Applications of Non-Regular Image Sampling using LFCR (Locally Fully Connected Reconstruction Network)

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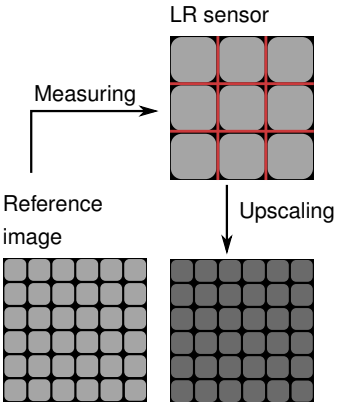
Outline

- Basics of Non-Regular Sampling
- Locally Fully Connected Reconstruction Network
- Application: Tetromino Sampling
- Conclusion and Future Work

Quarter Sampling (QS) and Three-Quarter Sampling (TQS)



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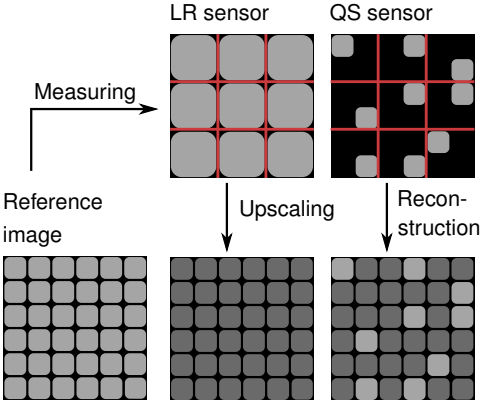

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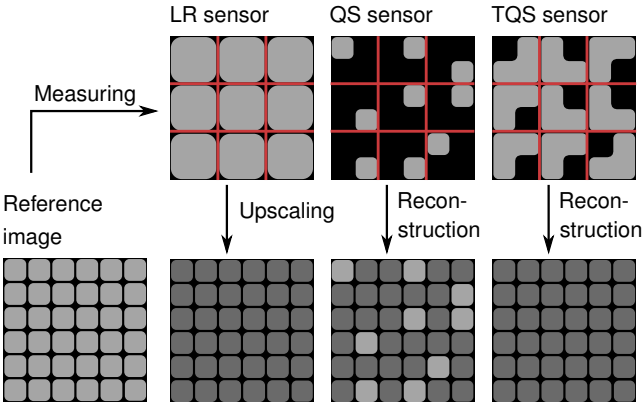

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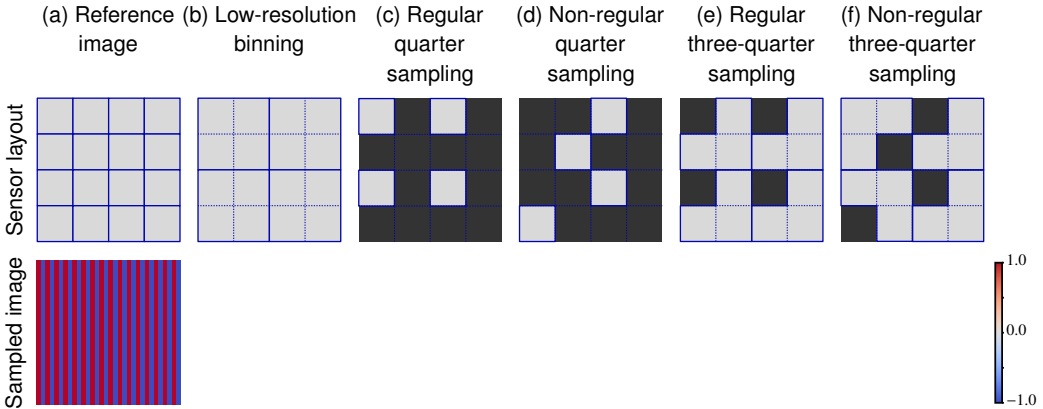
Illustrative Example

Example: Image with vertical stripes with 1 px width



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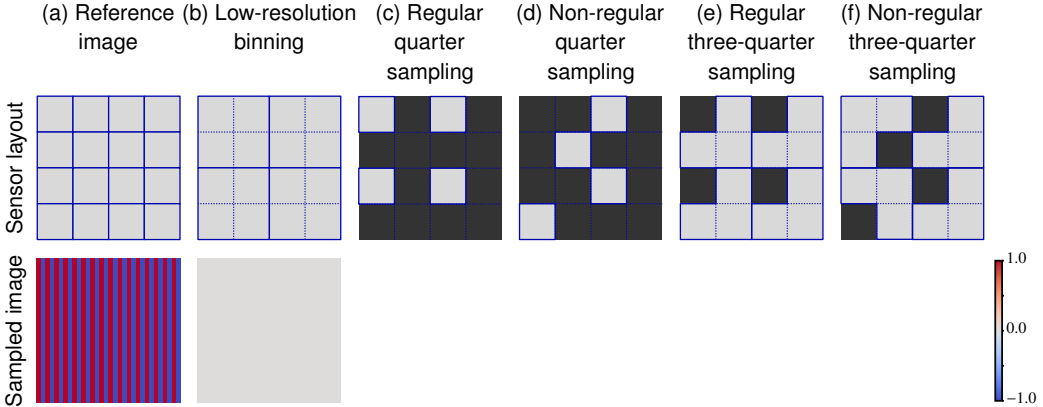

