Image quality assessment@DIPLab

- *Spatial Pooling for Image Quality Assessment*
- *Jensen Shannon divergence as reduced reference IQA metric*

A Novel Spatial Pooling Technique for Image Quality Assessment based on Luminance-Contrast Dependence

Motivation

Image **Luminance** and **Contrast** show:

- *independence* around fixation points in *natural* image *components*
  - highly *negative correlation* for *artificial* image *components*

A **novel** and **effective pooling** technique **for SSIM**

SSIM correlation with Mean Opinion Score (MOS) increases up to 8.3%

Goal: pooling method which measures the naturalness of image regions

Main idea: image defects are artificial image components

$\Rightarrow$ assign a higher weight to image regions that are highly unnatural and then a surprise to the human visual system

Method: **Luminance and Contrast correlation as features of fixation points**

- ✓ *Use the correlation coefficient ρ as a pooling weight for IQA*
- ✓ *Use SSIM (Structural SIMilarity Index) as IQA*

$$\Rightarrow SSIM_\rho = \frac{\sum_{x=1}^{n}\sum_{y=1}^{m} SSIM(x,y)(1-\rho(x,y))}{\sum_{x=1}^{n}\sum_{y=1}^{m}(1-\rho(x,y))}$$

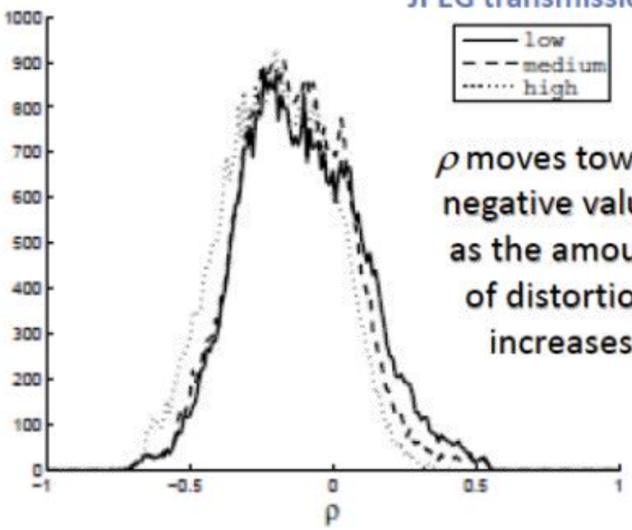
Why Luminance and Contrast correlation?

- in the early vision eye measures local ***luminance mean*** and ***contrast***:

  light adaptation (in the retina) and contrast gain (starts in the retina):

  two rapid mechanisms that control the gain of neural responses
- ***Low correlation*** of luminance mean and contrast in **natural** images
- ***Negative correlation*** of luminance mean and contrast in ***artificial*** images
- Fixation points change according to both image content and distortion kind
- Humans are attracted by the most unnatural parts of the image

JPEG transmission



ρ moves toward negative values as the amount of distortion increases

Why SSIM?

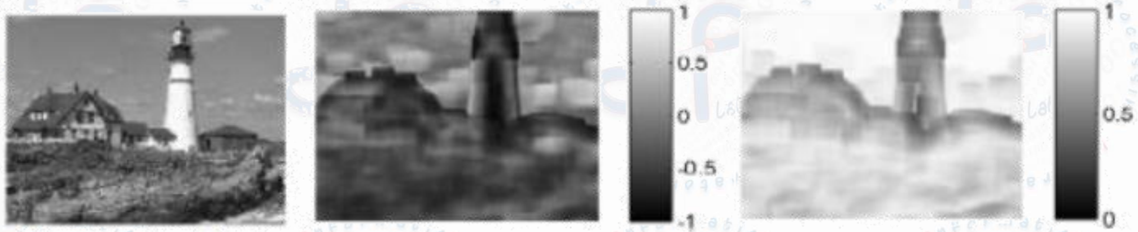
- dependent on local luminance mean and contrast
- straightforward spatial pooling and computationally efficient
- easily embeddable in image and video processing applications
- gives importance to the modification of image structures to which HVS is sensitive

$$SSIM(I,J) = \underbrace{\frac{2\mu_I\mu_J + C_1}{\mu_I^2+\mu_J^2+C_1}}_{\text{Luminance adaptation}}\;\underbrace{\frac{2\sigma_I\sigma_J + C_2}{\sigma_I^2+\sigma_J^2+C_2}}_{\text{Contrast masking}}\;\underbrace{\frac{\sigma_{IJ} + C_3}{\sigma_I\sigma_J+C_3}}_{\text{Spatial correlation}}$$

