352 & 0.293 & -1.006 \\ -0.661 & 1.350 & 0.689 & -0.055 & -0.425 & -0.599 & 0.254 & -0.412 \\ -1. & -0.335 & 1.171 & 0.102 & 0.5 & -0.020 & 0.868 & -0.502 \\ -0.229 & 0.162 & 0.115 & 0.711 & 0.956 & -1.902 & -0.108 & 1.454 \\ 0.023 & -0.173 & -1.707 & -1.529 & 0.630 & 0.109 & 1. & -0.603 \\ -0.110 & -0.383 & 0.105 & 0.470 & 0.005 & 0.568 & -0.470 & 0.111 \end{bmatrix}$$

# Discrete Cosine Transform (DCT)



- **Низкочастотная** информация  
(основные объекты на изображении)
- **Высокочастотная** информация  
(незаметные человеческому глазу детали)

# Discrete Cosine Transform (DCT)



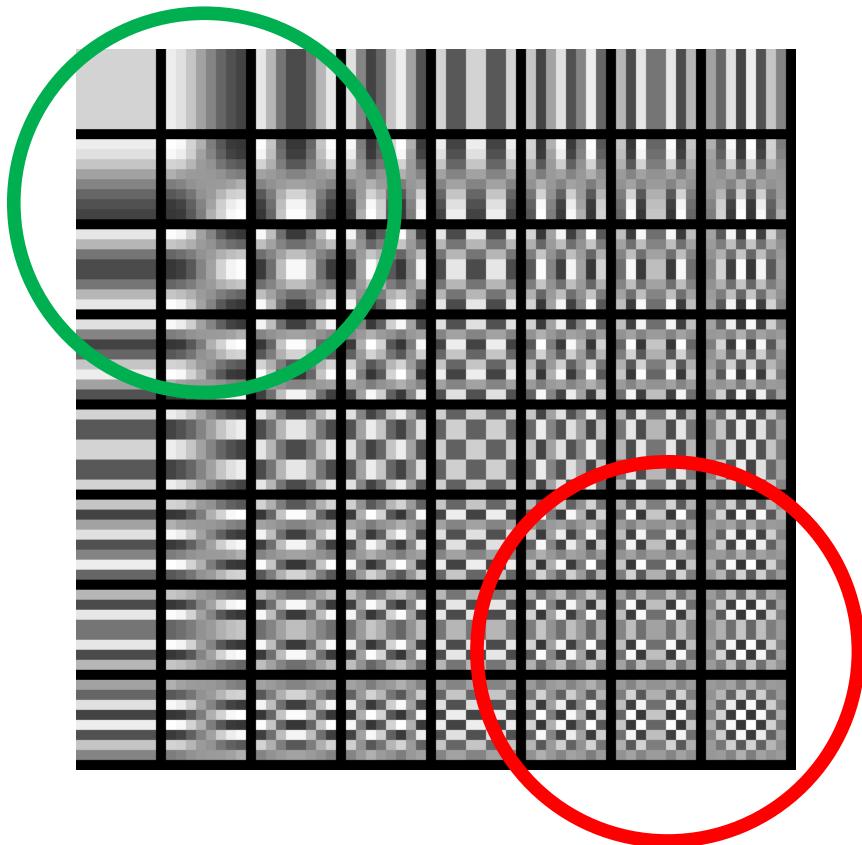
$$D(x) = F^{-1}(G(F(x)))$$



