MOTION-ADAPTED THREE-DIMENSIONAL FREQUENCY SELECTIVE EXTRAPOLATION

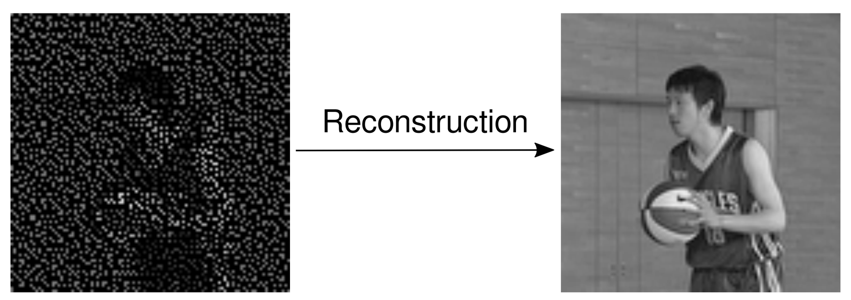
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Andreas Spruck, Markus Jonscher, Jürgen Seiler, and André Kaup

Multimedia Communications and Signal Processing
Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Cauerstr. 7, 91058 Erlangen, Germany

1. Introduction

- Acquistion of nonregular quarter sampled images [1]
  - Low resolution sensor to record high resolution video data
  - Recording of images with four times higher resolution using same amount of pixels
  - Save data-rate and storage space
- Reconstruction before usage
  - Three-dimensional frequency selctive extrapolation (3D-FSE) [2]
  - Support area extends along spatial and temporal neighborhood



- Motion blur due to spatial mismatch along temporal axis
  - Compensation by adapted spatial weighting function

2. 3D Frequency Selective Extrapolation

- Iterative generation of model $g[m,n,p]$ of weighted superimposed Fourier basis functions $\varphi_{(k,l,q)}[m,n,p]$ [2]

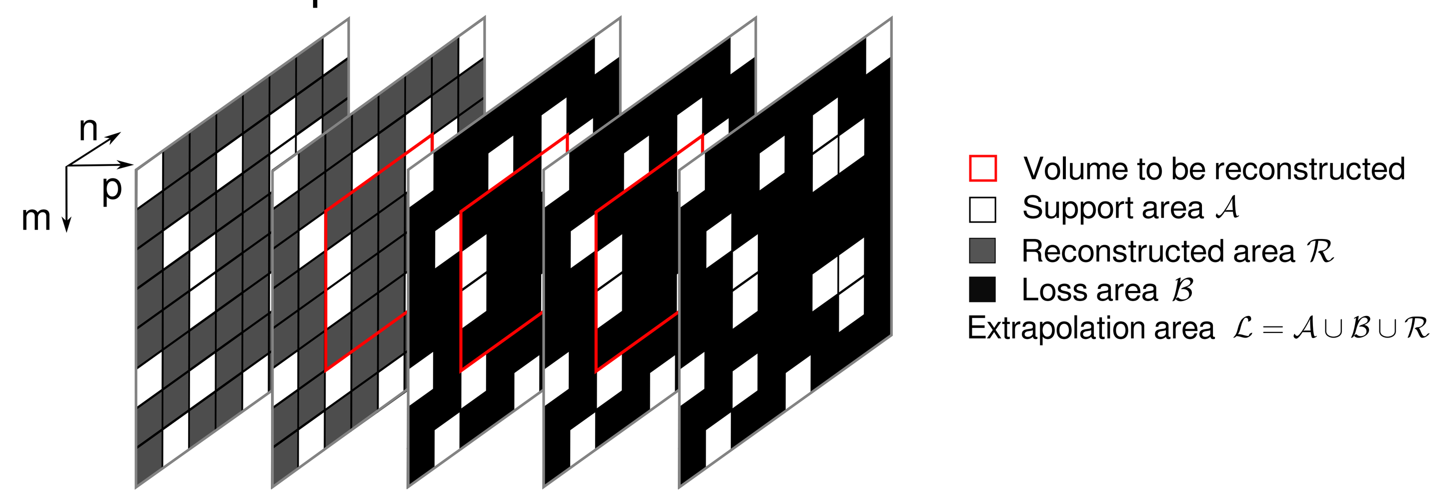
$$g[m,n,p] = \sum_{(k,l,q)\in\mathcal{K}} \hat{c}_{(k,l,q)}\varphi_{(k,l,q)}[m,n,p]$$