Cosine correlation coefficient

$$\rho_{cos}(x,y) = \frac{\sum_{(x,y)\in\Omega} \mu(x,y) C(x,y)}{\sqrt{\sum_{(x,y)\in\Omega} \mu^2(x,y)} \sqrt{\sum_{(x,y)\in\Omega} C^2(x,y)}}$$

It measures how “orthogonal” are luminance and contrast vectors



Masked noise ρ ρ_{cos}

Relation with correlation coefficient

$$\rho_{cos} = \frac{\|\mu\|_1 \, \|C\|_1}{\|\mu\|_2 \, \|C\|_2} + \rho \sqrt{\left(1 - \frac{\|\mu\|_1^2}{\|\mu\|_2^2}\right)\left(1 - \frac{\|C\|_1^2}{\|C\|_2^2}\right)}$$

$\rho = 0 \not\Rightarrow \rho_{cos} = 0$

If ρ_{cos} approaches $0 \Rightarrow \rho < 0$ with high probability

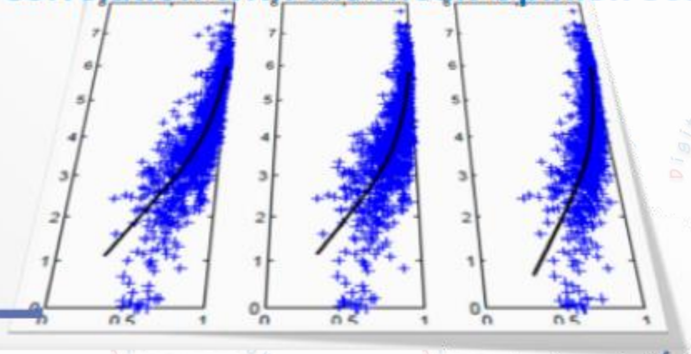
(a given quantity is subtracted from the 1st term)

ρ_{cos} is able to differentiate positive and negative correlations:

ρ_{cos} is more consistent with the perception of masked noise: less evident at the bottom of the image than near the contours of the houses or the lighthouse

Some results

Correlation with the Mean Opinion Score (MOS)



Comparisons with existing IQA

correlation with MOS	DB	$SSIM$	$SSIM_\rho$	$SSIM_{cos}$	VIF	FSIM	VSNR	$SSIM_\rho$ (from original)
Pearson Coeff.	TID	0.773	0.795	*0.835*	0.808	**0.874**	0.682	0.746
	LIVE	0.945	0.948	*0.954*	0.960	**0.961**	0.923	0.946
	CSIQ	0.861	*0.890*	0.870	**0.928**	0.912	0.800	0.888
Spearman Coeff.	TID	0.775	0.795	*0.838*	0.749	**0.881**	0.705	0.780
	LIVE	0.948	0.952	*0.958*	0.964	**0.965**	0.927	0.949
	CSIQ	0.876	*0.904*	0.879	0.919	**0.924**	0.811	0.901
Kendall Coeff.	TID	0.577	0.595	*0.644*	0.586	**0.695**	0.534	0.582
	LIVE	0.796	0.805	*0.817*	0.827	**0.836**	0.762	0.799
	CSIQ	0.691	*0.724*	0.696	0.754	**0.757**	0.625	0.720

Spearman correlation with MOS

for each defect class

defect	$SSIM$	$SSIM_\rho$	$SSIM_{cos}$	FSIM
awgn	0.811	0.810	0.829	**0.857**
Diff noise in color	0.803	0.801	0.827	**0.851**
Spat. corr. noise	0.815	0.827	0.837	**0.848**
Masked noise	0.779	0.788	**0.811**	0.802
High freq. noise	0.873	0.875	0.888	**0.909**
Impulse noise	0.673	0.643	0.628	**0.746**
Quantization	0.853	0.857	**0.881**	0.855
Blur	0.954	0.957	**0.959**	0.947
Image den.	0.953	0.953	**0.962**	0.960
JPEG	0.925	0.917	**0.929**	0.928
JP2K	0.962	0.964	0.966	**0.977**
JPEG trans.	0.868	0.867	**0.887**	0.871
JP2K trans.	0.858	0.854	**0.866**	0.854
Non ecc. patt. noise	0.711	0.712	**0.763**	0.750
Local block. dist.	0.846	0.818	0.823	**0.850**
Mean shift	0.723	0.728	**0.734**	0.670
Contrast change	0.525	0.615	0.574	**0.65**

