Iterative Optimization of Quarter Sampling Masks for Non-Regular Sampling Sensors

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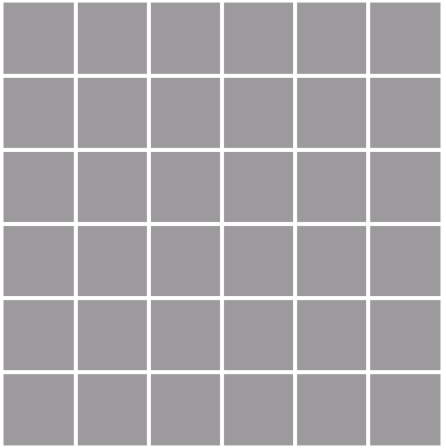
Outline

- Introduction to Quarter Sampling
- Importance of Proper Sampling Patterns
- Proposed Iterative Optimization Strategy
- Evaluation & Visual Comparisons
- Conclusion & Outlook

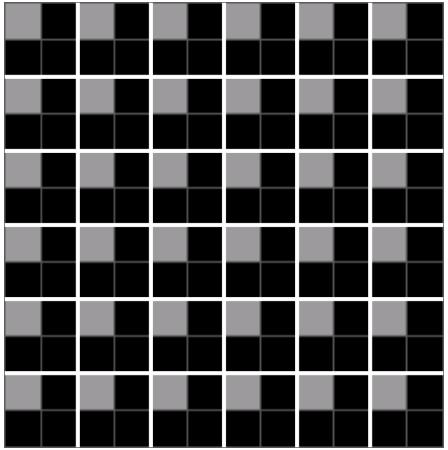
Quarter Sampling

Achieve higher resolution by physically covering ¾ of each pixel

Low-resolution Sensor

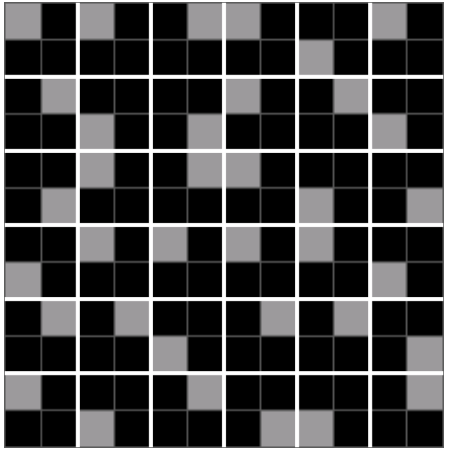


Regular Quarter Sampling



→ Iterpolate remaining pixels
→ Resolution limited by aliasing

Non-Regular Quarter Sampling



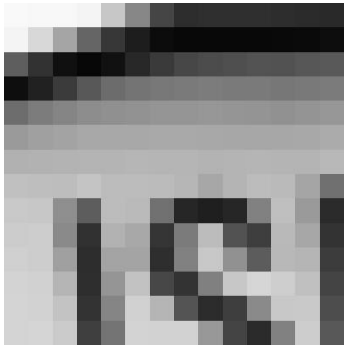
→ Higher resolution after appropriate reconstruction
→ Reduced aliasing

Schöberl et al., "Increasing imaging resolution by covering your sensor," in *Proc. 18th IEEE International Conference on Image Processing*, Brussels, Sep. 2011.

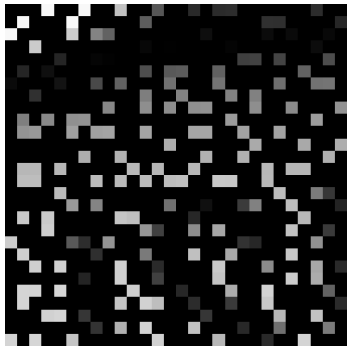
Quarter Sampling – Example

High-resolution reference

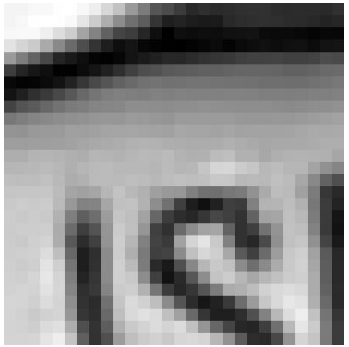
Low-resolution sensor



Quarter sampling sensor



Reconstruction



Reconstruction Algortihms and Testset

Reconstruction Algorithms

- Linear Interpolation
- Nearest Neighbour Interpolation
- Steering Kernel Regression (SKR)
- Frequency Selective Reconstruction (FSR)

