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# Non-reference assessment of sharpness in blur/noise degraded images ☆

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ABSTRACT

Image sharpness perception is not only affected by blur but also by noise. Noise effect on perceived image sharpness is a puzzling problem since image sharpness may increase, up to a certain amount of noise, on even regions when noise is added to an image. In this paper, we propose a NR perceived sharpness metric GSVD (Gradient Singular Value Decomposition), that shows to be effective in correlating with subjective quality evaluation of images affected by either blur or noise. This metric (i) requires no training on human image quality ratings, (ii) provides comparable performance with full reference (FR) peak signal to noise ratio (PSNR) and multiscale structural similarity (MSSIM), and (iii) performs better than most of the state-of-the-art NR sharpness metrics when assessing quality in blurry image sets and noisy image sets jointly.


## 1. Introduction

In recent years, the growing amount of visual content represented by images and videos have driven a pressing demand for review and control of image quality (IQ) [1]. Humans are the final users in many image applications, therefore human judgements are the most reliable way to assess IQ. In spite of that, IQ subjective evaluation is expensive and tedious, and is often difficult to carry out in real time applications. On the other hand, objective IQ assessment (IQA) refers to automatic-computational model based prediction of image quality as it would be perceived by a human being. If the prediction is based on the comparison of the original (i.e undistorted) image and distorted image, the model is named full reference (FR). Examples of FR IQA metrics include the peak signal-to-noise-ratio (PSNR) and the structural similarity (SSIM) [2,3]. When the metric uses only a small fraction of reference information (in the form of features extracted from the original image) the model is called reduced-reference (RR). Nonetheless, in many applications such as image denoising, deblurring, and enhancement where the reference image is absent, the IQA must be conducted without it. In these cases, a no reference (NR) model permits IQA without any access to the reference image [3–5].

In this paper we are concerned about the NR sharpness evaluation of noisy and blurry image data sets. Previous works on sharpness assessment focus on blur, since it is the most common type of image degradation that damages visual sharpness. In spite of their good performance on blurry images, we have found that they do not correlate well with perceived image quality when measuring perceptual sharpness in blurry and noisy image data sets combined.

Some NR image quality metrics have been developed to detect jointly blur and noise. In [6] Gabarda and Cristobal proposed a methodology based on the variance of the expected entropy in a set of predefined directions to evaluate image quality. Although this method produced a good match with human judgements in a reduced test dataset, this metric requires additional evaluation with publicly available image databases to be widely accepted as a QA metric. Moreover, this metric does not perform well if blur or noise varies spatially since it assumes even degradation across the whole image.

In [7], $S_3$ (spectral and spatial sharpness) measures local perceived sharpness in an image by combining spectral and spatial measures based on the slope of the local magnitude spectrum and the local maximum total variation (TV). A novel approach to sharpness/blur measure is based on local phase congruency [8]. LPC-SI (Local Phase Coherence sharpness index) is a sharpness estimator that accounts for strong local phase coherence near distinctive image features evaluated in the complex wavelet transform domain [8]. $S_3$ and LPC-SI outperform state-of-the-art NR sharpness metrics such as CPBD [9], JNDB [10], and general purpose metrics BRISQUE [11,12] and BLIINDS-II [13,14] in publicly available image databases LIVE [15,16,3], TID2008 [17], CSIQ [18], and IVC [19].

Although these algorithms are not designed to work with noise, they are analyzed when Gaussian noise is added to the image. $S_3$ and LPC-SI have shown sensitivity to spurious sharp locations due to spatially localized noise and decreasing monotonicity with

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the increase of noise, respectively. Nonetheless, $S_3$ and LPC-SI do not correlate well to human judgements in the joint evaluation of blurry and noisy image data sets. The effect of noise on perceived image sharpness has complicated issues. When noise is applied to an image, important perceptual changes occur in the uniform regions of the image, in which perceptual sharpness may increase [7]. Additionally, there are cases in which noise can affect the perceived sharpness at the sharp edges near an object, making difficult for a metric the distinction of details in the image.

The image gradient magnitude is responsive to artifacts introduced by compression, blur or additive noise, etc. The image gradient has been employed for FR-IQA in different ways [20–22]. However, in this work we concentrate on NF-IQA metrics based on localized gradient measures for sharpness evaluation in noisy and blurry images. Gradient based models are supported by the observation that sharpness and contrast of a local region are closely related to the energy in the dominant direction. Local gradients are decomposed into singular values that represent the energy in the local main directions of change [23,24]. In [23] Zhu and Milanfar define a no-reference objective sharpness H-metric that detects both blur and noise, and it depends on a priori knowledge of noise variance across the image. As a solution, in [24] Q metric implicitly accounts for the local noise variance and measures image content, but it is not a general no-reference image quality metric. As such, it does not correlate well to human judgements when assessing image relative quality.