Jensen Shannon divergence as reduced reference IQA metric

Objective: to introduce a **new** and effective Image Quality Assessment (**IQA**) measure able to well correlate with Human Visual System (**HVS**)

Method: use of Information Theory models

topic of interest in Digital CH

JSD and HVS

Perception of distortion as a problem of information transmission rate

Perceived distortion due to:

- degradation process, that generates the distorted image
- human vision, that differently reacts to different kinds of degradation, also according to the scene content

↓

perceived image = mixture of original and degraded information

(some degraded info is perceived as clean)

↓

JSD = capacity of a noisy information channel with two inputs giving the output distributions p and q

JSD can be used for image quality assessment using optimal weights!!!

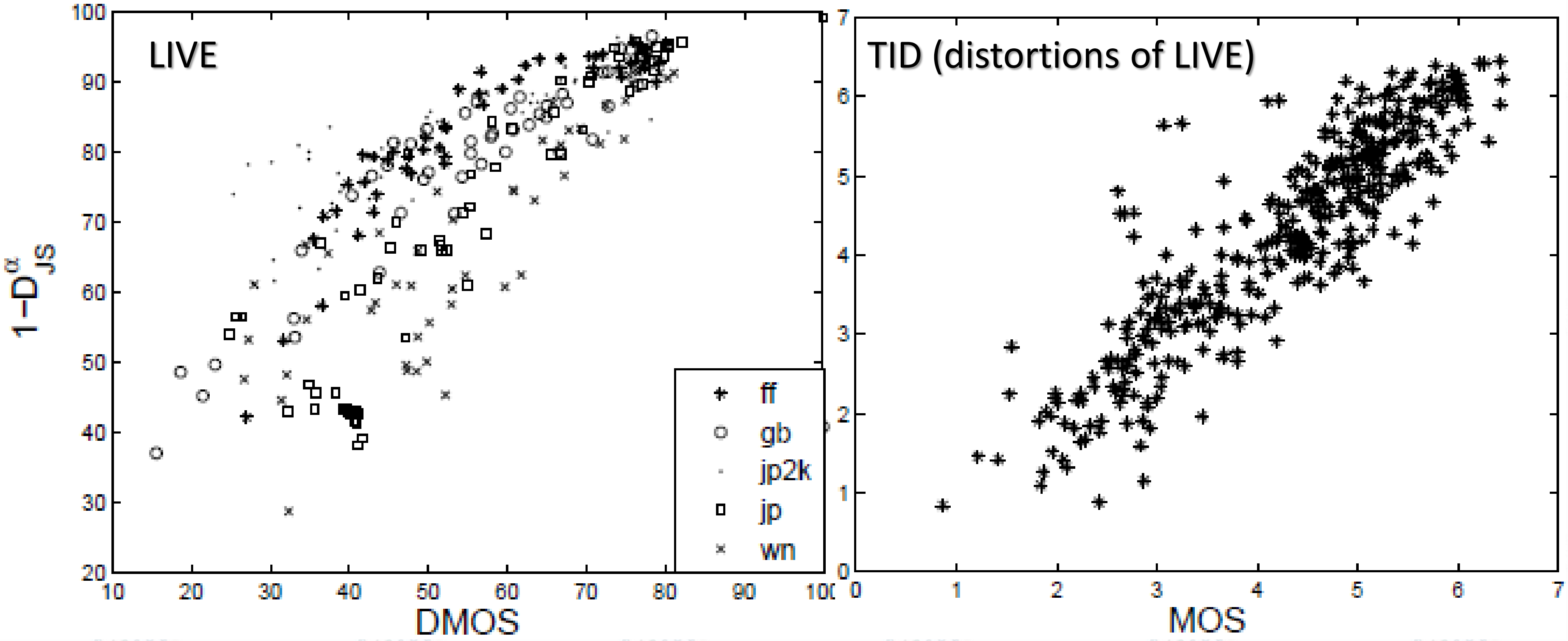
Properties of JSD

- it **well correlates with human visual perception**
- it **simply depends on Shannon entropy** of the original and degraded image (reduced reference metric)
- it has a **nice and tractable mathematical formulation**: more simple to embed in the optimization procedures used for restoration
- it measures the **difference between two images in terms of bits**, allowing its embedding in coding algorithms (storage and the diffusion of the material in digital libraries)
- suitable for local distortions