- Blockwise processing
- Spatial weighting function to steer influence of data points

$$w[m,n,p] = \begin{cases} \rho[m,n,p] & ,(m,n,p)\in\mathcal{A} \\ \delta\rho[m,n,p] & ,(m,n,p)\in\mathcal{R} \\ 0 & ,(m,n,p)\in\mathcal{B} \end{cases}$$

$$\rho[m,n,p] = \hat{\rho}^{\sqrt{\left(m-\frac{M-1}{2}\right)^2+\left(n-\frac{N-1}{2}\right)^2+\left(p-\frac{P-1}{2}\right)^2}}$$

- All calculations performed in Fourier domain



3. Proposed Motion Compensated Weighting

- Shifting the center of mass of the weighting function according to the motion in the sequence

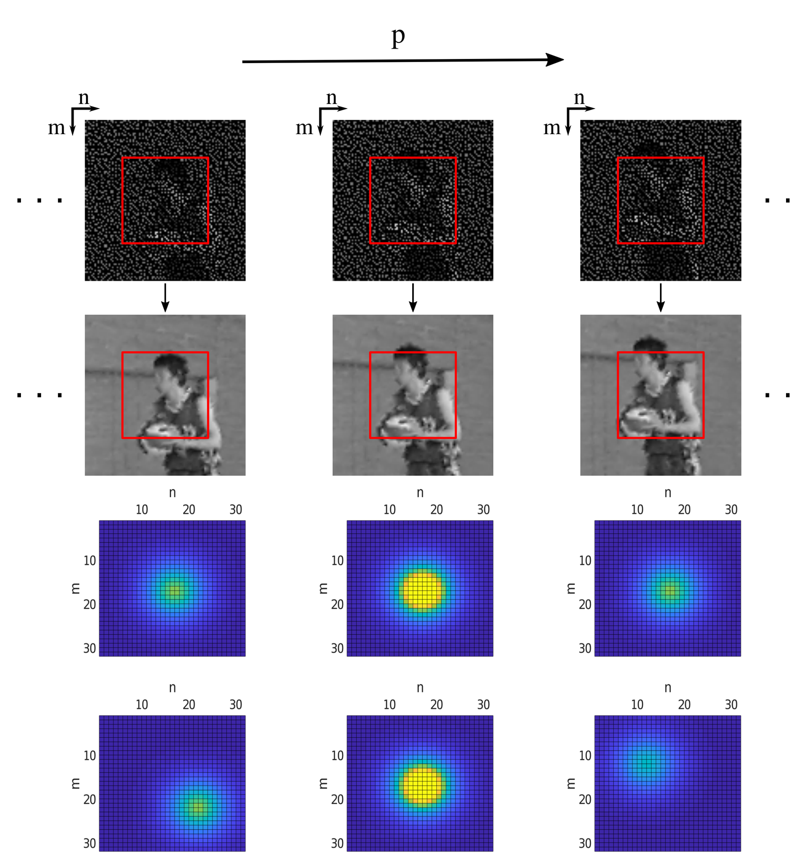
$$\tilde{\rho}[m,n,p] = \hat{\rho}^{\sqrt{\left(m-\frac{M-1}{2}-\bar{v}_{\mathrm{x}}[p]\right)^2+\left(n-\frac{N-1}{2}-\bar{v}_{\mathrm{y}}[p]\right)^2+\left(p-\frac{P-1}{2}\right)^2}}$$

$$\tilde{w}[m,n,p] = \begin{cases} \tilde{\rho}[m,n,p] & ,(m,n,p)\in\mathcal{A} \\ \delta\tilde{\rho}[m,n,p] & ,(m,n,p)\in\mathcal{R} \\ 0 & ,(m,n,p)\in\mathcal{B} \end{cases}$$