Image Testset

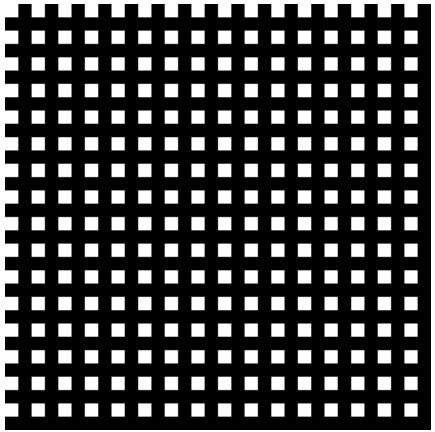
- Tecnick Dataset (2011)
- Natural 8-bit grayscale images
- 100 images
- 1200x1200 pixels




SKR: Takeda et al., "Kernel regression for image processing and reconstruction," *IEEE Transactions on Image Processing*, vol. 16, no. 2, pp. 349–366, 2007.
FSR: Seiler et al., "Resampling images to a regular grid from a non-regular subset of pixel positions using FSR," *IEEE Transactions on Image Processing*, vol. 24, no. 11, pp. 4540–4555, Nov. 2015.
Tecnick images: N. Asuni. (2011, April) Tecnick test image library,. [Online]. Available: http://testimages.tecnick.com

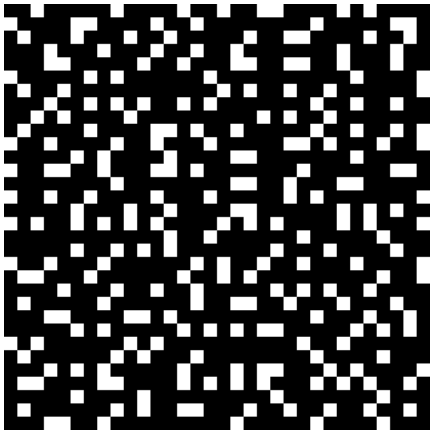
Importance of Proper Sampling Patterns

Regular Mask



→PSNR 33.2 dB (FSR)

Random Quarter Mask



→PSNR 33.6 dB (FSR)

Random Sampling Pattern

→PSNR 32.4 dB (FSR)