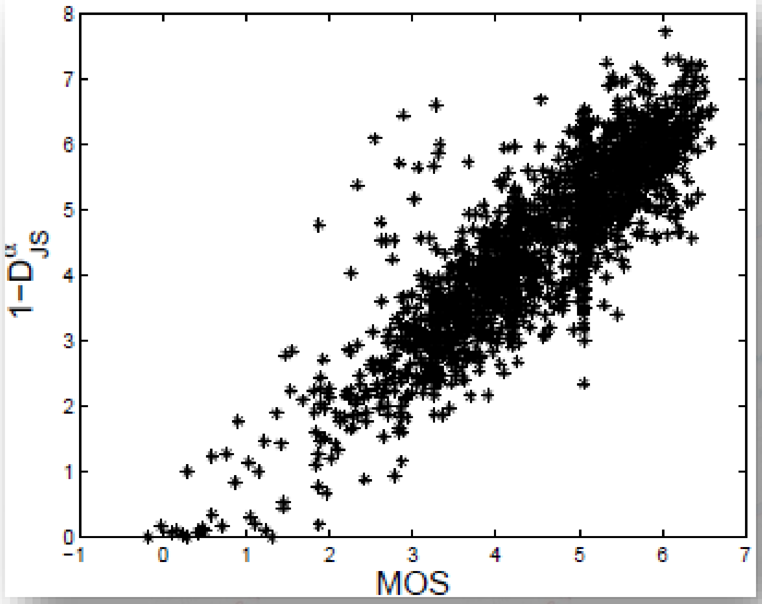
Some results: LIVE and TID database

	Pearson	Spearman	Kendall
D^{α}_{JS}	0.9246	0.9016	0.7444
$SSIM$	0.9250	0.9196	0.7778
VIF	0.9450	0.9572	0.8500

	Spearman	Kendall
D^{α}_{JS}	0.884	0.714
$SSIM$	0.920	0.750
VIF	0.935	0.776
$VIFP$	0.909	0.738



Some results: TID database



Each class of defects separately

Distortion	Pearson	Spearman	Kendall
Add. Gaussian Noise	0.6728	0.6690	0.4760
Different noise in color comp.	0.6299	0.6268	0.4484
Spatially correlated noise	0.6667	0.6494	0.4587
Masked noise	0.6552	0.6511	0.4784
High frequency noise	0.7304	0.7234	0.5022
Impulse noise	0.5704	0.7628	0.5311
Quantization noise	0.3956	0.4232	0.2989
Gaussian blur	0.8691	0.8798	0.7074
Image denoising	0.8249	0.8132	0.6264
JPEG compression	0.9461	0.9217	0.7320
JPEG2K compression	0.8764	0.8660	0.7068
JPEG transmission	0.8331	0.8262	0.6568
JPEG2K transmission	0.6776	0.6827	0.4962
Non eccentricity pattern noise	0.8263	0.8385	0.6241
Local blockwise distortion	0.8806	0.8760	0.6815
Mean shift	0.5131	0.5028	0.3608
Contrast change	0.6311	0.5645	0.3664

Some results: TID database

Distortion
Add. Gaussian Noise
Different noise in color comp.
Spatially correlated noise
Masked noise
High frequency noise
Impulse noise
Quantization noise
Gaussian blur
Image denoising
JPEG compression
JPEG2K compression
JPEG transmission
JPEG2K transmission
Non eccentricity pattern noise
Local blockwise distortion
Mean shift
Contrast change

