The Divisive Normalization Transform Based Reduced-Reference Image Quality Assessment in the Shearlet Domain

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ABSTRACT: **Reduced-reference (RR) image quality assessment (IQA)** metric aims to employ less partial information about the original reference image to achieve higher evaluation accuracy. In this paper, we propose a novel RRIQA metric based on the **divisive normalization transform (DNT)** in **the discrete nonseparable shearlet transform (DNST)** domain. In this metric, the coefficients in the DNST domain are normalized employing the **Gaussian scale mixture statistical model**, and then the marginal distribution of the coefficients changes into **approximate Gaussian distribution**. A set of statistical features is extracted from DNT-domain representations of the reference and distorted images, respectively. The weighting of these features is performed based on the characteristics of the human visual system**. Structural similarity comparison** of these features is conducted as an objective quality score of the distorted image. The proposed metric is evaluated on the public LIVE database and demonstrates fairly good performance across a wide range of image distortions.

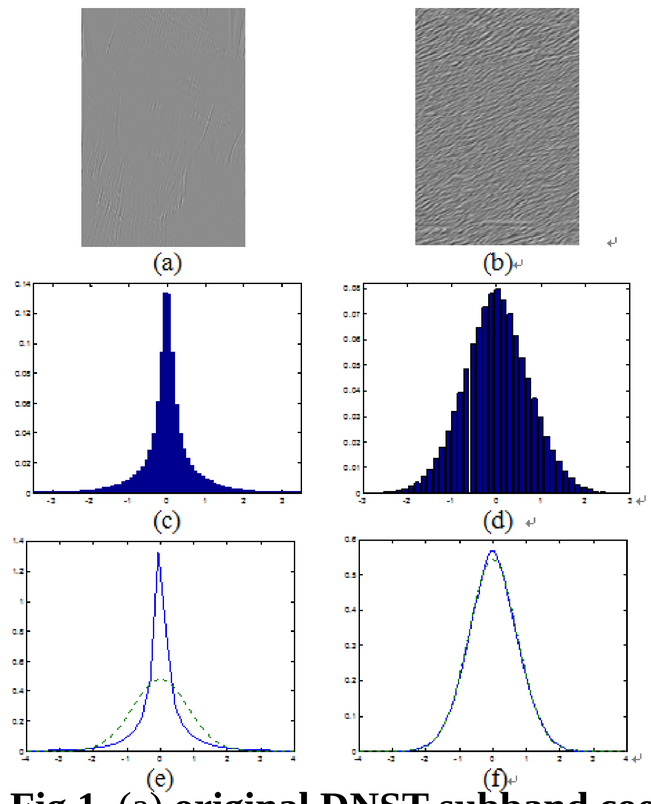

Fig.1. (a) **original DNST subband coefficients**;
(b**) the DNST subband coefficients after the DNT**;
(c) marginal statistics of Fig.1(a) and its kurtosis is 22.52;
(d) marginal statistics of Fig.1(b) and its kurtosis is 3.01;
(e) the **histogram** of Fig.1(a) (**solid curve**) and the **fitting Gaussian curve** with the same variance (**dashed curve**);
(f) the **histogram** of Fig.1(b) (**solid curve**) and the **fitting Gaussian curve** with the same variance (**dashed curve**)