→ Observation: Good sampling patterns should be **uniform** and **non-regular**

Importance of Proper Sampling Patterns

Uniformity

- Local density ≈ global density
- Details can be anywhere in the image

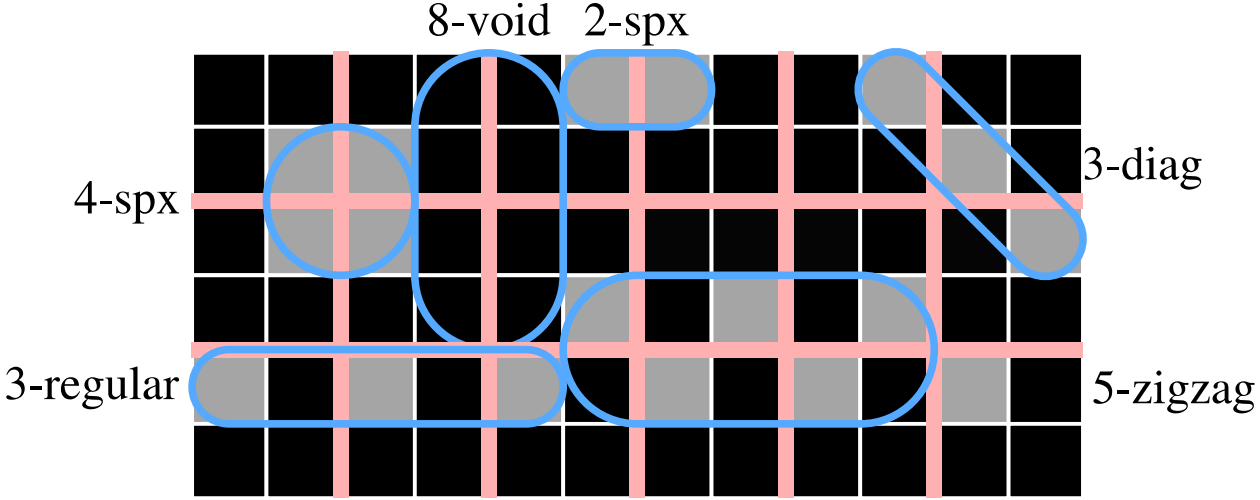
Non-Regularity

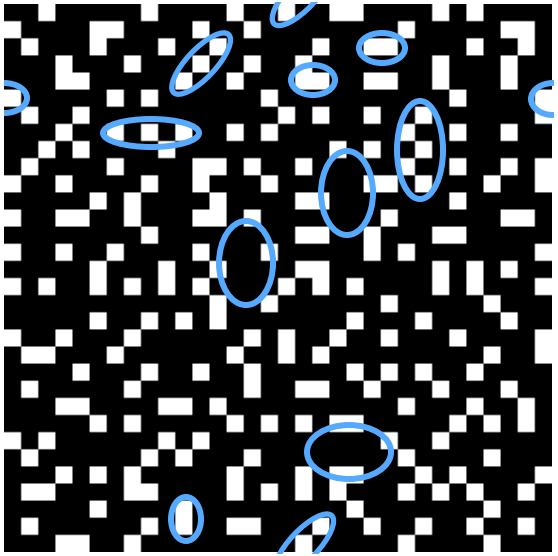
- Flat frequency spectrum
- Reduce aliasing

How to combine both properties in a single sampling pattern?

Proposed Iterative Optimization Strategy

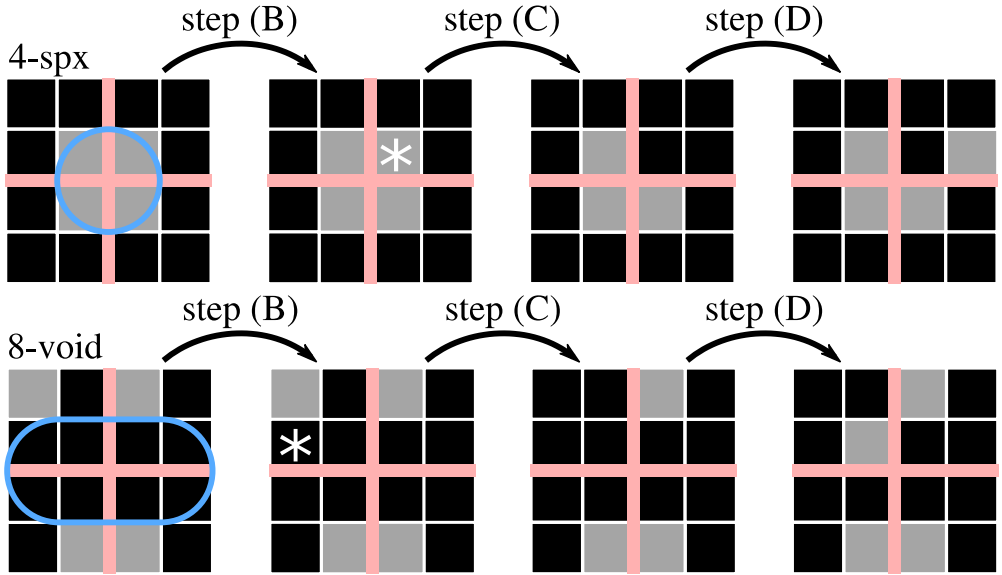
step (A): Identify unwanted structures (with periodic boundaries)