JPEG



# Discrete Cosine Transform (DCT)



$$D(x) = F^{-1}(G(F(x)))$$

$$G(i,j) = \exp(-2\pi^2\sigma^2(i^2+j^2))$$



Blur

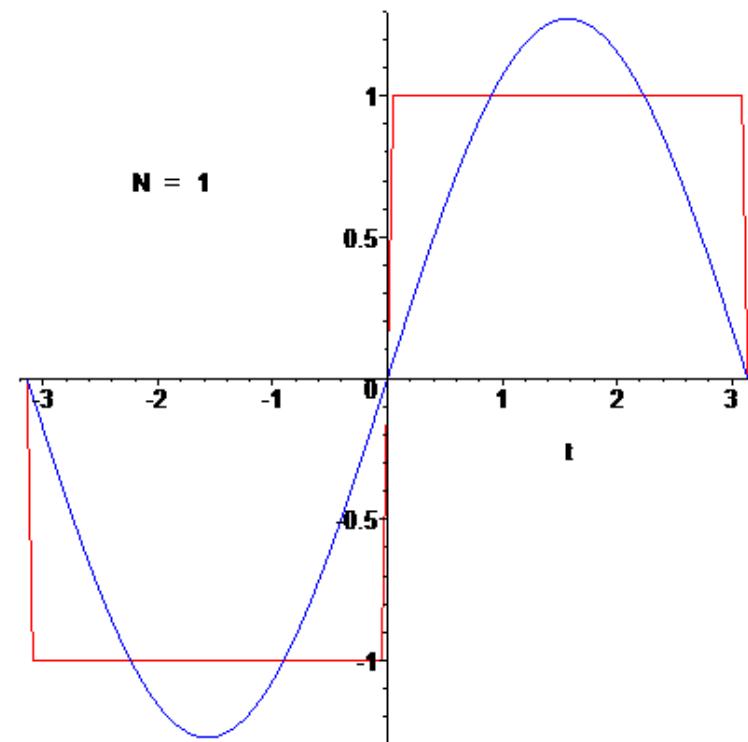


# Discrete Cosine Transform (DCT)

## Ringing effect



ЯВЛЕНИЕ ГИББСА для непрерывной функции

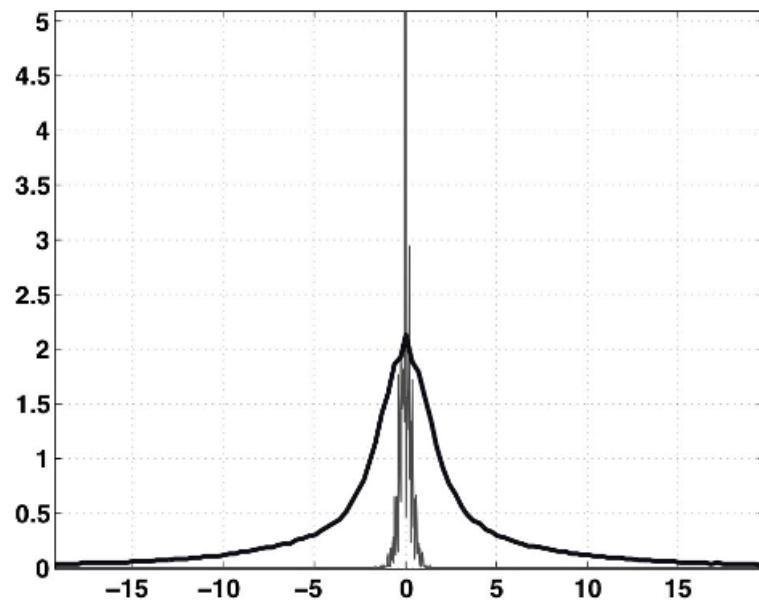


# BLIINDS method

CONTRAST

STRUCTURE

ANISOTROPY



- Коэффициент эксцесса:

$$\kappa(x) = \frac{E(x - \mu)^4}{\sigma^4}$$

# BLIINDS method

CONTRAST

STRUCTURE

ANISOTROPY

- Из изображения извлекаются «однострочные» патчи по направлениям 0, 45, 90, 135 градусов, к ним применяется DCT.
- Патчи нормируются, и подсчитывается энтропия Ренъи:

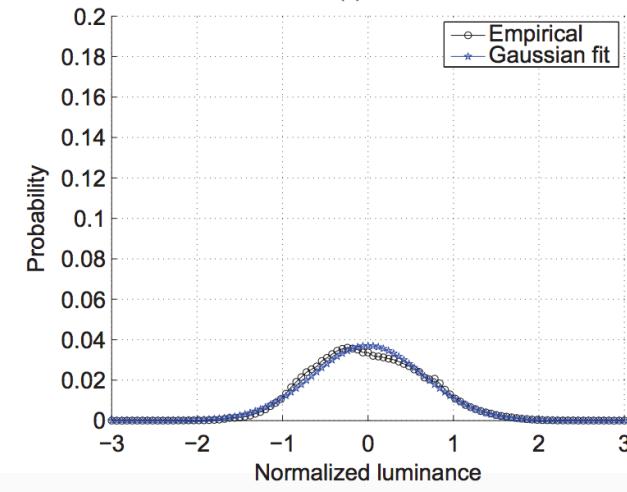
$$\tilde{P}_\theta[n, k] = \frac{P_\theta[n, k]^2}{\sum_k P_\theta[n, k]^2} \quad R_\theta[n] = -\frac{1}{2} \log \left( \sum_k \tilde{P}_\theta[n, k]^3 \right).$$

- Вычисляются средние значения энтропии по 4-м направлениям, дисперсия выборки из 4-х значений становится признаком.

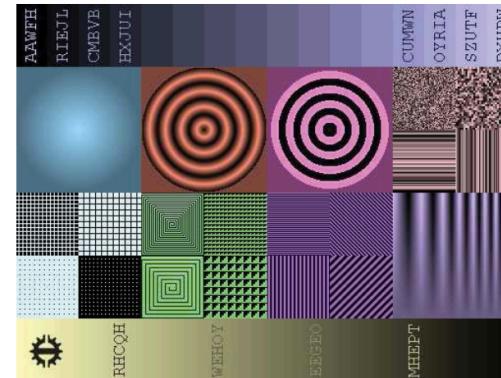
# BRISQUE method



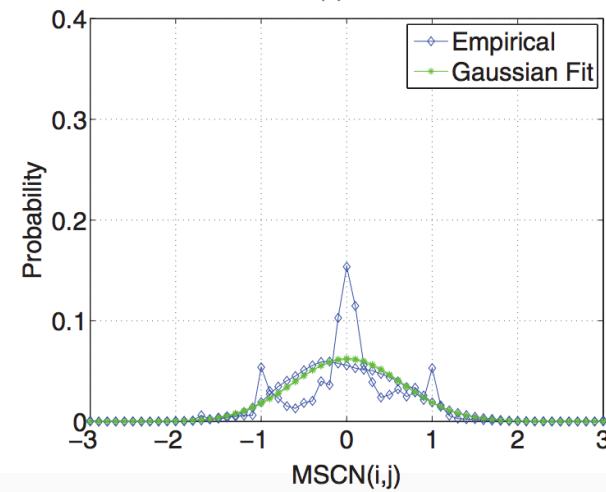
(a)



(c)

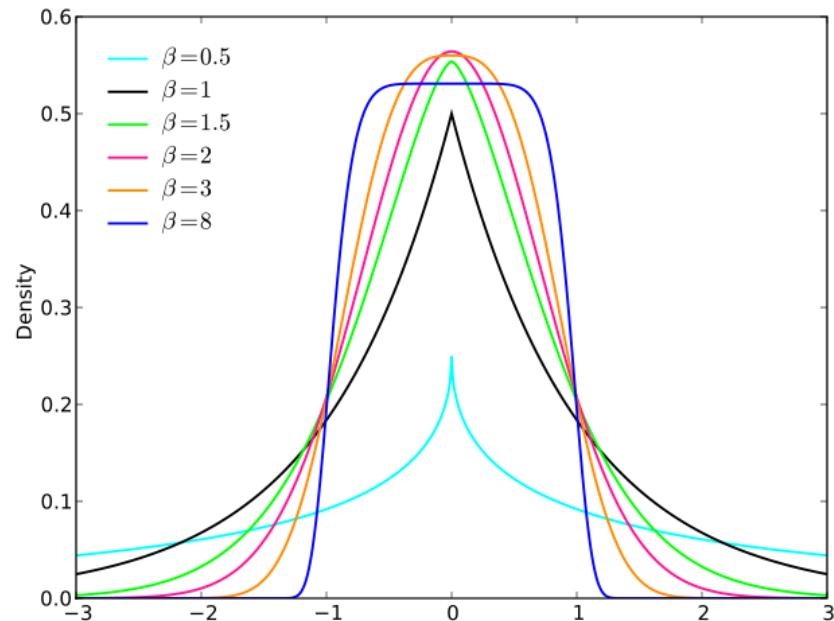


(b)



