Inpainting-based Camera Anonymization

S. Mandelli, L. Bondi, S. Lameri, V. Lipari, P. Bestagini, S. Tubaro

Motivations

- When **privacy** related to digital images ownerships is a concern
    - Censorship
    - Photo-reporters protection in hot zones

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Motivations

- When **privacy** related to digital images ownerships is a concern
  - Censorship
  - Photo-reporters protection in hot zones

- **Remove** every way to back-track to the original photographer
  - Metadata manipulation
 - Sensor fingerprint removal or obfuscation

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- Camera characterized by a certain
  Photo-Response-Non-Uniformity signal

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Problem Formulation

- Camera characterized by a certain **Photo-Response-Non-Uniformity** signal

- Image shot with the same camera

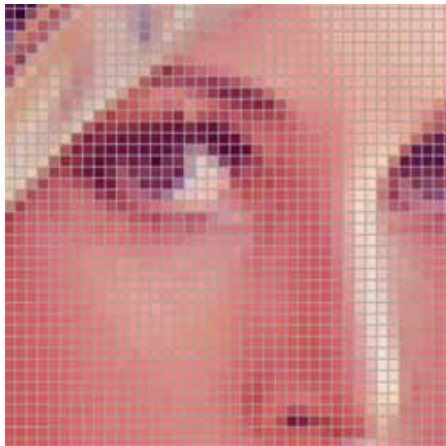POLITECNICO DI MILANO
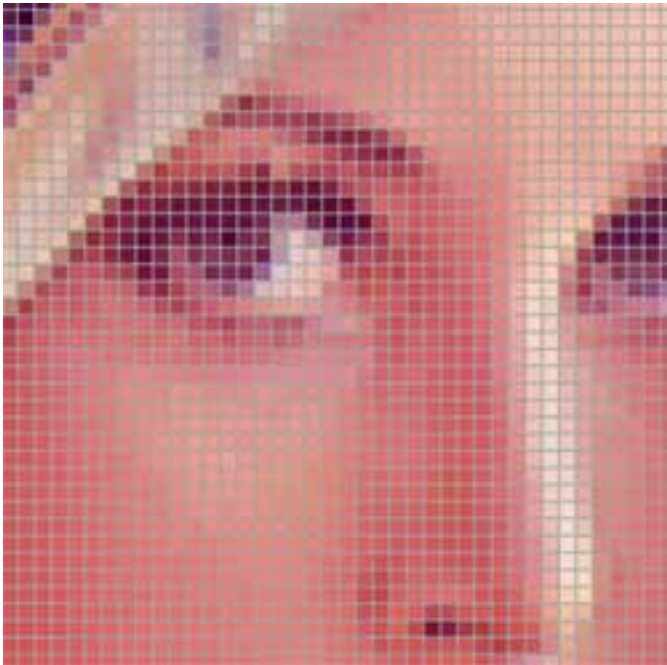
Problem Formulation
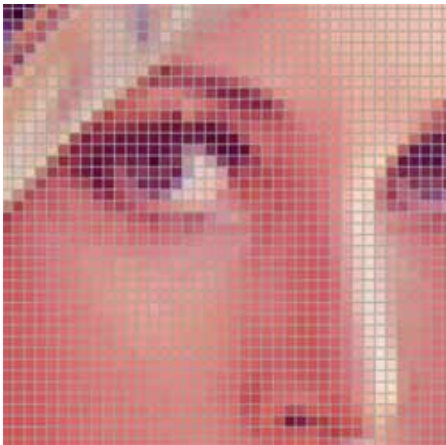
- Camera characterized by a certain **Photo-Response-Non-Uniformity** signal