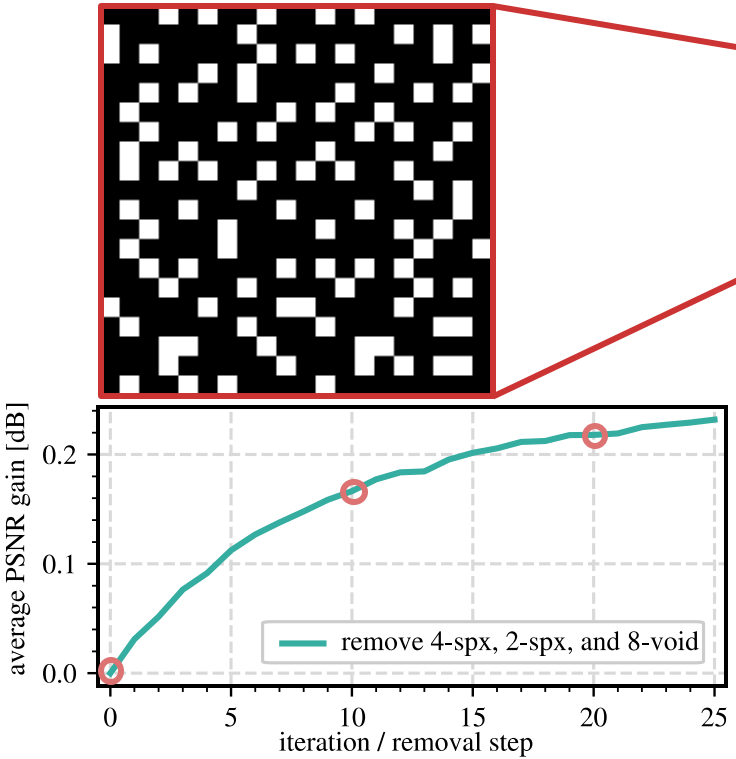


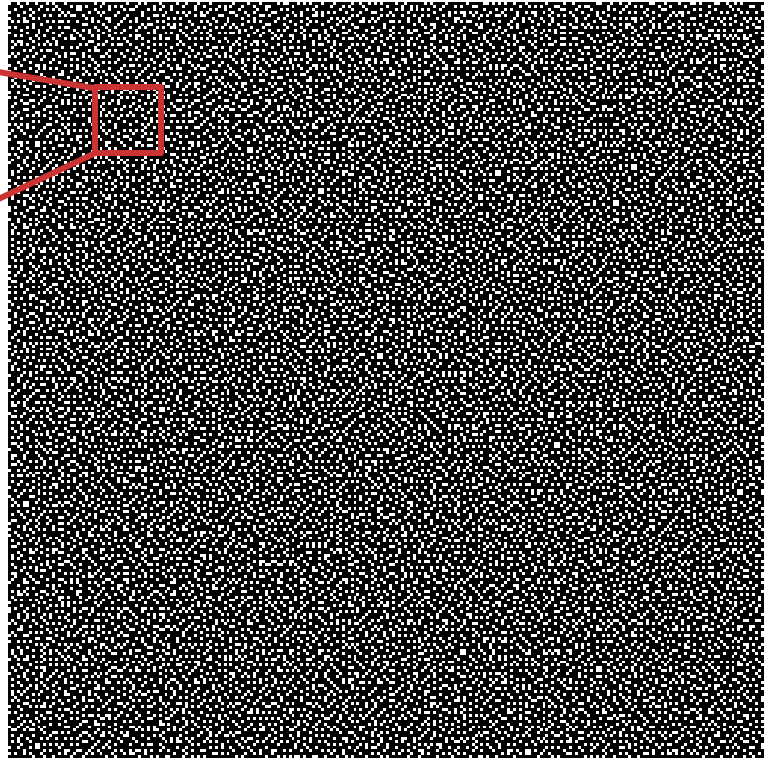
Proposed Iterative Optimization Strategy

steps (B)-(D): Remove the structures



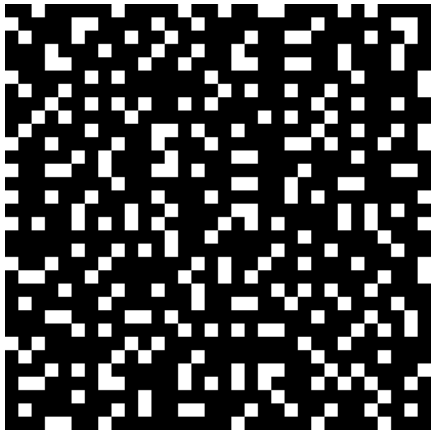
Proposed Iterative Optimization Strategy





Optimized Quarter Sampling Mask

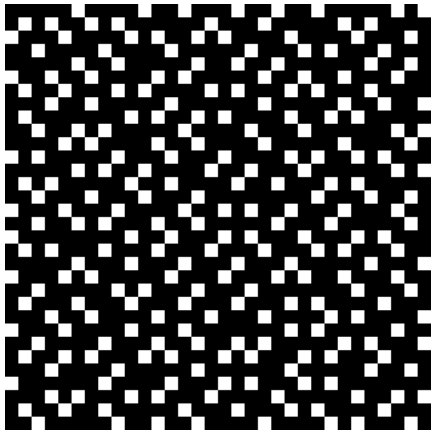
Random Quarter Mask



→PSNR 33.6 dB (FSR)