(d)

# BRISQUE method



- GGD:

$$f(x; \alpha, \sigma^2) = \frac{\alpha}{2\beta\Gamma(1/\alpha)} \exp\left(-\left(\frac{|x|}{\beta}\right)^\alpha\right)$$

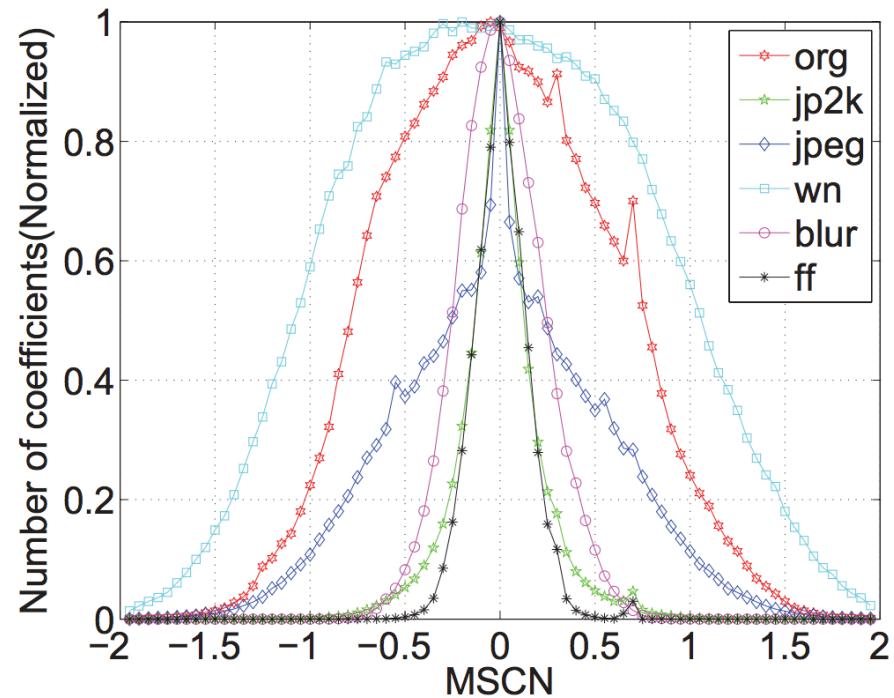
where

$$\beta = \sigma \sqrt{\frac{\Gamma(1/\alpha)}{\Gamma(3/\alpha)}}$$

and  $\Gamma(\cdot)$  is the gamma function:

$$\Gamma(a) = \int_0^\infty t^{a-1} e^{-t} dt \quad a > 0.$$

# BRISQUE method



- GGD:

$$f(x; \alpha, \sigma^2) = \frac{\alpha}{2\beta\Gamma(1/\alpha)} \exp\left(-\left(\frac{|x|}{\beta}\right)^\alpha\right)$$