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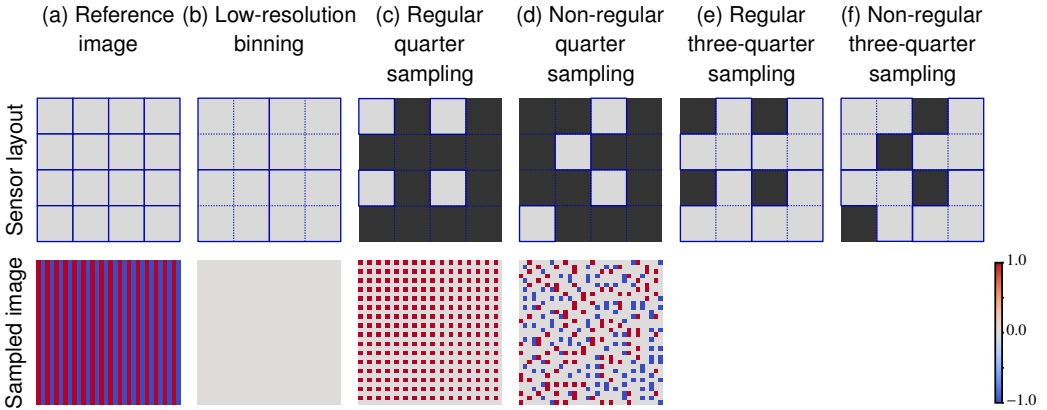

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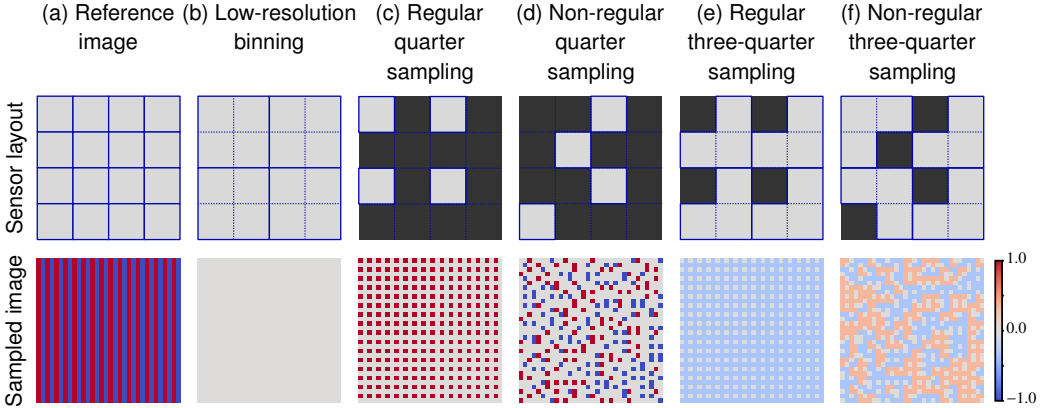

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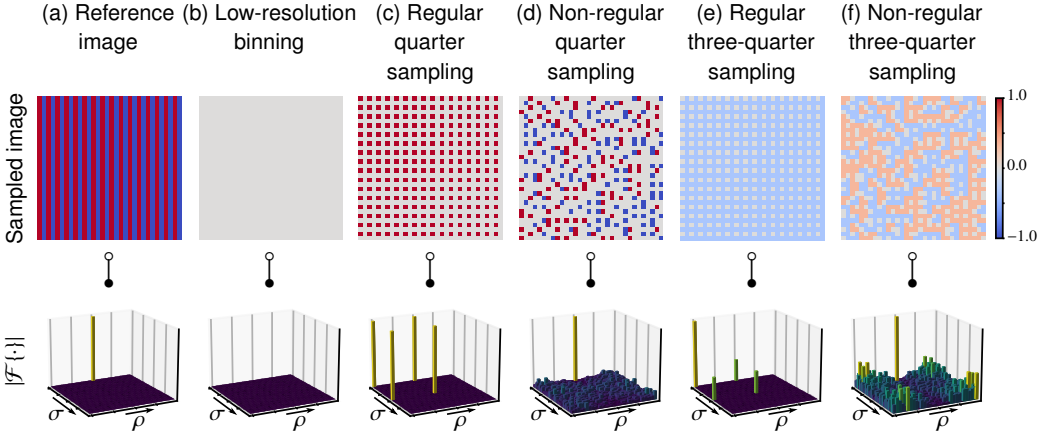

Reconstruction

Reconstruction algorithms

- Linear interpolation, nearest neighbor interpolation
- Frequency Selective Reconstruction (FSR)
- ...

