



Super-Resolution Techniques for Mixed-Resolution Multi-View Images

André Kaup

Chair of Multimedia Communications and Signal Processing
Friedrich-Alexander University Erlangen-Nürnberg

Motivation – Mixed-Resolution Multi-View

- Linear mixed-resolution multi-view setup:



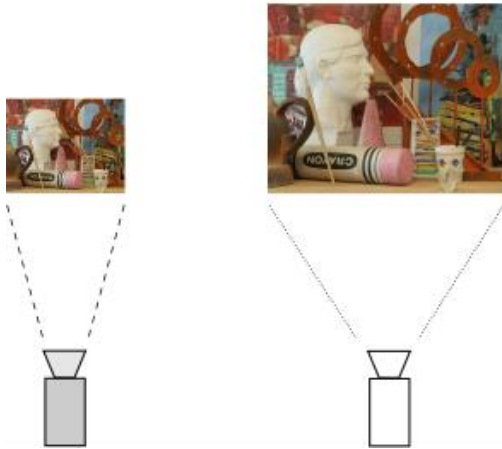
Motivation – Mixed-Resolution Multi-View

- Using mixed-resolution setups leads to
 - ✓ less complexity regarding data transmission
 - ✓ less complexity regarding data storage
 - ✓ less financial costs
 - ✓ an easy expandability of existing setups
- ✗ Multi-view approaches might require high-resolution images from all available perspectives

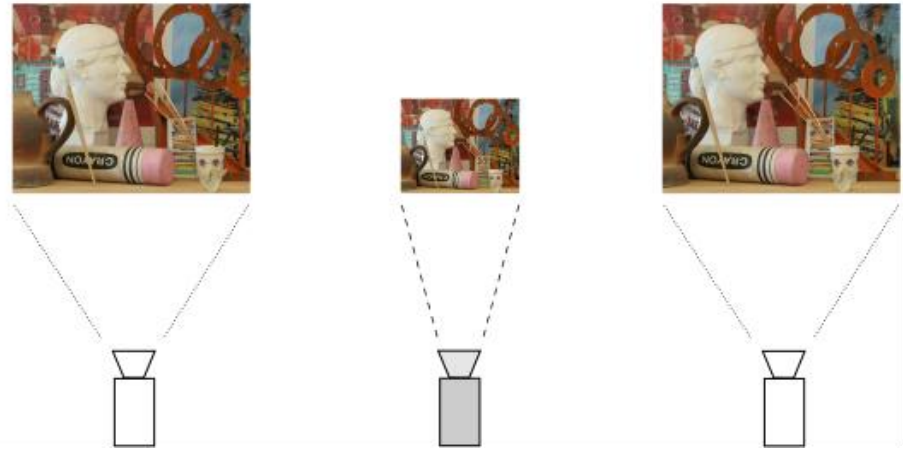
Motivation – Super-Resolution

- Considered multi-camera setups:

Stereo setup: LH

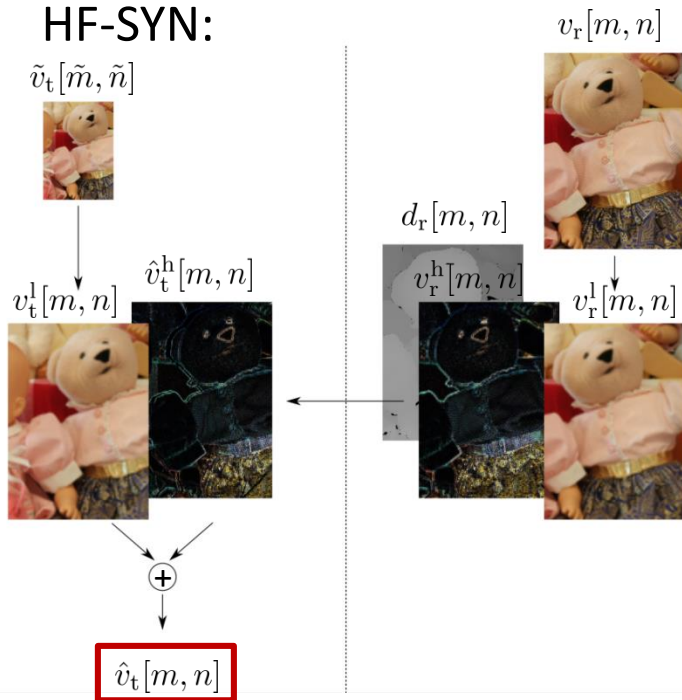


Three-camera setup: HLH



Super-Resolution Based on High-Frequency Synthesis

■ HF-SYN:



- Capture images
- Resize target view
- Split reference view
- Project high-frequency part
- Add synthesized high-frequency part

Super-Resolution Based on High-Frequency Synthesis

- Simulation results: ■ Downsampling factor 4

	<i>aloe</i>	<i>art</i>	<i>baby1</i>	<i>books</i>	<i>bowling1</i>	<i>cloth1</i>	<i>dolls</i>	<i>moebius</i>	<i>reindeer</i>	Δ PSNR
BIC	26.60	30.93	30.88	28.86	34.70	27.32	29.84	31.38	30.18	-
[Kim2010]	27.53	32.56	31.50	30.07	35.73	28.76	31.14	32.50	31.04	1.13
[Yang2010]	27.64	32.40	31.44	29.95	35.65	28.82	31.07	32.44	30.99	1.08
camera setup: LH										
HF-SYN	31.98	33.45	35.37	33.60	37.76	35.23	33.74	34.89	33.65	4.33
camera setup: HLH										
HF-SYN	33.29	34.82	36.78	35.32	38.80	37.02	35.08	36.17	35.36	5.77

[Kim2010] K.I. Kim, Y. Kwon. *Single-Image Super-Resolution Using Sparse Regression and Natural Image Prior*. IEEE Trans. on Pattern Analysis and Machine Intelligence, 2010

[Yang2010] J. Yang, J. Wright, T. Huang, Y. Ma. *Image Super-Resolution via Sparse Representation*. IEEE Trans. on Image Processing, 2010

Super-Resolution Based on High-Frequency Synthesis

- Experimental mixed-resolution multi-view setup:



Spatial resolutions:

Kinect: 640x480

Webcams: 1920x1080

Super-Resolution Based on High-Frequency Synthesis

- Self-recorded dataset:



Super-Resolution Based on High-Frequency Synthesis

- Experimental results:
 - Camera setup: HLH

BIC



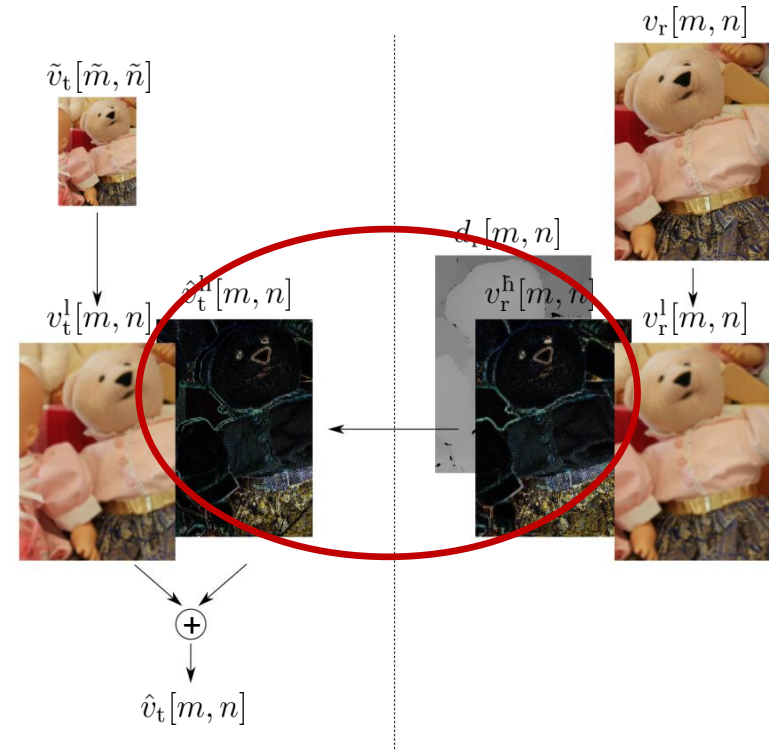
HF-SYN



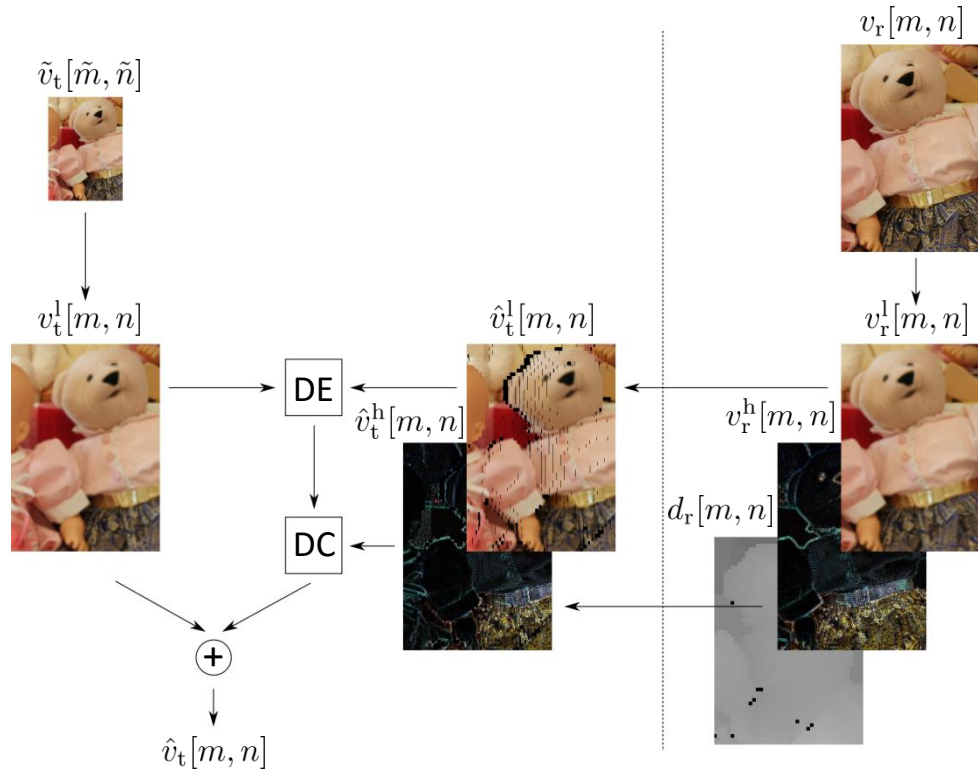
Robust High-Frequency Synthesis

- SR quality highly depends on the quality of the depth information $d_r[m, n]$

How to robustly synthesize $\hat{v}_t^h[m, n]$ in case of inaccurate depth information?



Robust High-Frequency Synthesis

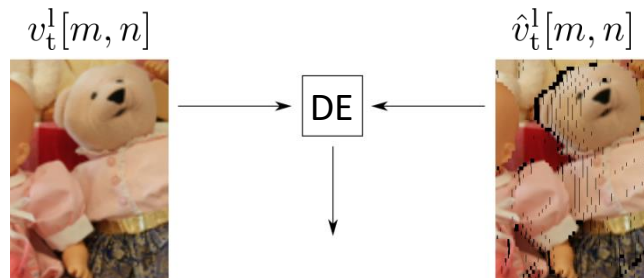


- Capture images
- Resize target view and split reference view
- Project low- and high-frequency part
- Estimate the displacement
- Compensate the displacement
- Add displacement-compensated synthesized high-frequency part

Robust High-Frequency Synthesis

- Displacement estimation (DE):

- Estimate a proper displacement between $\hat{v}_t^1[m, n]$ and $v_t^1[m, n]$



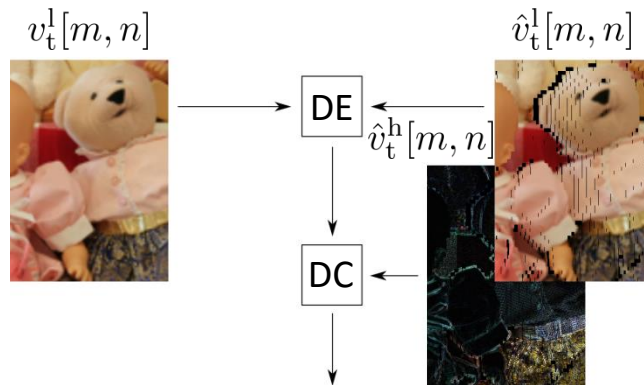
- DE is done in a **depth-dependent** and **blockwise** manner by searching for the most similar block within a search window in $v_t^1[m, n]$

Robust High-Frequency Synthesis

- Displacement compensation (DC):

- Estimated displacement is compensated for $\hat{v}_t^h[m, n]$

⇒ $\hat{v}_t^h[m, n]$ is adapted to $v_t^l[m, n]$



- Color-based consistency check to further improve the SR result (DC-CC) [Richter2015c]

[Richter2015c] T. Richter, J. Seiler, W. Schnurrer, A. Kaup. *Robust Super-Resolution for Mixed-Resolution Multiview Image plus Depth Data*. IEEE Transactions on Circuits and Systems for Video Technology, 2015

Robust High-Frequency Synthesis

■ Simulation results:

■ Downsampling factor 4

■ Camera setup: HLH

	<i>aloe</i>	<i>art</i>	<i>baby1</i>	<i>books</i>	<i>bowling1</i>	<i>cloth1</i>	<i>dolls</i>	<i>moebius</i>	<i>reindeer</i>	Δ PSNR
BIC	26.60	30.93	30.88	28.86	34.70	27.32	29.84	31.38	30.18	-
upsampled and scaled depth										
HF-SYN-E [Richter2015a]	24.21	28.69	28.90	27.79	32.61	24.73	27.32	29.17	28.39	-2.10
DC-CC	32.07	34.10	36.18	33.79	38.53	35.77	34.30	35.08	34.22	4.82
upsampled and zoomed depth										
HF-SYN-E [Richter2015a]	29.07	30.55	34.31	31.58	35.20	30.50	30.38	31.29	30.58	1.42
DC-CC	31.40	33.44	35.91	33.47	37.70	35.16	33.03	34.06	33.30	4.09

[Richter2015a] T. Richter, A. Habermann, A. Kaup. *Super-Resolution for Mixed-Resolution Multiview Images using a Relative Frequency Response Estimation Method*. IEEE Int. Conf. on Visual Communications and Image Processing, 2015

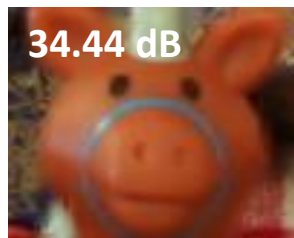
Robust High-Frequency Synthesis

- Simulation results: ■ Downsampling factor 4 ■ Camera setup: HLH ■ *dolls*

ground-truth

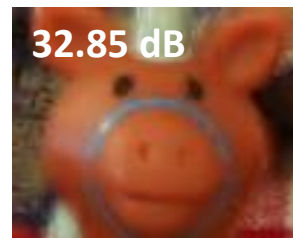


upsampled
depth

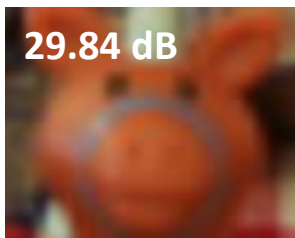


DC-CC

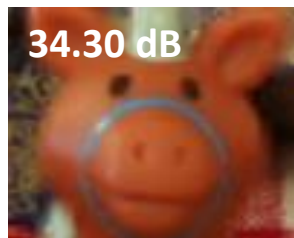
upsampled
and shifted
depth



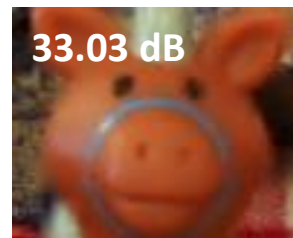
BIC



upsampled
and scaled
depth



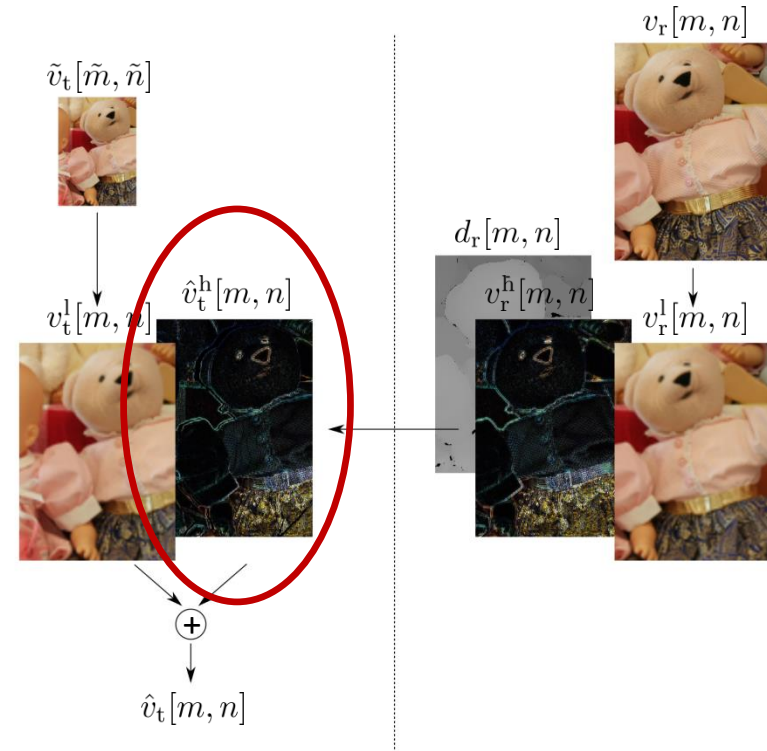
upsampled
and zoomed
depth



Occlusion Handling

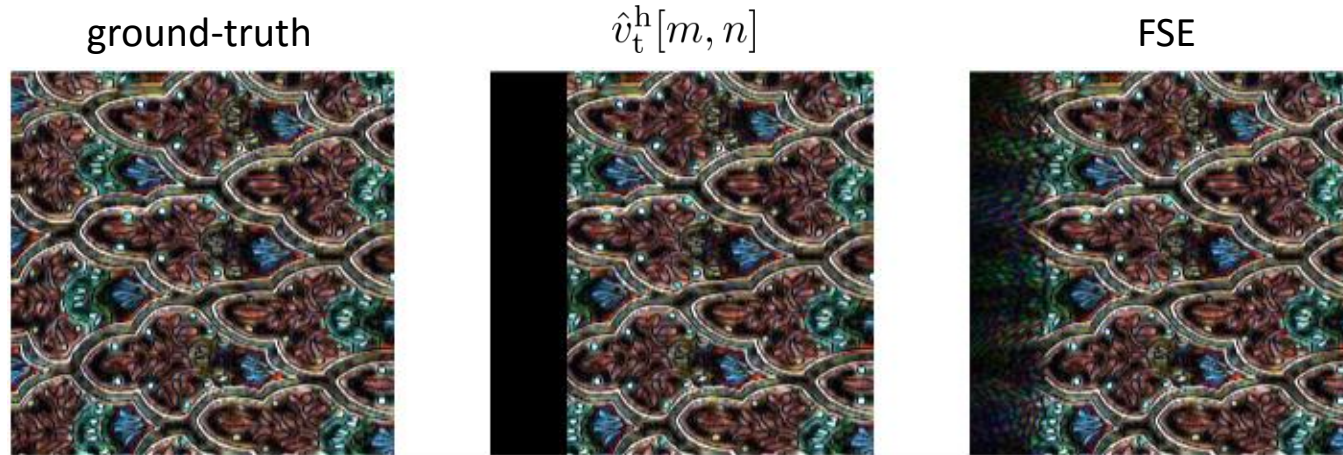
- Occluded areas cannot be directly super-resolved using the concept of HF-SYN

How to estimate the missing high-frequency parts in $\hat{v}_t^h[m, n]$?



Occlusion Handling

- FSE reconstruction performance:



✗ Especially at image borders, reconstruction of large loss areas is very challenging

Occlusion Handling

- Simulation results:
 - Downsampling factor 4
 - Camera setup: LH
 - DC-CC with upsampled depth information
 - PSNR only evaluated on occluded areas

	<i>aloe</i>	<i>art</i>	<i>baby1</i>	<i>books</i>	<i>bowling1</i>	<i>cloth1</i>	<i>dolls</i>	<i>moebius</i>	<i>reindeer</i>	Δ PSNR
BIC	26.05	28.97	30.52	30.14	35.76	28.08	28.82	30.39	30.25	-
[Oh2009]	23.49	27.02	28.60	28.23	33.47	25.99	26.98	28.39	27.54	-2.14
[Afonso2011]	26.01	28.79	30.92	30.18	35.72	28.51	29.20	30.57	30.24	0.13
FSE	26.26	29.43	31.25	31.25	35.98	28.33	29.72	31.40	31.10	0.64
BM	27.08	29.85	31.31	31.18	36.12	29.81	29.61	31.19	31.09	0.92
BM-FSE	27.46	30.25	31.96	31.72	36.38	30.32	30.32	31.81	31.68	1.44

[Oh2009] K.-J. Oh, S. Yea, Y.-S. Ho. *Hole Filling Method Using Depth Based In-Painting for View Synthesis in Free Viewpoint Television and 3-D Video*. Proc. Picture Coding Symposium, 2009

[Afonso2011] M. V. Afonso, J. M. Bioucas-Dias, M. A. T. Figueiredo. *An Augmented Lagrangian Approach to the Constrained Optimization Formulation of Imaging Inverse Problems*. IEEE Trans. on Image Processing, 2011

Summary

- For mixed-resolution setups, HF-SYN is a convincing super-resolution concept under **ideal** conditions.
- For inaccurate depth information, DC-CC achieves PSNR gains of up to **6.92 dB** compared to HF-SYN-E.
- For occluded areas, BM-FSE achieves an average PSNR gain of **0.80 dB** compared to FSE.
- Developed algorithmic concepts have been **successfully applied to real data**.

Acknowledgement & Literature

- Special thanks to Thomas Richter, Jürgen Seiler, Wolfgang Schnurrer

- Comprehensive Reference:

Thomas Richter: Super-Resolution Techniques for Mixed-Resolution Multi-View Images, München: Verlag Dr. Hut, ISBN 978-3-9439-2981-3, 2017.