- Image shot with the same camera

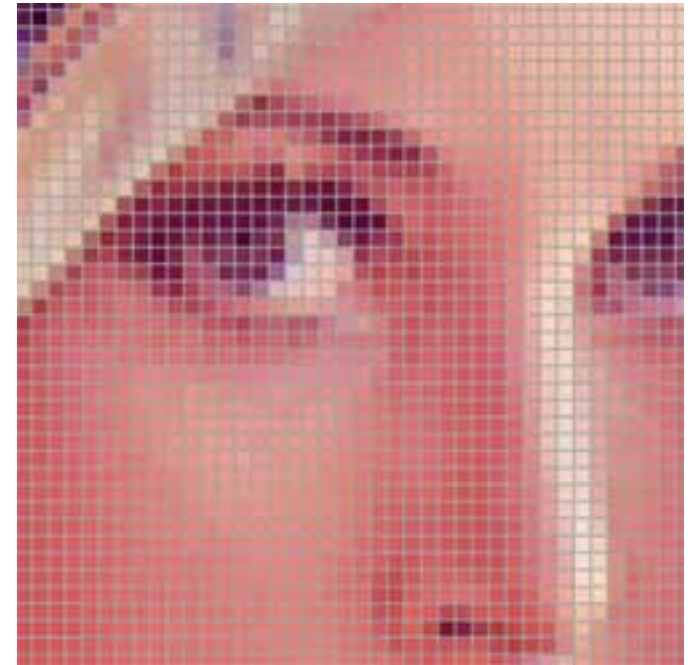- **Noise residual** extracted from the image to perform **cross-correlation** test

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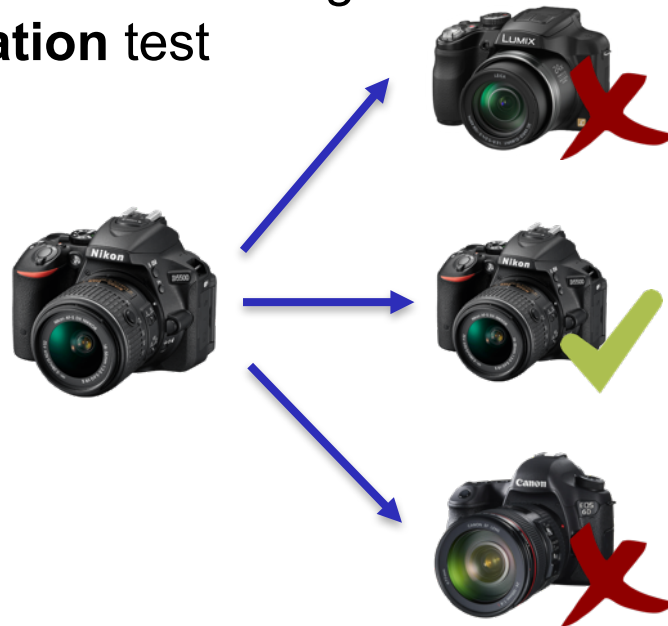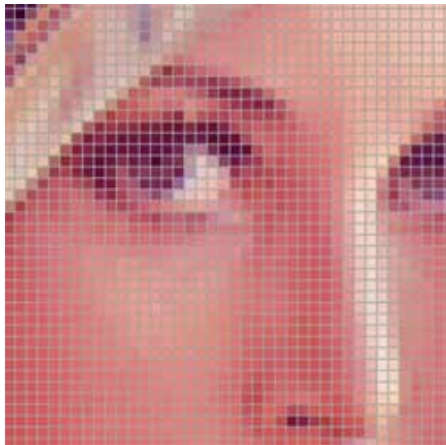
- **Anonymize** the image

- Preserving perceived image quality

- **Reducing cross-correlation** so that image source attribution becomes impossible

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- **Substitute** each **pixel** of the image with an **inpainted** version based on its **neighbors**, so to corrupt PRNU traces embedded into it