In this paper, we analyze image sharpness from the perspective of quality features extracted from undistorted images and propose a NR IQA metric that is properly correlated with human judgements. This proposal comes from the idea that the sharpness degradation of an image caused by blur or noise can be expressed as its distance to the quality feature model obtained from undistorted images.

We name our sharpness metric as GSVD (Gradient Singular Value Decomposition) to underline that quality features derive from the products of gradient singular values computed within local patches in the image assessed. Gradient singular values represent energy in main gradient directions, and they are sensitive to noise and blur. This metric does not require a priori knowledge of distorted images, nor any training on human evaluations.

Our key contributions are: (i) no reference sharpness evaluation model that only makes use of gradient based quality features and distances to undistorted images without knowledge of the expected image distortion, nor training on subjective quality evaluation (ii) validation of the proposed model accuracy on three publicly available human rated image databases degraded by blur and noise. The proposed NR perceptual sharpness metric GSVD outperforms most of the state-of-the-art NR algorithms when measuring quality in blurry and noisy image sets jointly. GSVD delivers comparable performance with full reference (FR) peak signal to noise ratio (PSNR) and multiscale structural similarity (MSSIM).

The remainder of this article is organized as follows. Section 2 provides a detailed description of the proposed perceptual sharpness metric. In Section 3, we analyze the results of GSVD for quality assessment of blurry and noisy images and prediction monotonicity. Finally, Section 4 concludes this paper. A MATLAB implementation of the proposed methodology is available on-line at https://github.com/jeospina/GSVD.git.

## 2. Gradient singular value decomposition IQA measure

We propose a new NR IQA measure based on quality features extracted from the product of energies of local dominant orientation, and its perpendicular direction. The quality measure is the Euclidean distance between the test image features and the reference model, which is obtained from a set of pristine natural images. Fig. 1 shows the process diagram of the proposed measure.

### 2.1. Spatial domain features

Quality features are calculated from the products between energies in the local dominant direction and its perpendicular orientation. This process begins by applying the mean subtracted contrast normalization (MSCN) [25] to the test image $I$:

$$\widehat{I}_{(i,j)} = \frac{I_{(i,j)} - \mu_{(i,j)}}{\sigma_{(i,j)}} \quad (1)$$

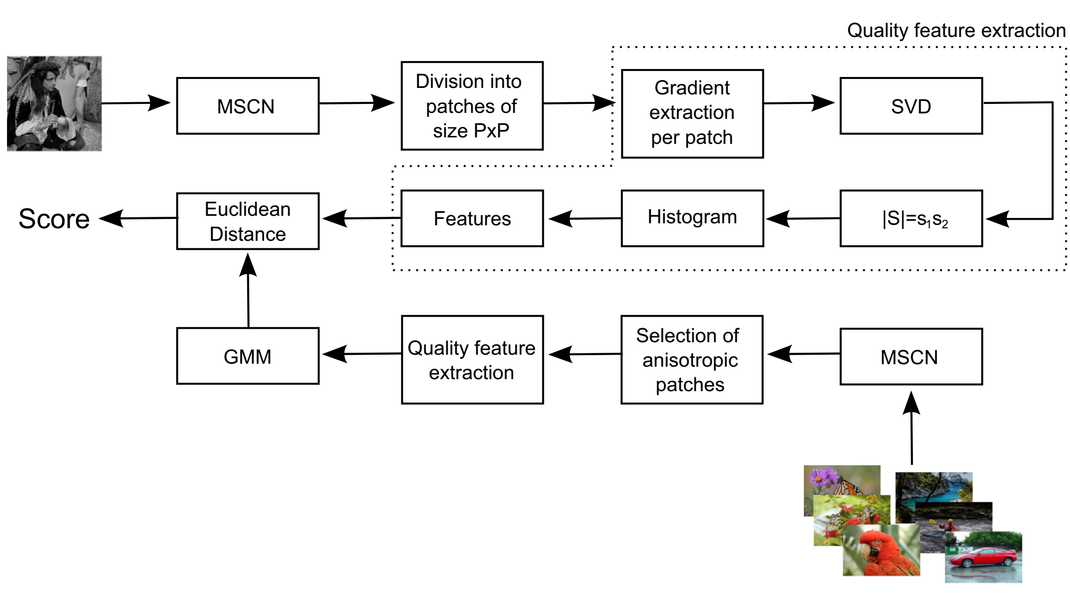


**Fig. 1.** Stages of the proposed Gradient Singular Value Decomposition (GSVD) IQA metric. In the first stage quality features are extracted from the test image. Then, the sharpness measure is the Euclidean distance in the quality feature space between Gaussian Mixture Model (GMM) of pristine images and the test image.