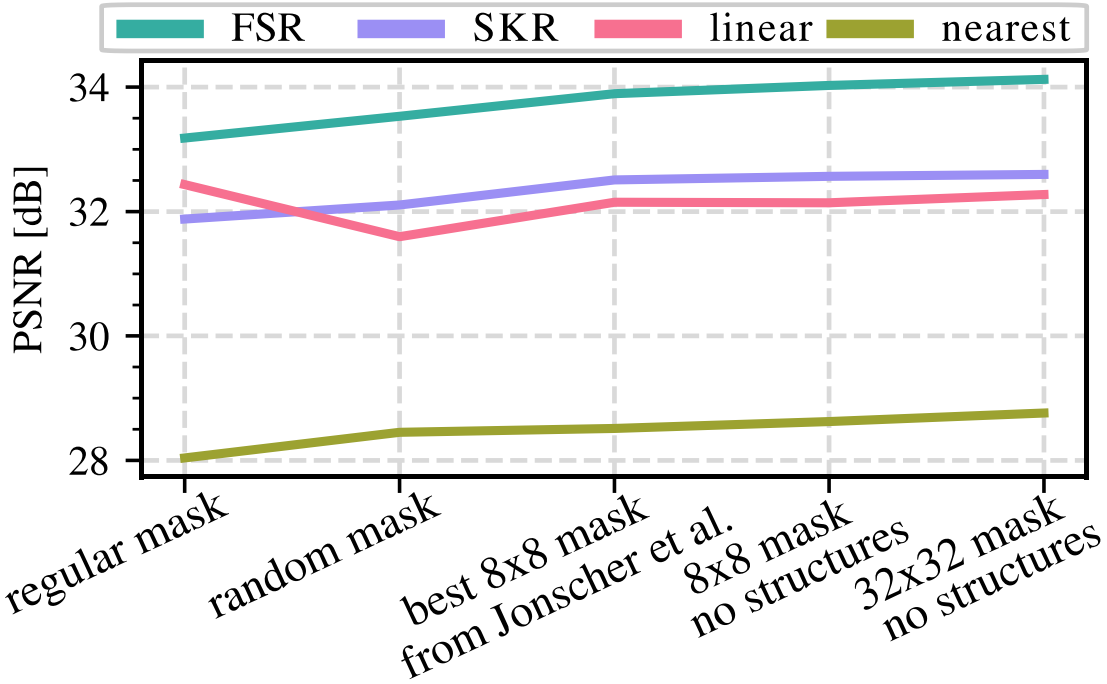
Remove all structures

Proposed Quarter Mask



→PSNR 34.1 dB (FSR)