Original image

Anonymized image

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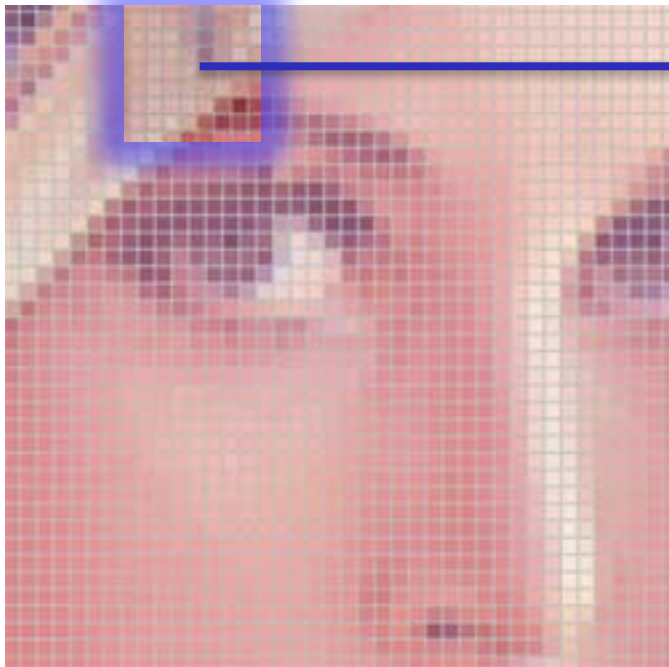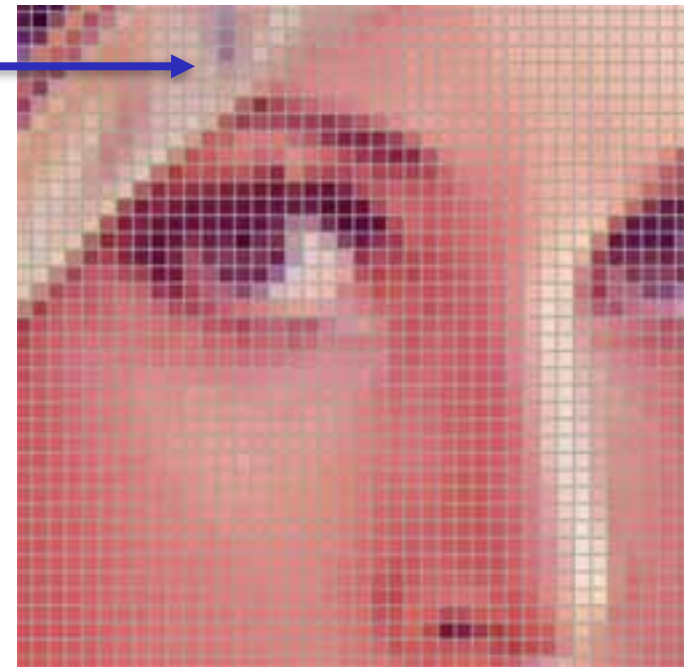