Important for scanning and transmission of archived material

Some results: TID database

Distortion
Add. Gaussian Noise
Different noise in color comp.
Spatially correlated noise
Masked noise
High frequency noise
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Gaussian blur
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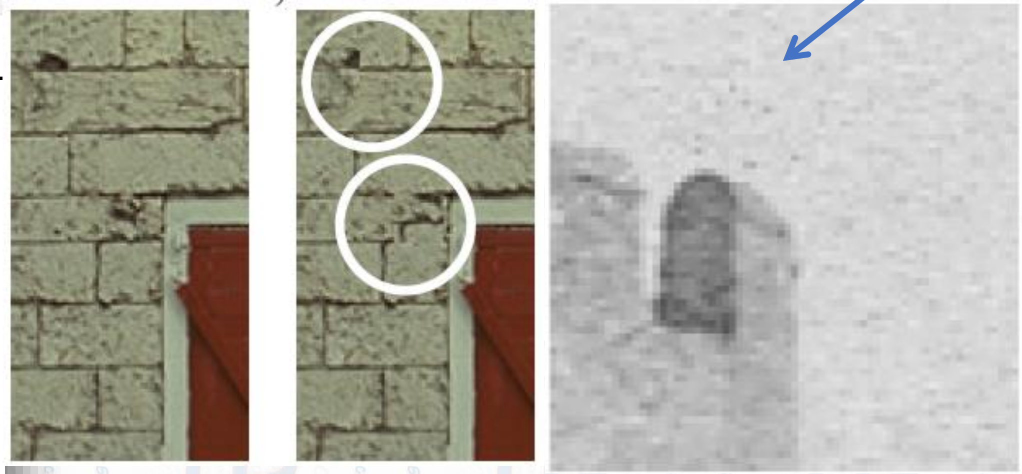
JPEG compression
JPEG2K compression
JPEG transmission
JPEG2K transmission
Non eccentricity pattern noise
Local blockwise distortion
Mean shift
Contrast change



Restoration /compression artifacts

Restoration /compression artifacts

Some results: TID database

Distortion
Add. Gaussian Noise
Different noise in color comp.
Spatially correlated noise
Masked noise
High frequency noise
Impulse noise
Quantization noise
Gaussian blur
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JPEG transmission
JPEG2K transmission
Non eccentricity pattern noise
Local blockwise distortion
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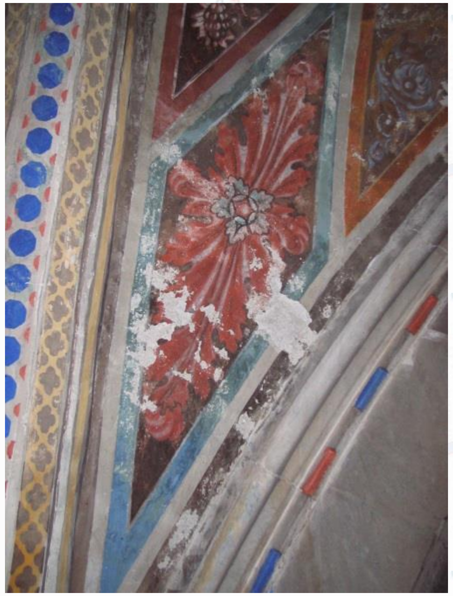
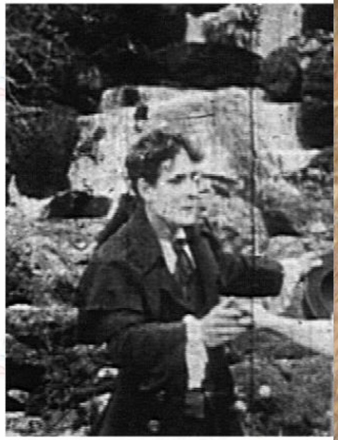
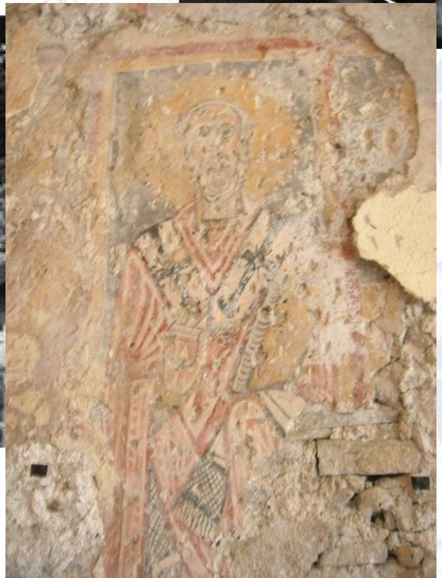
Contrast change

