Inpainting of Image and Video Data Using Rapid Frequency Selective Reconstruction

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The Rapid Frequency Selective Reconstruction (FSR) is a high-quality signal extrapolation algorithm. Recently, the original method was extended by a signal and loss geometry aware processing order as well as a texture dependent parameter refinement to achieve a real-time capable signal extrapolation method. FSR is proven to achieve outstanding results for the following fields of application: Inpainting, error concealment, image reconstruction, image resampling, and non-regular sampling.

I. Algorithmic Description

The FSR is a powerful approach to reconstruct missing samples in an image block for arbitrary loss patterns and is described in detail in [1], [2]. Successively, the signal of a distorted block is extrapolated using known samples and already reconstructed pixels as support. FSR generates the complex-valued model

$$g[m,n] = \sum_{(k,l)\in\mathcal{K}} \hat{c}_{k,l} \cdot \varphi_{k,l}[m,n], \tag{1}$$

which approximates the undistorted samples in the extrapolation area of size $M \times N$ depicted by integer coordinates m and n as a weighted linear combination of Fourier basis functions $\varphi_{k,l}[m,n]$. Hence, the missing samples are estimated as well and can be extracted after the model was set up. In above equation, $\hat{c}_{k,l}$ denote the expansion coefficients, $\varphi_{k,l}[m,n]$ name the Fourier basis functions and set $\mathcal{K}$ contains the indices (k,l) that are used in the model $g[m,n]$. An important feature of FSR is the fact that the calculations are carried out in the Fourier domain, which leads to a fast implementation. The generation of the model is an iterative procedure, whereby basis functions and expansion coefficients are selected step by step. With the adaptions proposed in [4], the described algorithm is real-time capable as demonstrated in [5].

II. Evaluation compared to existing inpainting methods in OpenCV

For comparing the FSR to the existing OpenCV inpainting methods, each method is applied to the same RGB input images. The Kodak and Tecnick image sets are used as input images after being distorted with five different error masks. The mean Peak Signal-to-Noise-Ratio (PSNR) and Structural Similarity (SSIM) values of the reconstructed images are calculated for quality assessment. The implementations of the two inpainting methods part of the OpenCV photo-module are publicly available at [6]. Both methods restore the distorted image areas using the pixels near its boundary, whereby one method is Navier-Stokes based (NS) [7] and the other method by Alexandru Telea is based on the Fast Marching Method [8]. The obtained results using the three methods can be found in Tab. I. Additionally, Fig. 1 provides a visual example of the reconstruction by the different methods.

TABLE I: Mean PSNR and SSIM for Kodak and Tecnick image set.

	FSR Fast	FSR Best	NS	Telea
PSNR [dB]	29.038	30.064	27.413	27.524
SSIM	0.909	0.912	0.895	0.895
Runtime [s]	7.828	114.290	1.100	2.158

It can be concluded that the FSR outperforms the existing inpainting methods by achieving a very high reconstruction quality, in terms of PSNR and SSIM as well as in terms of visual quality. Gains of 2.7 dB and 2.5 dB PSNR are accomplished compared to the NS and to the Telea method, respectively.

References

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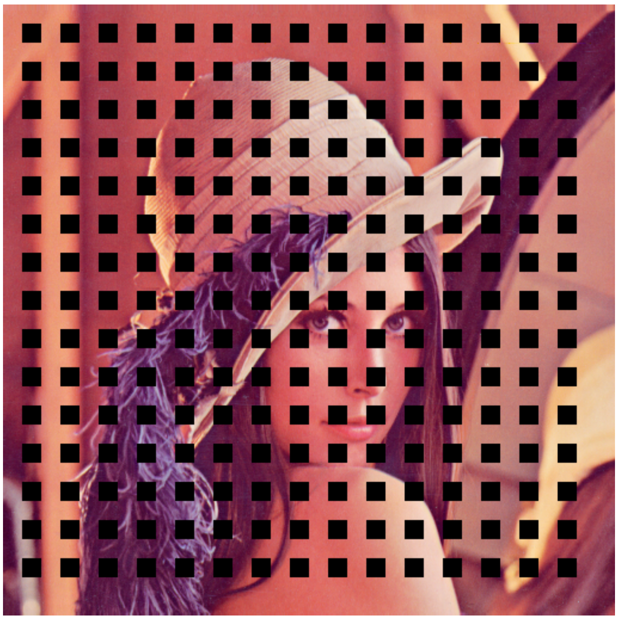
Fig. 1: Original and distorted ”lena” image, reconstructed with different inpainting methods. PSNR, SSIM and runtime values are given for each method.

(a) Original



(b) Distorted

(c) FSR (Best): 33.592 dB, 0.945, 90.598 s.

(d) FSR (Fast): 32.848 dB, 0.942, 3.691 s.

(e) NS: 29.352, 0.925, 0.201 s.

(f) Telea: 28.942 dB, 0.921, 0.201 s.