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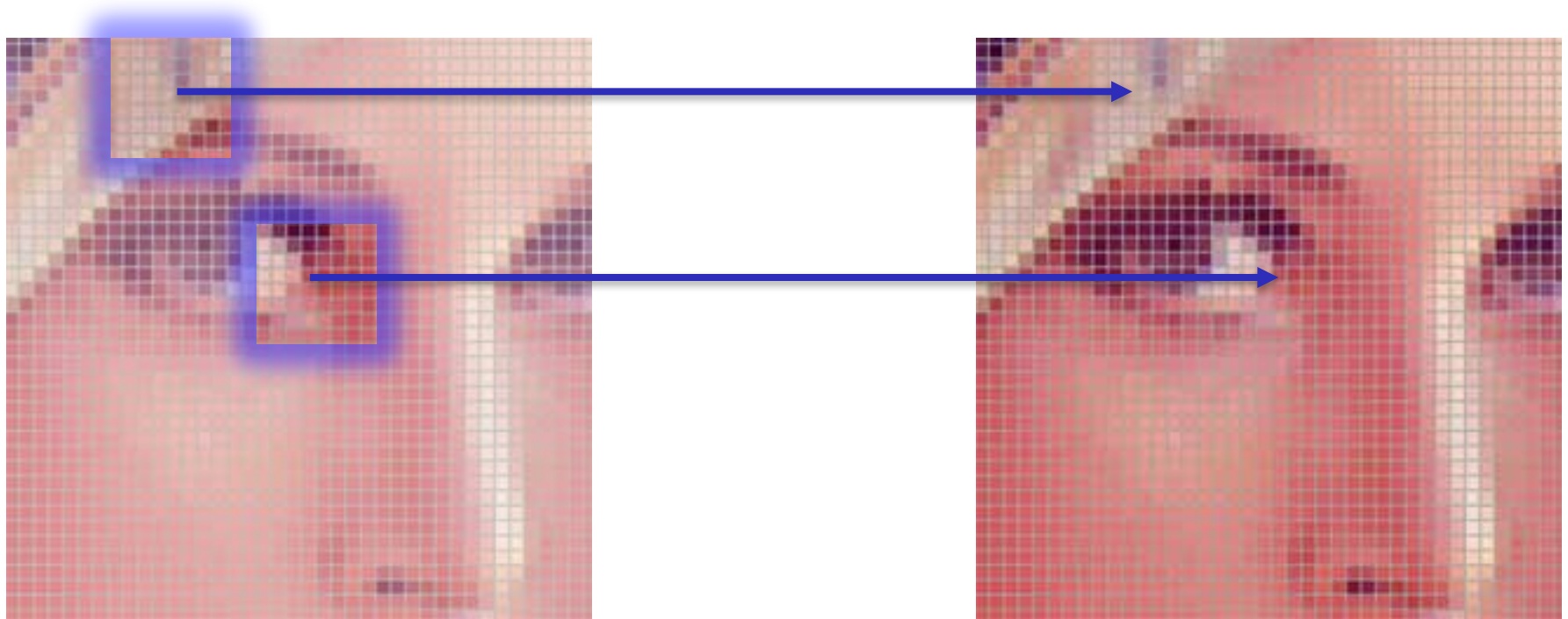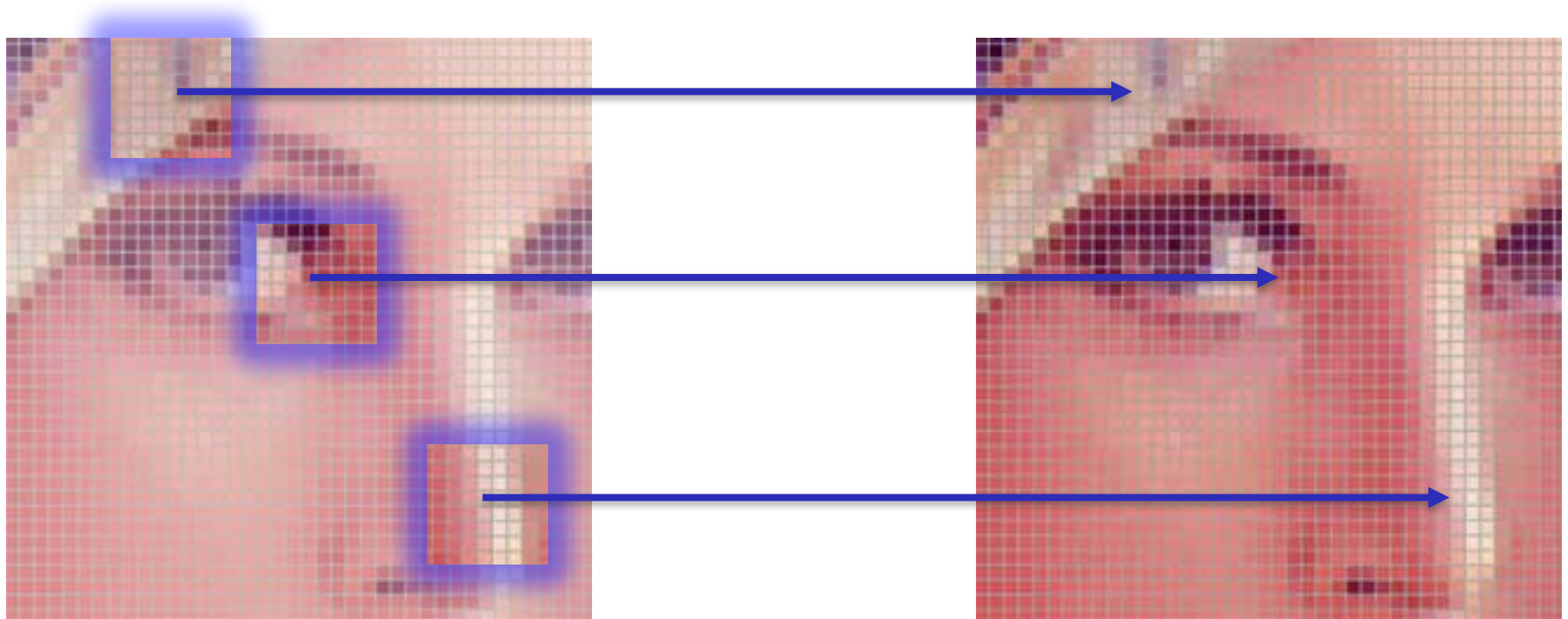