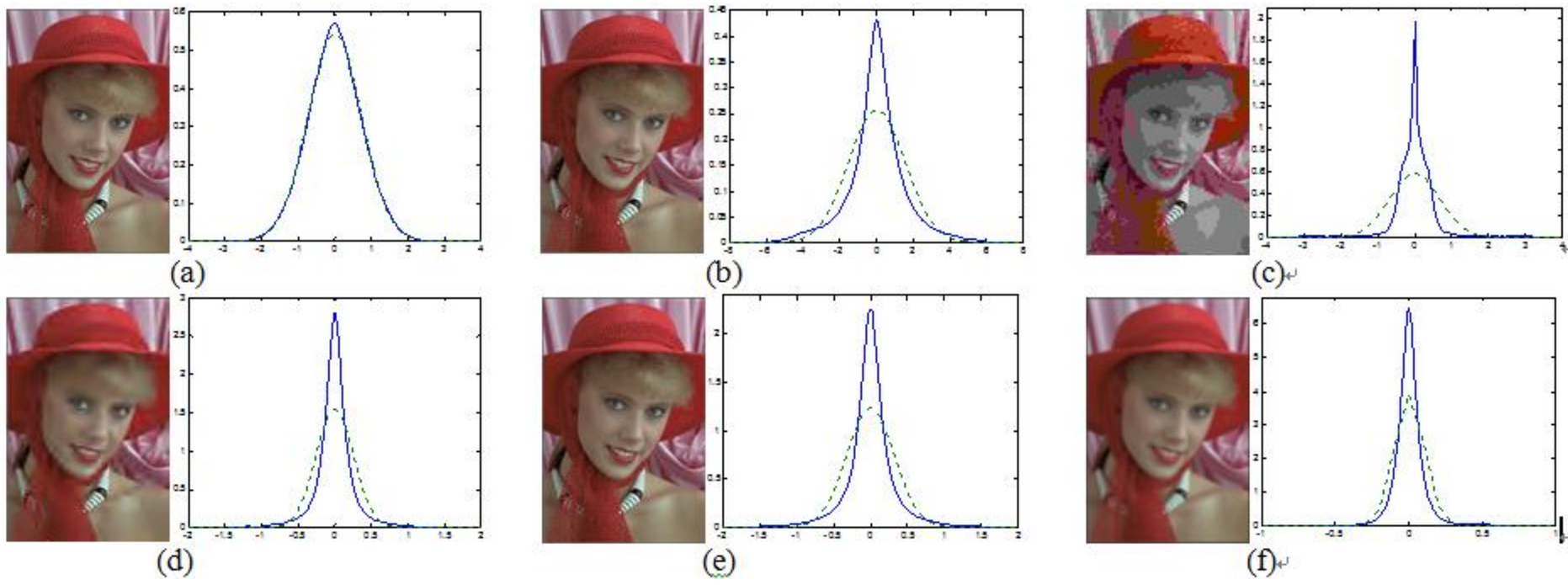

Fig.2. **Histograms** of the **coefficients** in **the DNT domain** under different distortion types. The solid and dashed curves are histograms of the coefficients in the DNT domain of the original and distorted images, respectively. In each figure, the dashed curve has the same variance as the solid curve. (a)**original image**; (b)**white noise**; (c)**JPEG compression**; (d)**JPEG2000 compression**; (e)**fast fading channel distortion**; (f)**Gaussian blur**.

The flow diagram of the sender side

The DNST is performed to the reference image.
↓
DNT is performed to each subband.
↓
The standard deviation, the sknewness and the kurtosis of each subband are computed.
↓
The Kullback-Leibler distance (KLD) between subband and the Gaussian model is computed.

The flow diagram of the receiver side

The DNST is performed to the distorted image.
↓
DNT is performed to each subband.
↓
The standard deviation, the sknewness and the kurtosis of each subband are computed.
↓
The KLD of each subband between the distorted and reference images is computed.
↓
The contrast sensitivity function is employed to weight the the KLD, three statistical parameters.
↓
The assessment model is constructed.

Here we apply a model of the contrast sensitivity function (CSF) H(f,θ)

$$H(f,\theta)=\begin{cases}2.6(0.0192+\lambda f_\theta)\exp[-\lambda f_\theta] & f \geq f_{peak}\\ 0.981 & \text{otherwise}\end{cases}$$
$$f_\theta = f/[0.15\cos(4\theta)+0.85]$$

Here, we apply the SSIM philosophy into the measurement of statistical features extracted from the DNT coefficients at different subbands,

$$g'_\sigma(\sigma'_r,\sigma'_d)=\frac{\|\sigma'_r\|^2+\|\sigma'_d\|^2+c_1}{2(\sigma'_r\cdot\sigma'_d)+c_1}$$
$$g'_s(s'_r,s'_d)=\frac{\|s'_r\|^2+\|s'_d\|^2+c_2}{2(s'_r\cdot s'_d)+c_2}$$
$$g'_k(k'_r,k'_d)=\frac{\|k'_r\|^2+\|k'_d\|^2+c_3}{2(k'_r\cdot k'_d)+c_3}$$

Finally, the weighted sum of all subbands distortions is computed as the overall evaluation

$$D=g'_\sigma(\sigma'_r,\sigma'_d)g'_s(s'_r,s'_d)g'_k(k'_r,k'_d)\log(1+\frac{1}{D_0}\sum_m\sum_n H(f,\theta)|_{f=m,\theta=n}\cdot|\hat{d}(p_{mn}||q_{mn})|)$$

In this paper, the **five-level DNST** is applied to decompose the image into subbands with **16, 16, 16, 8, 8** directions from finer to coarser scales. To each subband, the DNT is applied using **17 neighboring coefficients**, including 9 from the same subband, 1 from the subband at the coarse scale and 7 from the same spatial location in the other orientation subbands at the same scale. **Four features Kullback-Leibler distance**, the **standard deviation**, the **sknewness** and the **kurtosis** are extracted from each subband of the reference image and are sent to the receiver side for the quality evaluation of the distorted image.

The Live database is used to test the proposed metric.

Three criteria are employed: correlation coefficient after a nonlinear mapping, Spearman rank-order correlation coefficient and outlier ratio.

we compare the proposed metric with stateof-the-art RRIQA metrics, namely WNISM, RRED. In addition, two FRIQA metrics, namely SSIM and PSNR, are also been compared.

The results show that the proposed metric significantly outperforms PSNR and is competitive as compared to SSIM. Meanwhile, it outperforms the already existing RRIQA metrics: WNISM, RRED.