Local defects like blotches, scratches, dirt







Some results: TID database

Distortion
Add. Gaussian Noise
Different noise in color comp.
Spatially correlated noise
Masked noise
High frequency noise
Impulse noise
Quantization noise
Gaussian blur
Image denoising
JPEG compression
JPEG2K compression
JPEG transmission
JPEG2K transmission
Non eccentricity pattern noise
Local blockwise distortion
Mean shift
Contrast change

fading

Some results: TID database

Distortion
Add. Gaussian Noise
Different noise in color comp.
Spatially correlated noise
Masked noise
High frequency noise
Impulse noise
Quantization noise
Gaussian blur
Image denoising
JPEG compression
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JPEG2K transmission
Non eccentricity pattern noise
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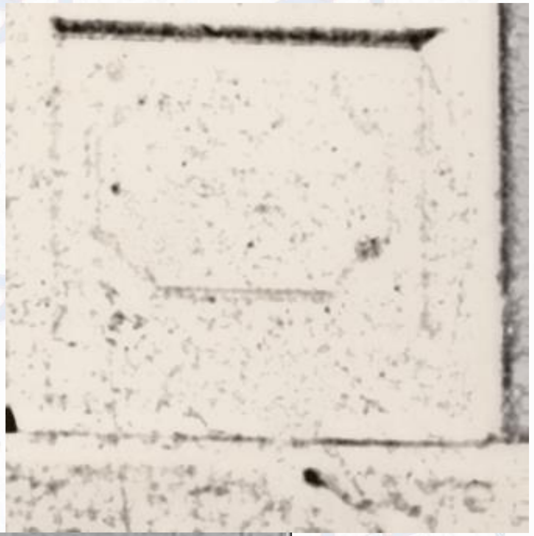
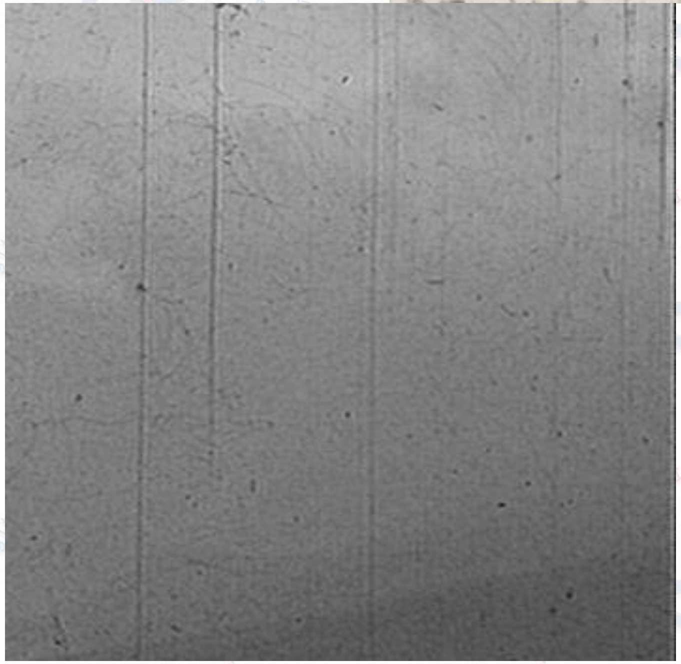
Mean shift
Contrast change