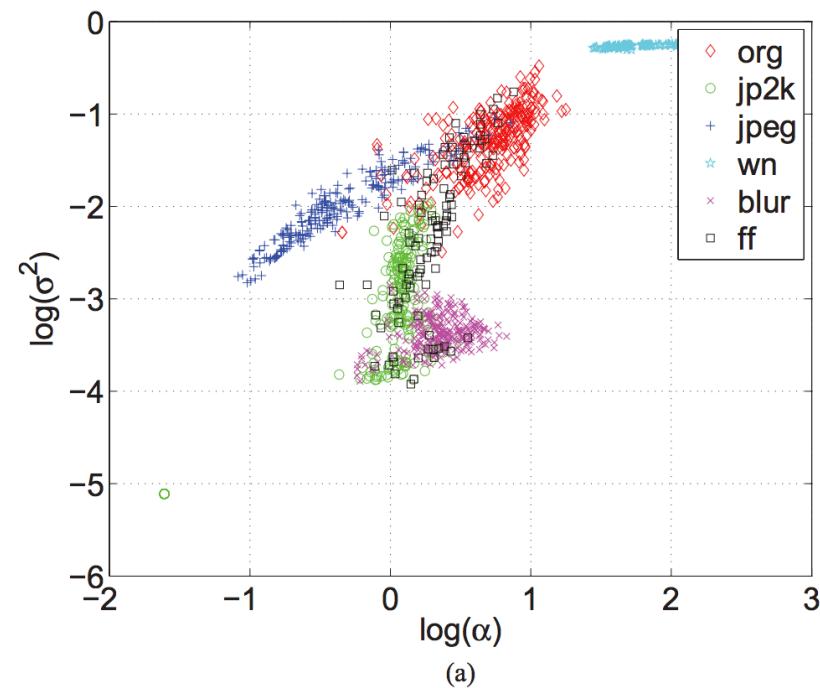
where

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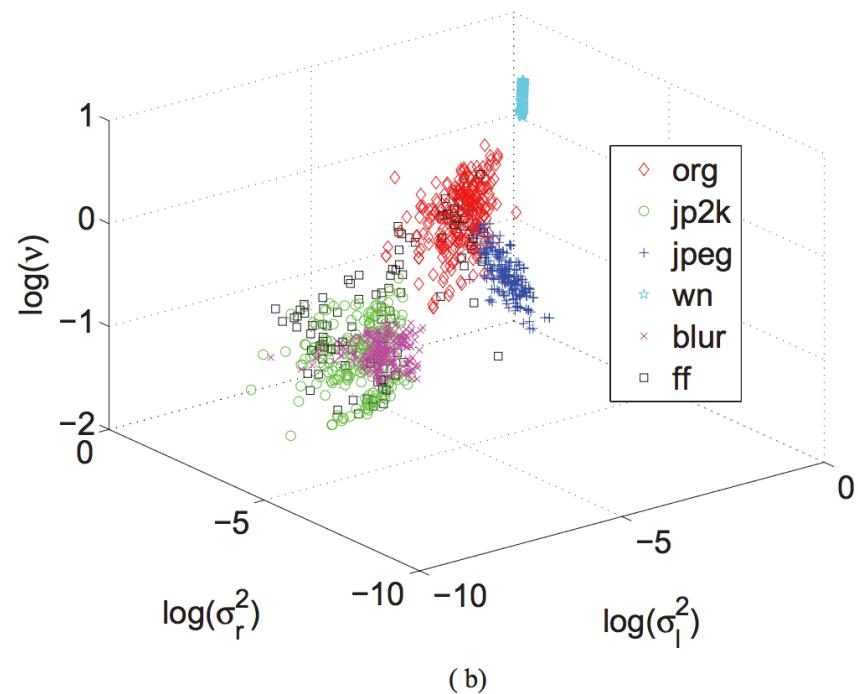
and  $\Gamma(\cdot)$  is the gamma function:

$$\Gamma(a) = \int_0^\infty t^{a-1} e^{-t} dt \quad a > 0.$$

# BRISQUE method



(a)



(b)

# BRISQUE method

	i, j	i, j+1
i-1, j+1	i+1, j	i+1, j+1

- AGGD:

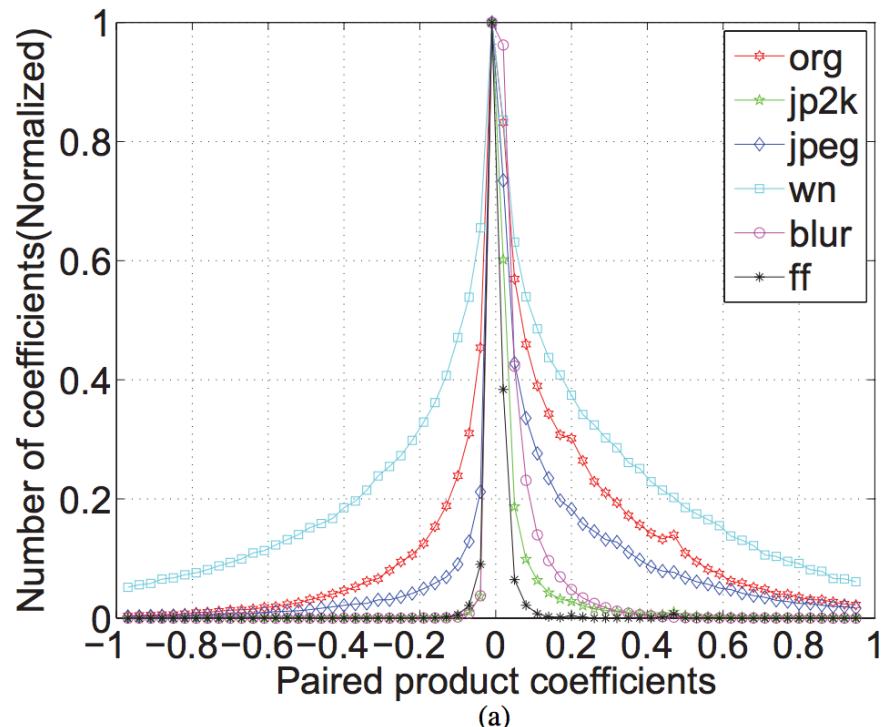
$$f(x; \nu, \sigma_l^2, \sigma_r^2) = \begin{cases} \frac{\nu}{(\beta_l + \beta_r)\Gamma\left(\frac{1}{\nu}\right)} \exp\left(-\left(\frac{-x}{\beta_l}\right)^\nu\right) & x < 0 \\ \frac{\nu}{(\beta_l + \beta_r)\Gamma\left(\frac{1}{\nu}\right)} \exp\left(-\left(\frac{x}{\beta_r}\right)^\nu\right) & x \geq 0 \end{cases}$$

where

$$\beta_l = \sigma_l \sqrt{\frac{\Gamma\left(\frac{1}{\nu}\right)}{\Gamma\left(\frac{3}{\nu}\right)}}$$

$$\beta_r = \sigma_r \sqrt{\frac{\Gamma\left(\frac{1}{\nu}\right)}{\Gamma\left(\frac{3}{\nu}\right)}}$$