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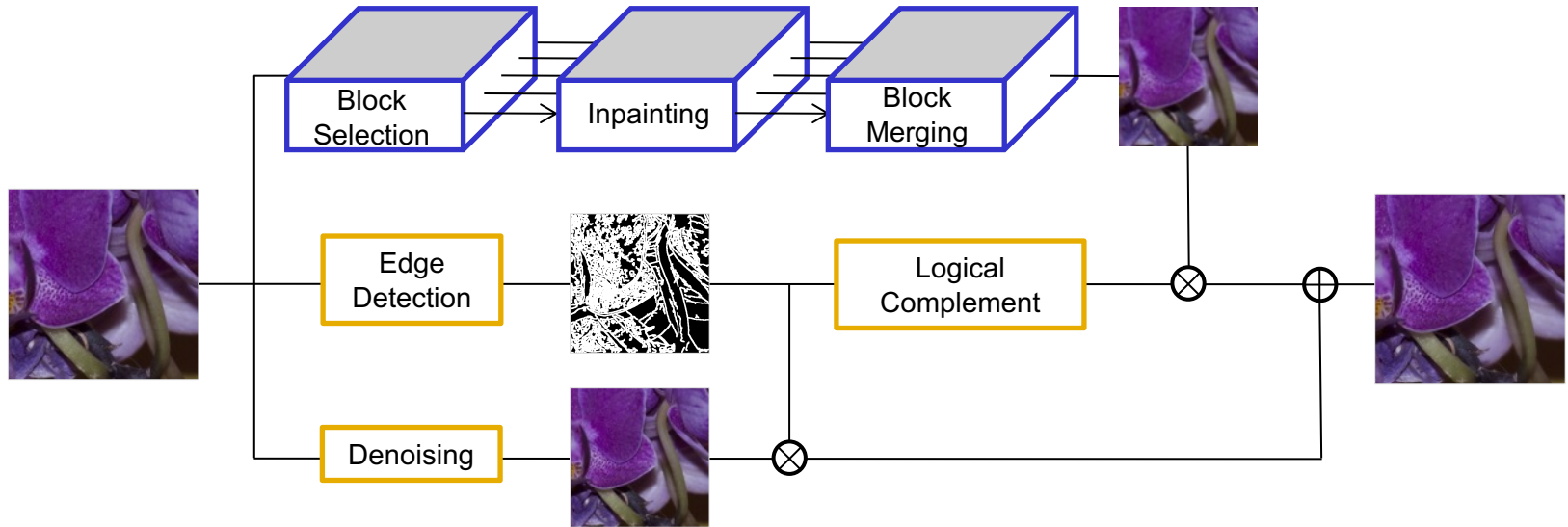