Optimized Quarter Sampling Mask – Evaluation

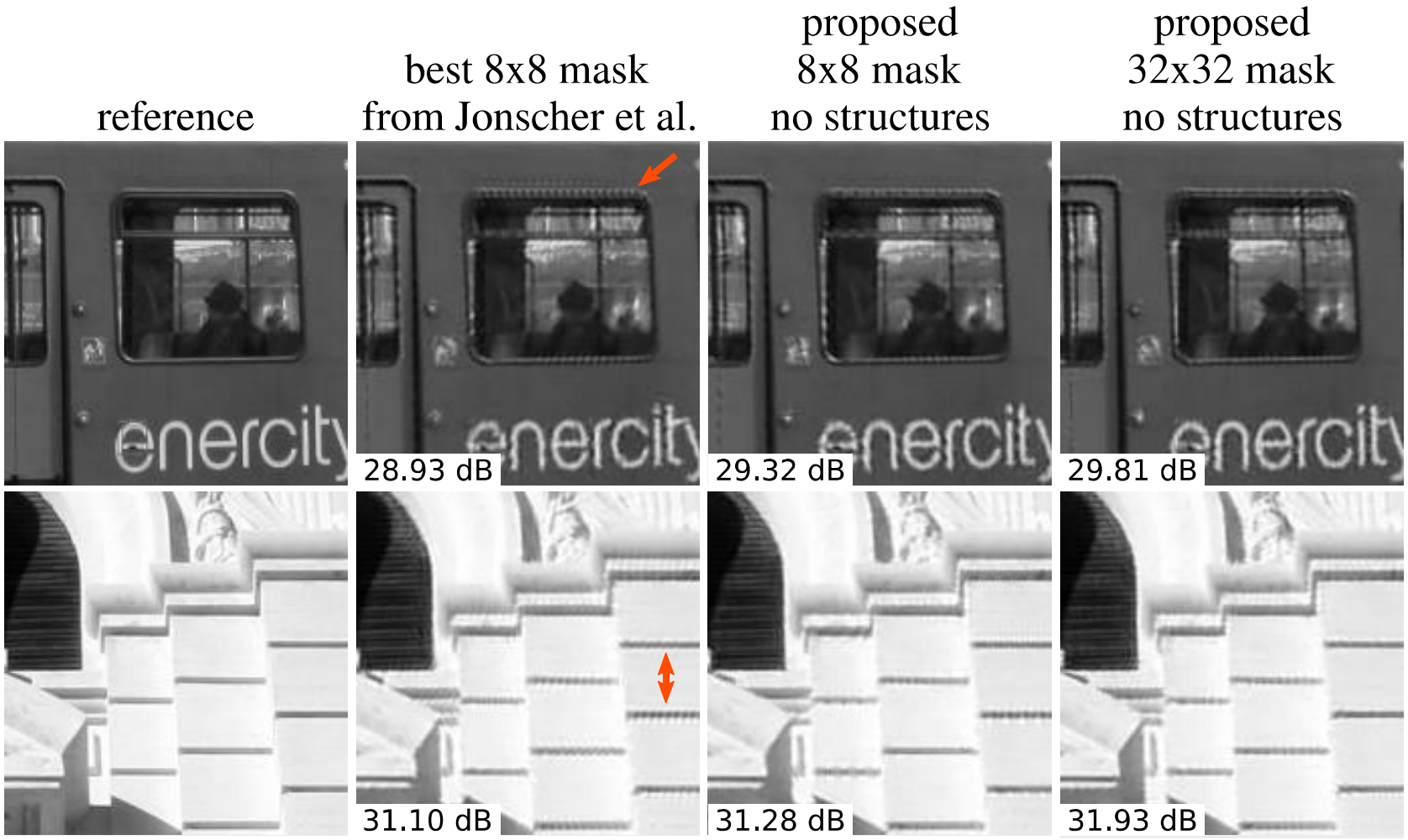


→ Proposed masks superior for all reconstruction algorithms

→ Gain compared to random mask at least +0.31dB (up to +0.68dB)

→ For FSR (highest PSNR): +0.59dB (vs. random) +0.23dB (vs. Jonscher et al.)

Jonscher et al., "Reducing randomness of non-regular sampling masks for image reconstruction," in *Proc. IEEE VCIP*, Valletta, Dec. 2014, pp. 266–269.



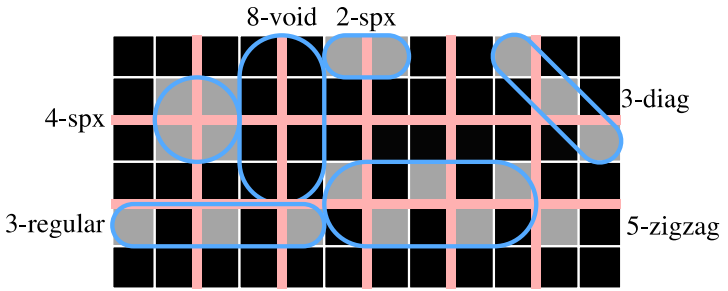
PSNR evaluate on shown section.

Jonscher et al., "Reducing randomness of non-regular sampling masks for image reconstruction," in *Proc. IEEE VCIP*, Valletta, Dec. 2014, pp. 266–269.

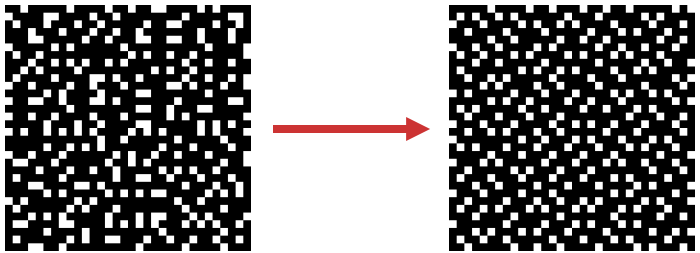
Conclusion

- Non-regular quarter sampling can achieve higher resolution per pixel using an appropriate reconstruction method

- Observation: Good sampling patterns should be uniform and non-regular
- Proposal: Iterative optimization strategy to remove certain structures



- Gain over random mask as well as mask from literature independent of reconstruction algorithm. Up to +0.68 dB compared to random mask.



Outlook

- Use proposed masks as a limit for optimization of density-independent sampling patterns
- More theoretical foundation pending

- NEW: FSR Matlab-Reference Implementation available at
  `https://gitlab.lms.tf.fau.de/LMS/Rapid-FSR`
  - Bundles latest research on FSR
  - Dynamic parameter estimation
  - Three quality profiles: fast, compromise, best