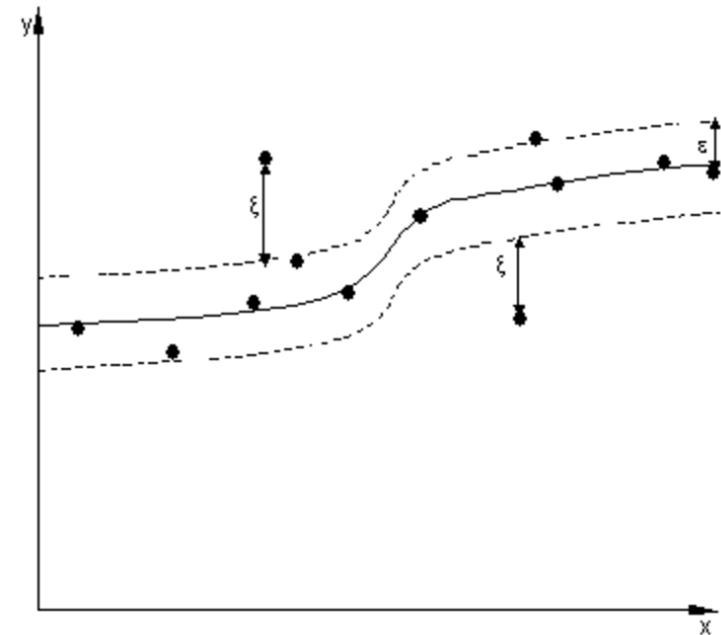
# BRISQUE method



- 2 признака по общей гистограмме
- по 3 признака на каждое направление

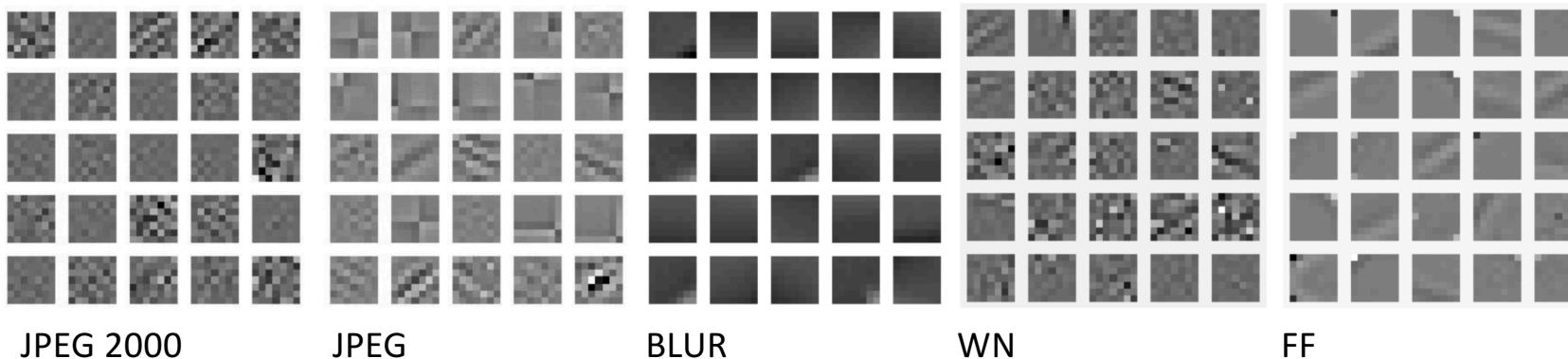
# Support Vector Regression ( $\epsilon$ -SVR)

$$\begin{aligned} \min_{\mathbf{w}, b, \xi, \xi^*} \quad & \frac{1}{2} \mathbf{w}^T \mathbf{w} + C \sum_{i=1}^l \xi_i + C \sum_{i=1}^l \xi_i^* \\ \text{subject to} \quad & \mathbf{w}^T \phi(\mathbf{x}_i) + b - z_i \leq \epsilon + \xi_i, \\ & z_i - \mathbf{w}^T \phi(\mathbf{x}_i) - b \leq \epsilon + \xi_i^*, \\ & \xi_i, \xi_i^* \geq 0, i = 1, \dots, l. \end{aligned}$$



# Pure learning-based approach: CORNIA method

- Codebook (словарь) обучается с помощью K-Means:



- Для каждого патча из тестируемого изображения рассчитываем расстояние до каждого элемента из словаря с помощью скалярного распределения.

