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Performance Evaluation of Sparseness Significance Ranking Measure (SSRM) on Holographic Content

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Abstract: The Sparseness Significance Ranking Measure (SSRM) was recently proposed as full reference quality measure for regular images. In this paper, we evaluate its performance on holographic content in comparison to MSE, PSNR and the Versatile Similarity Measure (VSM). The experimental results based on subjective quality assessment show a significant gain over the classical methods.

OCIS codes: 090.1995, 110.3000.

1. Introduction

In comparison to the significant efforts deployed to develop holographic displays, holographic capturing techniques, computer-generated holography algorithms, proportionally less research has been devoted to quality assessment, distortion analysis and ideally perceptual quality prediction of holographic data [1, 2]. Even for the sole purpose of signal error analysis of complex wavefields (without taking into account the perceptual aspects), only few options like MSE, PSNR, and SSIM are available, which are mainly transferred from real-valued data analysis. Recently, we have introduced another framework which is specifically tailored for the complex data called Versatile Similarity Measure (VSM) [3]. The experiments on some of its several instances have demonstrated its potential for the specific case of holography [4].

Sparse coding has been suggested to be an underlying strategy in our brain's neural processes. Considering the fact that specific tasks like visual quality assessment should be implemented through those neural activities, we assumed that there should be a significant relation between these two. To investigate validity of our assumption, we proposed a novel perceptual quality predictor algorithm which solely takes into account the importance of the features with respect to the sparsity criterion. The detailed explanation of the way SSRM predicts the overall similarity value between a reference image and its distorted version can be found in [5]. It was shown that SSRM depicts a highly competitive performance w.r.t the state-of-the-art and highly correlated with the subjective scores at a rather low computational cost. Since SSRM only exploits the gathered data from the spectral domain, it can be readily applied for the other data modalities including complex valued data. In this research, we propose some early stage experiments to check the potential of deploying SSRM on the holographic data.

2. Experimental Results

We tested the performance of 5 measures applied in the complex domain namely PSNR, MSE, our recently introduced framework called Versatile Similarity Measure (VSM), SSRM, and a combination of SSRM with VSM. In the latter, the core similarity formula of SSRM was replaced with the tested VSM instance. All methods were tested on the complex wavefield of 96 holograms from the INTERFERE-I database [6]. The Mean Opinion Scores (MOS) of the database, which was acquired from human subjects who viewed the reconstructed holograms, were used as reference. The absolute part of the complex wavefields was re-scaled to the range of [0,1] before calculations. In this case the selected peak value for PSNR was set to 1. The selected components for VSM were: $\gamma_M \{ \text{Gaus} \} = \{ 2, 1 \}$, $\gamma_0 \{ \text{GausM} \} = \{ 10^{-4} \}$, $\lambda = -1(z,w)$ [4], which hereafter, we refer to this specific version simply as VSM. Fig 1. shows the scatter plots of the tested quality predictors versus MOS. In Fig 1.(a), PSNR shows its typical behaviour where it continuously grows even after the Human Visual System (HVS) is unable to distinguish the distortion. MSE and VSM, illustrated in in Fig 1.(b) and (c), demonstrate a certain amount of insensitivity to the highly distorted complex wavefields. However, VSM depicts a slightly better performance overall. To the contrary, SSRM performs significantly and consistency better along the full MOS range (Fig 1.(d)). Also, its predictions have an almost linear correlation with respect to the subjective scores. Fig 1.(e) illustrates that combining the assets of SSRM and VSM slightly improves the consistency while shifting the overall range of SSRM scores toward the high end. Table 1. shows the Pearson Correlation Coefficient (PCC), Spearman Rank Order Correlation Coefficient (SROCC)
Fig. 1: Scatter plots of the predicted quality scores from different methods versus subjective mean opinion scores of the INTERFERE-I database. (a) PSNR, (b) MSE, (c) VSM, (d) SSRM and (e) SSRM-VSM and Kendall Rank Order Correlation Coefficient (KROCC) for the tested methods. Both SSRM and its combination with VSM improve the quality assessment performance compared to MSE, PSNR and VSM with respect to all three correlation coefficients.

Overall, based on the current results, SSRM appears to be an interesting choice for holographic quality assessment. Nonetheless, it should be noted that a generalization of the current results to the entire domain of holographic imaging, especially for holograms of highly diffused objects with a wide FOV, requires more in-depth investigations.

Table 1: Pearson (PCC), Spearman (SROCC) and Kendall (KROCC) correlation coefficients for the tested quality predictors. Values nearer to 1 or -1 show higher correlation with respect to the MOS.

<table>
<thead>
<tr>
<th></th>
<th>PSNR</th>
<th>MSE</th>
<th>VSM</th>
<th>SSRM</th>
<th>SSRM-VSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCC</td>
<td>0.679</td>
<td>-0.832</td>
<td>0.846</td>
<td>0.912</td>
<td>0.911</td>
</tr>
<tr>
<td>SROCC</td>
<td>0.769</td>
<td>-0.769</td>
<td>0.785</td>
<td>0.808</td>
<td>0.811</td>
</tr>
<tr>
<td>KROCC</td>
<td>0.581</td>
<td>-0.581</td>
<td>0.591</td>
<td>0.626</td>
<td>0.633</td>
</tr>
</tbody>
</table>

3. Conclusion

In this experiment, we tested the performance of the SSRM for the case of digital holography. Our early results on the only available holographic, subjective quality database reveals a significant gain compared to the available methods in terms of predicting the perceptual quality of the reconstructed holograms from their complex wavefields.

References