Dust/Dark spots





Comparisons with Reduced Reference metrics

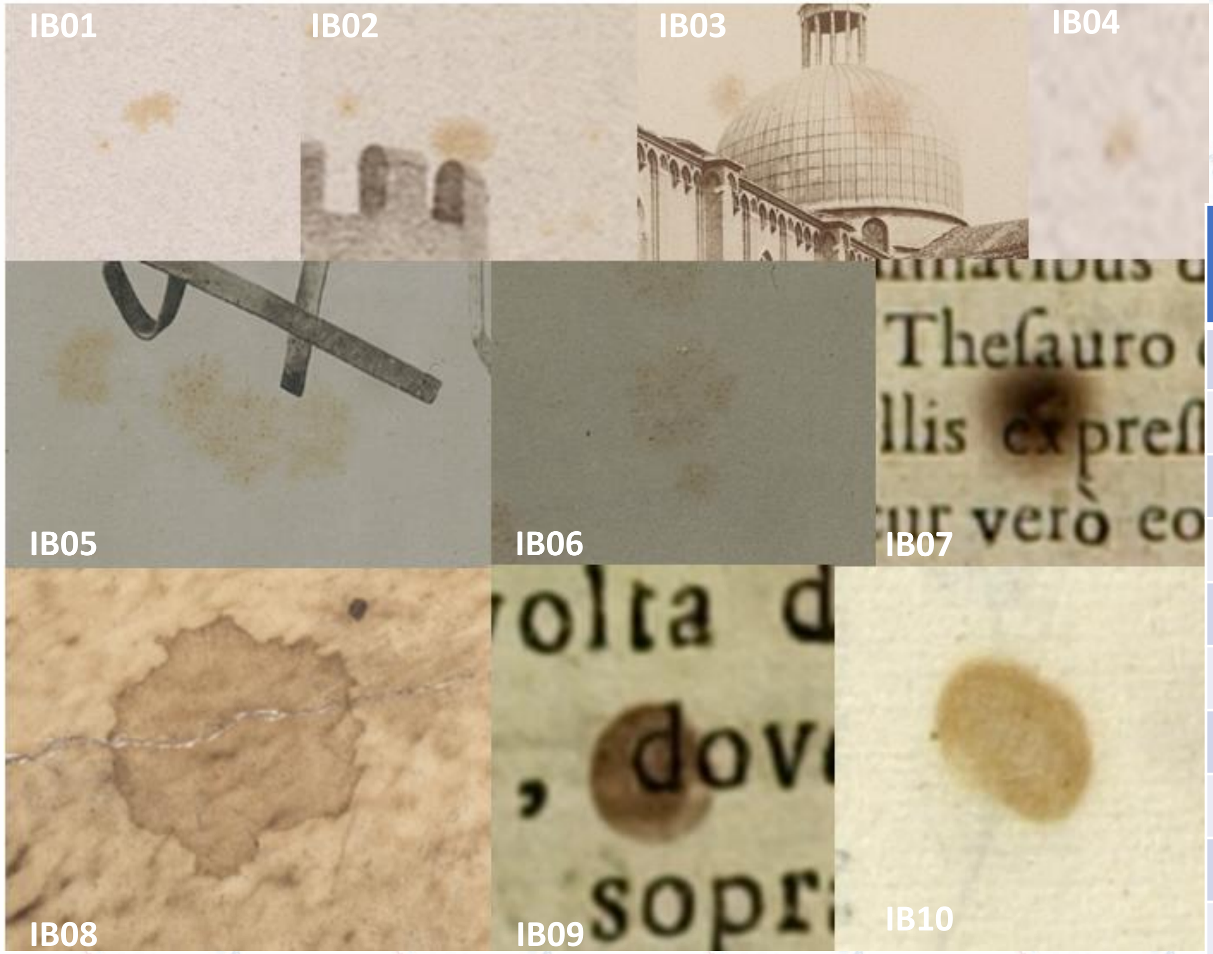
WNISM: it works in the wavelet domain and evaluates the distance between the probability distributions of image wavelet coefficients

RRED: it works in the wavelet domain and measures the entropy value of wavelet coefficients

Distortion	D^{α}_{JS}	RRED	WNISM
Add. Gaussian Noise	0.669	0.702	0.603
Different noise in color comp.	0.627	0.684	0.604
Spatially correlated noise	0.649	0.712	0.599
Masked noise	0.651	0.744	0.633
High frequency noise	0.723	0.794	0.708
Impulse noise	0.763	0.549	0.593
Quantization noise	0.423	0.591	0.619
Gaussian blur	0.880	0.935	0.871
Image denoising	0.813	0.925	0.864
JPEG compression	0.922	0.819	0.834
JPEG2K compression	0.866	0.948	0.935
JPEG transmission	0.826	0.782	0.875
JPEG2K transmission	0.683	0.628	0.691
Non eccentricity pattern noise	0.838	0.277	0.452
Local blockwise distortion	0.876	0.691	0.590
Mean shift	0.503	0.418	0.292
Contrast change	0.564	0.723	0.701

Some results:

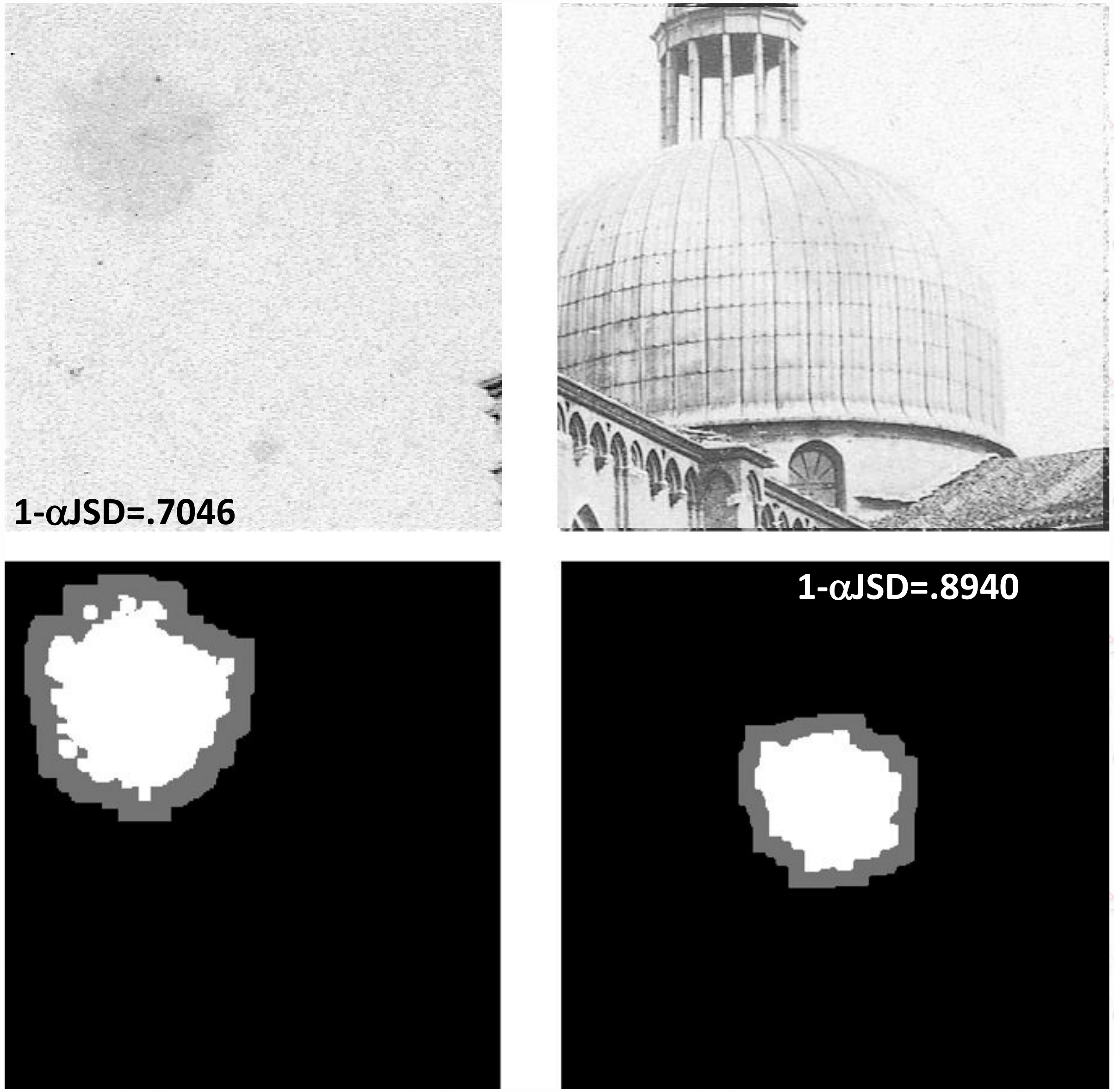
JSD as No Reference measure for local degradation



Img	1-αJSD	α	1-JSD α=.5
IB01	0.658	0.499	0.658
IB02	0.812	0.598	0.804
IB03	0.761	0.680	0.716
IB04	0.729	0.503	0.729
IB05	0.733	0.602	0.725
IB06	0.793	0.499	0.793
IB07	0.593	0.558	0.581
IB08	0.541	0.536	0.536
IB09	0.612	0.529	0.610
IB10	0.163	0.468	0.159

Some results:

JSD as No Reference measure for local degradation



Some results:

JSD as No Reference measure for local degradation