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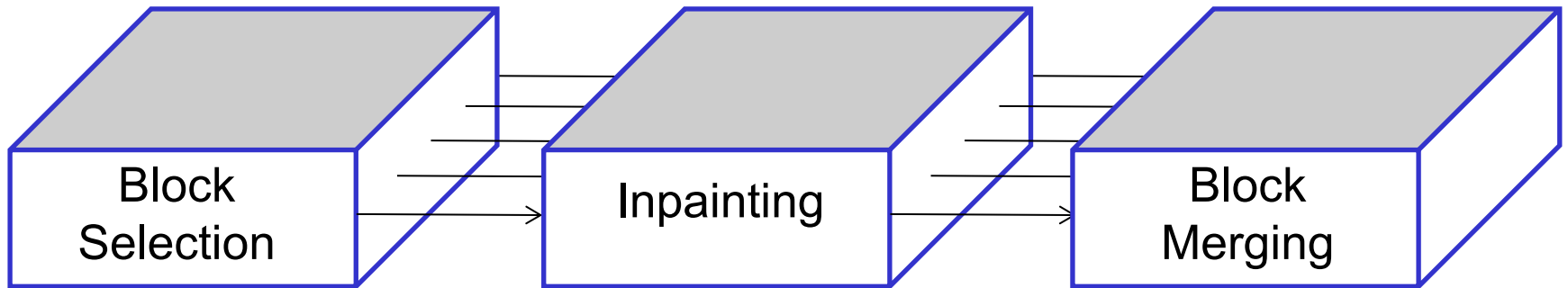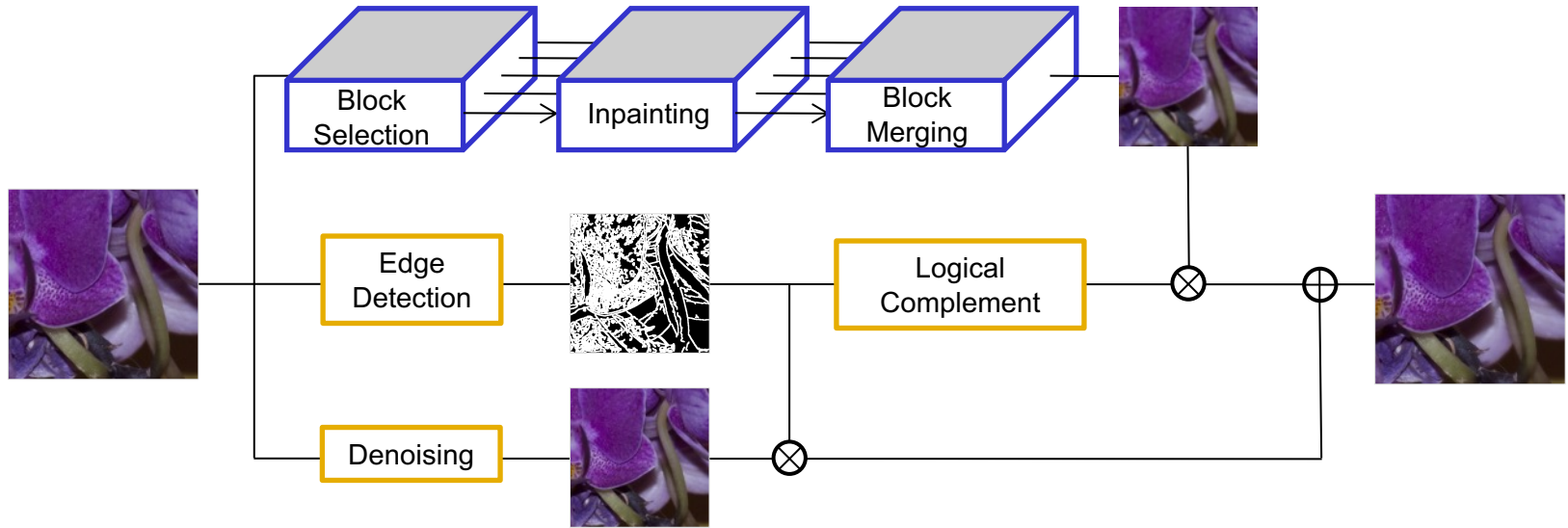

