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Image quality assessment method based on nonlinear feature extraction in kernel space

Key words: Image quality assessment, Full-reference method, Feature extraction, Kernel space, Support vector regression

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Motivation

- A wide variety of distortions may be introduced in images during acquisition, processing, compression, storage, transmission and reproduction, which result in a degradation of visual quality. How to evaluate the quality of the images accurately has become a hot topic in the recent years.
- It is important to develop an objective IQA method which can automatically measure the perceptual image quality that is consistent with subjective human evaluation.
- To match human perception, extracting perceptual features effectively plays an important role in image quality assessment.

Main idea

- In contrast to most existing methods that use linear transformations or models to represent images, we employ a complex mathematical expression of high dimensionality to reveal the statistical characteristics of the images. Furthermore, by introducing kernel methods to transform the linear problem into a nonlinear one, a full-reference image quality assessment method is proposed based on high-dimensional nonlinear feature extraction.
- The proposed method achieves a promising performance that is consistent with human subjective evaluation.

Method

- There are three processing stages in the proposed method.
  1. In the color space conversation stage, the input reference and distorted images are separated into RGB channels.
  2. In the feature extraction stage, nonlinear features for each channel are extracted after dimension reduction.
  3. Finally, with a dedicated support vector machine based pooling strategy, the aggregation evaluation is given by synthesizing the features in each channel.

Major results

- The proposed method achieves a comparatively larger SRCC on each distortion type, validating it as a powerful method for image quality assessment.

Table 2 Spearman rank-order correlation coefficient (SRCC) comparison on individual distortion types in the LIVE database

Method	SRCC				
	JP2K	JPEG	WN	Gblur	FF
PSNR	0.8954	0.8809	**0.9854**	0.7823	0.8907
ASVD	0.9146	0.9112	0.9425	0.8226	0.9048
MSDD	0.8991	0.8828	0.9461	0.9480	0.9226
SSIM	0.9614	0.9764	0.9694	0.9517	0.9556
MS-SSIM	0.9654	0.9793	0.9731	0.9584	0.9321
VIF	0.9683	**0.9842**	0.9845	**0.9722**	0.9652
FSIM	0.9717	0.9834	0.9652	0.9708	0.9499
GSM	**0.9759**	0.9392	0.8577	0.9589	0.8925
QDFS	0.9603	0.9517	0.9656	0.9527	0.9415
Proposed	0.9639	0.9766	0.9724	0.9633	**0.9658**

JP2K: JPEG2000 images; WN: white noise images; Gblur: Gauss blurred images; FF: fast-fading images. The best result of each distortion type is in boldface

Major results (Cont'd)

- The proposed method, FSIM and VIF give the best performance on almost all the three databases. However, in terms of the robustness on different databases, the proposed scheme and FSIM give more consistent and stable performances across all the three databases in comparison with the other methods.

Table 3 Performance comparison on different databases

Database	Criterion	PSNR	SSIM	MS-SSIM	MSDD	FSIM	VIF	GSM	Proposed
LIVE	PLCC	0.8723	0.9449	0.9409	0.8900	**0.9597**	**0.9598**	0.9437	0.9476
	SRCC	0.8756	0.9479	0.9513	0.8901	**0.9634**	**0.9632**	0.9554	0.9543
	RMSE	13.3597	8.9454	9.2593	**7.3413**	7.6780	7.6670	9.0376	**7.6502**
TID2008	PLCC	0.5726	0.7710	0.8451	–	**0.8738**	0.8090	0.8462	**0.8467**
	SRCC	0.5794	0.7749	0.8542	–	**0.8805**	0.7496	**0.8554**	0.8488
	RMSE	1.1003	0.8546	0.7173	–	**0.6525**	0.7888	**0.7151**	0.7210
CSIQ	PLCC	0.7998	0.8612	0.8990	–	0.9120	**0.9227**	0.8979	**0.9143**
	SRCC	0.8005	0.8756	0.9133	–	**0.9242**	**0.9195**	0.9126	0.9124
	RMSE	0.1576	0.1334	0.1150	–	0.1077	**0.0980**	0.1156	**0.1068**

PLCC: Pearson linear correlation coefficient; SRCC: Spearman rank-order correlation coefficient; RMSE: root mean square error. Two best results for each criterion on each database are in boldface

Conclusions

- A method has been proposed as a successful attempt to extract nonlinear features of images and apply them in the framework of IQA.
- Experimental results show that nonlinear features have equivalent and even better ability to evaluate the image quality.
- The accuracy and robustness across different distortion types and databases demonstrate the proposed method to be a general-purpose and stable approach.