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What about: Data driven approaches, neural networks (?)

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Neural Network Reconstruction – Concepts

- Issue: Non-regular sampling is not shift invariant
  - Shifted reference image leads to different measured values and different reconstruction
  - Convolutional layers seem to be inappropriate

S. Grosche et al., "A Novel End-To-End Network for Reconstruction of Non-Regularly Sampled Image Dat Using Locally Fully Connected Layers," in *Proc. International Workshop on Multimedia Signal Processing*, Tampere, Oct. 2021.

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- Solution:
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- Solution:
  - Re-introduce shift-invariance by repeating sampling pattern/sensor layout after several pixels, e.g., after 8 pixels
  - Start with convolutional layer with stride (8 pixels)
  - Next, use several convolutional layers with kernel size 1×1 → fully connected
  - As last layer, use de-convolution with stride (8 pixels)

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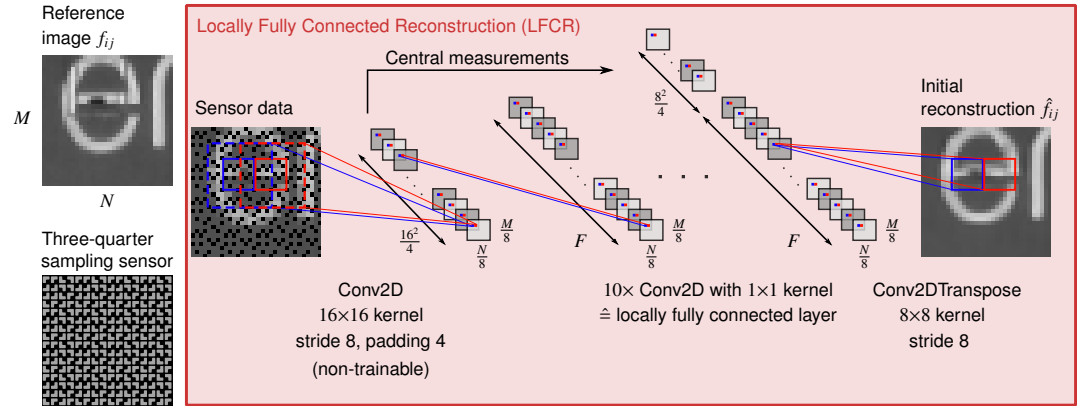
Locally Fully Connected Network (LFCR)



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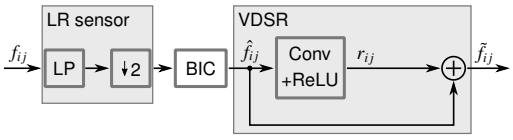
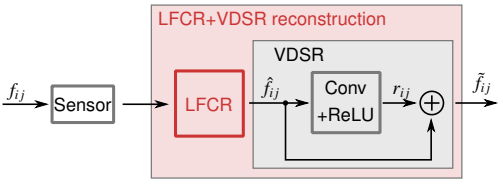
Append a VDSR Network

Sampling and reconstruction for LR sensor



Sampling and reconstruction for QS and TQS sensor



LP	Low-pass filter	VDSR	Very Deep Super-Resolution Network
↓2	Twofold spatial sub-sampling	LFCR	Locally Fully Connected Reconstruction
BIC	Bicubic upscaling		

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VDSR: J. Kim et al., "Accurate image super-resolution using very deep convolutional networks,"in *Proc. Conference on Computer Vision and Pattern Recognition (CVPR)*, Jun. 2016.