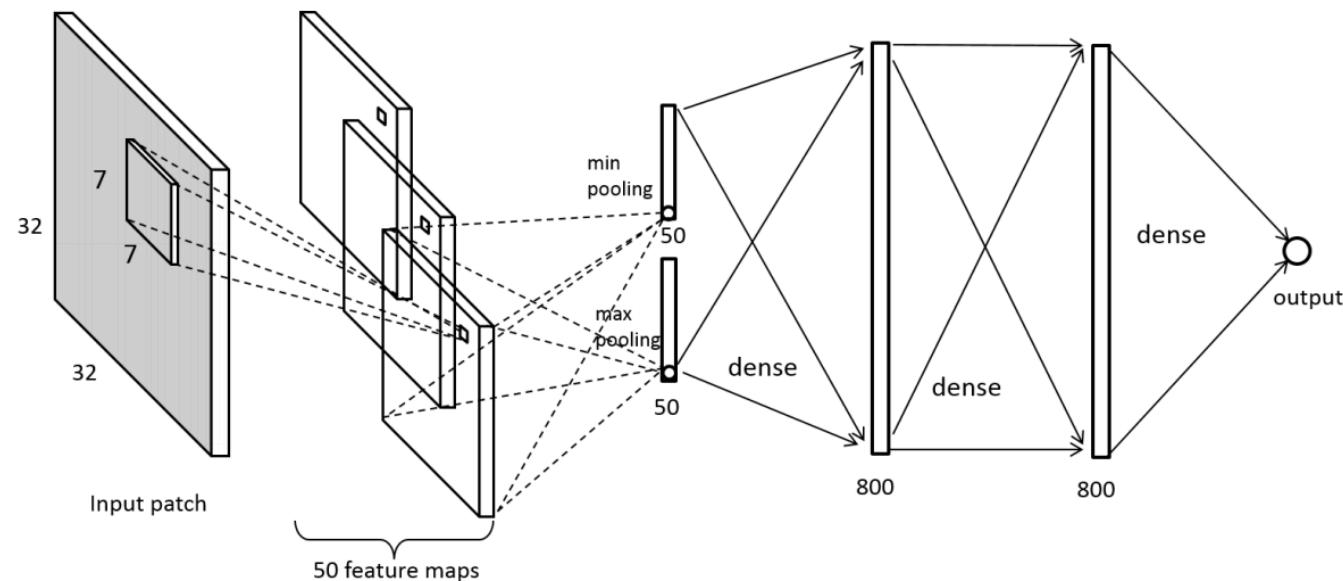
# Pure learning-based approach: CORNIA method

- Soft-assignment function:

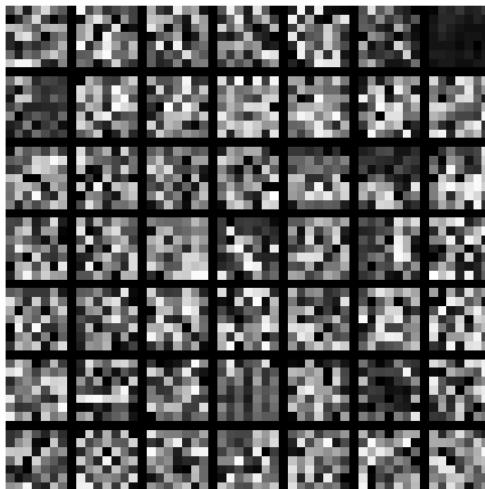
$$c_i = [\max(s_{i1}, 0), \dots, \max(s_{id}, 0), \\ \max(-s_{i1}, 0), \dots, \max(-s_{id}, 0)]^T$$

- Max-pooling
- SVR

# Convolutional Neural Networks



# Convolutional Neural Networks



- Max and min pooling after convolutions.
- Dense layers with ReLU activation:

$$g = \max(0, \sum_i w_i a_i).$$

- Objective function:

$$L = \frac{1}{N} \sum_{n=1}^N \|f(x_n; w) - y_n\|_{l_1}$$

- Learning with SGD and backprop.
- Momentum + dropout.

# Results

SROCC	JP2K	JPEG	WN	BLUR	FF	ALL
BLIINDS-II	0.929	0.942	0.969	0.923	0.889	0.931
BRISQUE	0.914	0.965	0.979	0.951	0.877	0.940
CORNIA	0.943	0.955	0.976	<b>0.969</b>	0.906	0.942
CNN	<b>0.952</b>	<b>0.977</b>	0.978	0.962	<b>0.908</b>	<b>0.956</b>

LCC	JP2K	JPEG	WN	BLUR	FF	ALL
BLIINDS-II	0.935	0.968	0.980	0.938	0.896	0.930
BRISQUE	0.922	0.973	0.985	0.951	0.903	0.942
CORNIA	0.951	0.965	0.987	<b>0.968</b>	0.917	0.935
CNN	<b>0.953</b>	<b>0.981</b>	0.984	0.953	<b>0.933</b>	<b>0.953</b>