- Motion estimation using optical flow [3]
  - Averaging motion vector field to one motion vector per block

$$\begin{pmatrix}\bar{v}_{\mathrm{x}}[p] \\ \bar{v}_{\mathrm{y}}[p]\end{pmatrix} = \frac{1}{MN}\cdot\sum_{\forall m,n}\begin{pmatrix}v_{\mathrm{x}}[m,n,p] \\ v_{\mathrm{y}}[m,n,p]\end{pmatrix}$$

- 3D-FSE with motion compensated weighting of the support area (3D-MCW-FSE) copes with motion within the support area



4. Simulations & Results

- Test parameters:
  - 50 frames of each sequence of classes C and D of HEVC testset [4]
  - Block-size of 4×4×1,
  - $\hat{\rho} = 0.7$, and δ are set to 0.5
  - Borderwidth of 14 in all directions

Sequence	2D-FSE [5]	3D-GF [6,7]	3D-FSE [2]	3D-MCW-FSE
Basketball Pass	30.18 dB	29.70 dB	31.49 dB	**31.64 dB**
Blowing Bubbles	28.04 dB	28.04 dB	29.93 dB	**30.19 dB**
BQ Square	21.02 dB	22.17 dB	23.77 dB	**23.84 dB**
Race Horses	28.40 dB	27.30 dB	28.94 dB	**30.69 dB**
Basketball Drill	31.55 dB	29.81 dB	31.27 dB	**31.80 dB**
BQ Mall	28.72 dB	27.12 dB	29.24 dB	**29.72 dB**
Party Scene	23.74 dB	24.13 dB	26.26 dB	**26.38 dB**
Race Horses	28.58 dB	27.09 dB	28.97 dB	**30.62 dB**
Average	27.53 dB	26.92 dB	28.73 dB	**29.36 dB**

- Test results:
  - Highest reconstruction quality in test
  - Highest gain in sequences with much motion
  - For sequences with little motion 3D-FSE approaches 3D-MCW-FSE

a) 2D-FSE [5] b) 3D-GF [6,7] c) 3D-FSE [2] d) 3D-MCW-FSE e) original

f) 2D-FSE [5] g) 3D-GF [6,7] h) 3D-FSE [2] i) 3D-MCW-FSE j) original

5. Conclusion

- Recording of quarter sampled sequences
- Reconstruction of the not directly acquired image areas
- Estimating the average motion per block
- Shifting the spatial weighting function corresponding to the motion
- Compensation of ghosting and blurring caused by motion during the reconstruction
- Highest gains for sequences with much motion
- Gains up to 1.75 dB compared to 3D-FSE

[1] M. Schöberl, J. Seiler, S. Foessel, and A. Kaup, "Increasing imaging resolution by covering your sensor," in 18th IEEE International Conference on Image Processing, Sept 2011, pp. 1897–1900.

[2] K. Meisinger and A. Kaup, "Spatiotemporal selective extrapolation for 3D signals and its applications in video communications," IEEE Transactions on Image Processing, vol. 16, no. 9, pp. 2348–2360, 2007.

[3] G. Farnebäck, "Two-frame motion estimation based on polynomial expansion," Image analysis, pp. 363–370, 2003.

[4] F. Bossen et al., "Common test conditions and software reference configurations," in 11th Meeting: Joint Collaborative Team on Video Coding of ITU-T SG, 2011, vol. 16.

[5] J. Seiler and A. Kaup, "Complex-valued frequency selective extrapolation for fast image and video signal extrapolation" in IEEE Signal Processing Letters, Nov 2010, vol. 17, pp. 949–952.

[6] D. Garcia, "Robust smoothing of gridded data in one and higher dimensions with missing values," Computational statistics & data analysis, vol. 54, no. 4, pp. 1167–1178, 2010.

[7] G. Wang, D. Garcia, Y. Liu, R. De Jeu, and A. J. Dolman, "A three-dimensional gap filling method for large geophysical datasets: Application to global satellite soil moisture observations," Environmental Modelling & Software, vol. 30, pp. 139–142, 2012.

ICASSP 2019