LFCR Network – Results

LFCR vs LFCR+VDSR:

	Quarter sampling	Three-quarter sampling
LFCR (only)	27.61 dB	28.45 dB
LFCR+VDSR	28.13 dB (+0.52 dB)	29.12 dB (+0.67 dB)

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Simulation results:

	Urban 100 PSNR / SSIM	Tecnick PSNR / SSIM
Low-resolution sensor		
BIC + VDSR [14]	28.92 / 0.9299	36.20 / 0.9746
prop. LFCR (only)	28.35 / 0.9243	35.86 / 0.9736
prop. LFCR + VDSR	28.73 / 0.9283	36.01 / 0.9739
Quarter sampling sensor		
FSR [5], [6]	27.08 / 0.9116	34.11 / 0.9644
FSR + VDSR-QS [15]	29.29 / 0.9382	35.58 / 0.9709
prop. LFCR (only)	28.65 / 0.9309	35.35 / 0.9698
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Three-quarter sampling sensor		
L-JSDE [10], [11]	27.09 / 0.9083	34.22 / 0.9654
prop. LFCR (only)	29.47 / 0.9373	36.40 / 0.9751
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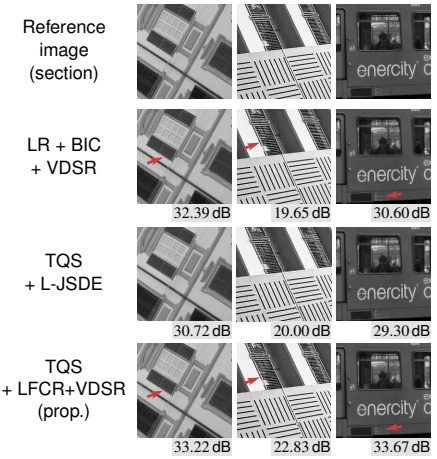
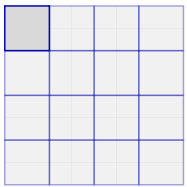


Drawback: Reduced Light Efficiency

- QS and TQS sensors have reduced light efficiency compared to LR sensor
- How to increase light efficiency to 100% while maintaining non-regularity?

Low-resolution sensor



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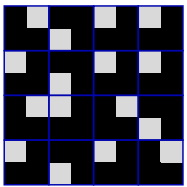

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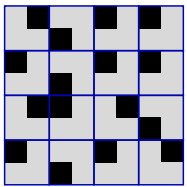

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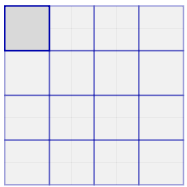

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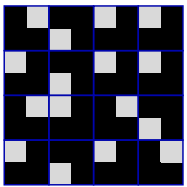

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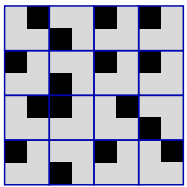
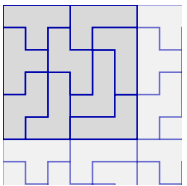
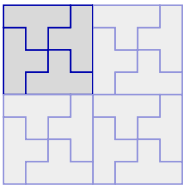


Tetromino sensor from Galdo et al.



4×4 T-tetromino sensor (prop.)



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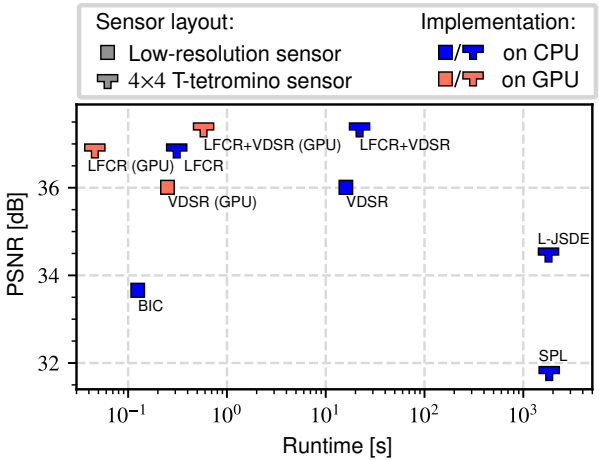
Tetromino Sampling – Results



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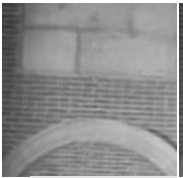
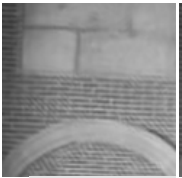
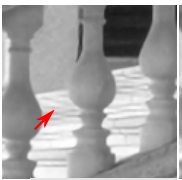
Tetromino Sampling – Visual Results

Reference section	LR sensor + BIC	LR sensor + VDSR	Tetromino sensor from Galdo et al. + L-JSDE	4x4 T-tetromino sensor (prop.) + L-JSDE	4x4 T-tetromino sensor (prop.) + LFCR+VDSR
					
Section from image 10	30.27 dB / 0.8081	30.63 dB / 0.8370	33.96 dB / 0.9171	34.23 dB / 0.9195	35.88 dB / 0.9490
					
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Conclusion and Future Work

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- T-tetromino sampling: Increased reconstruction quality and 100% fill factor

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Possible future work

- Different network layouts? For non-repeating sensor layouts?
- How about color measurements?
- More optimal sensor layout?