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Proposed Algorithm
Overview

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Proposed Algorithm
Block selection

- Create **several versions** of the image with **missing** pixels
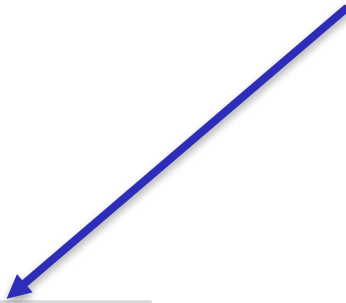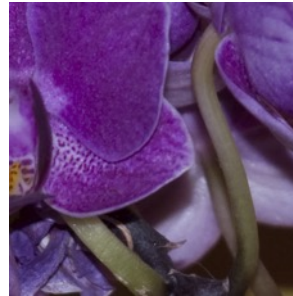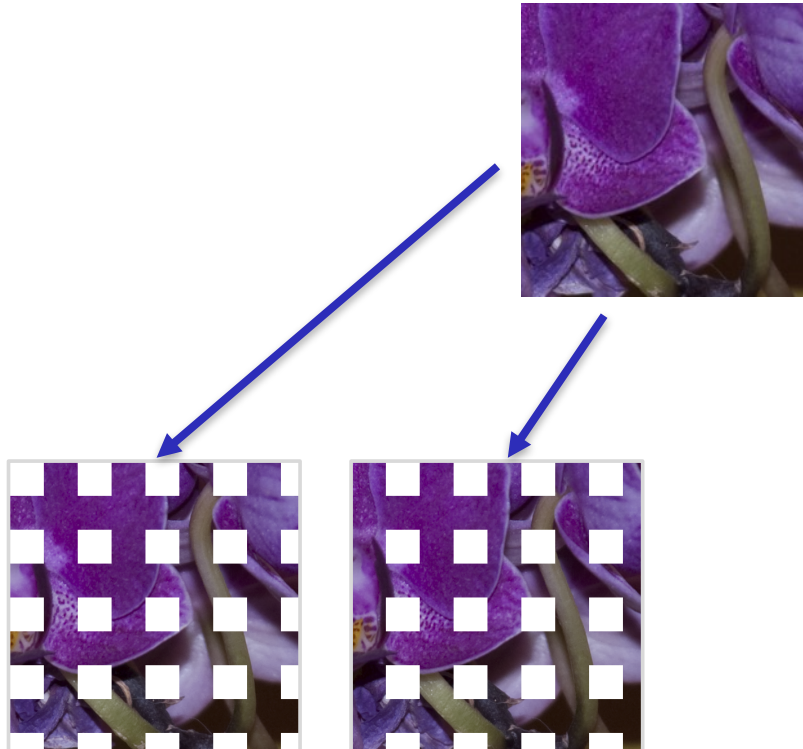
- Holes based on a regular grid

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Proposed Algorithm
Block selection

- Create **several versions** of the image with **missing** pixels

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Proposed Algorithm
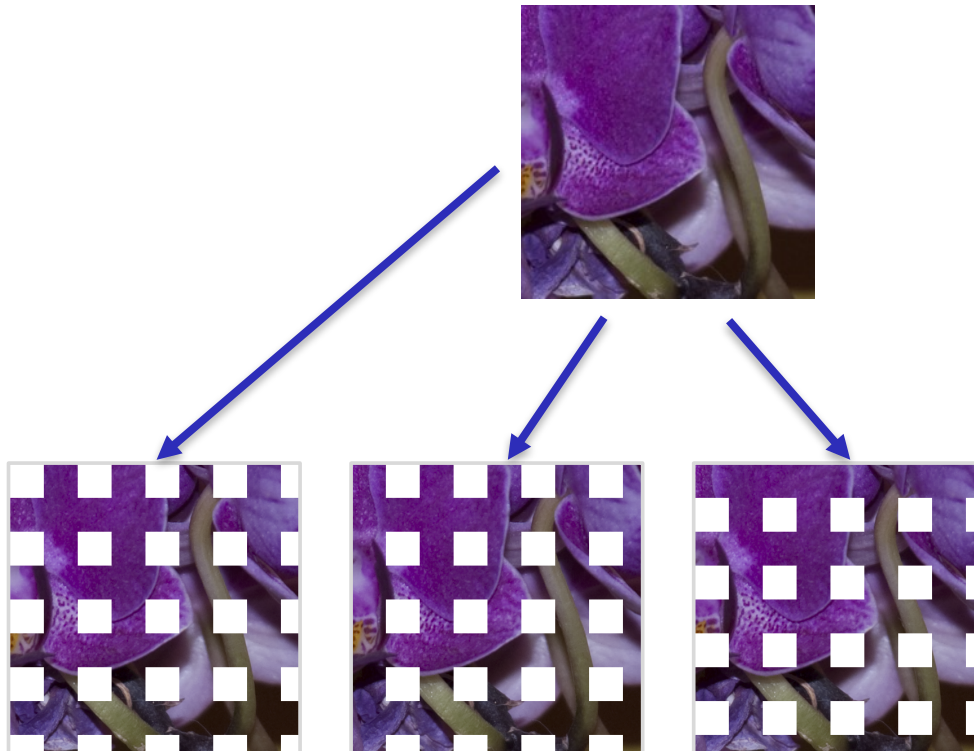## Block selection

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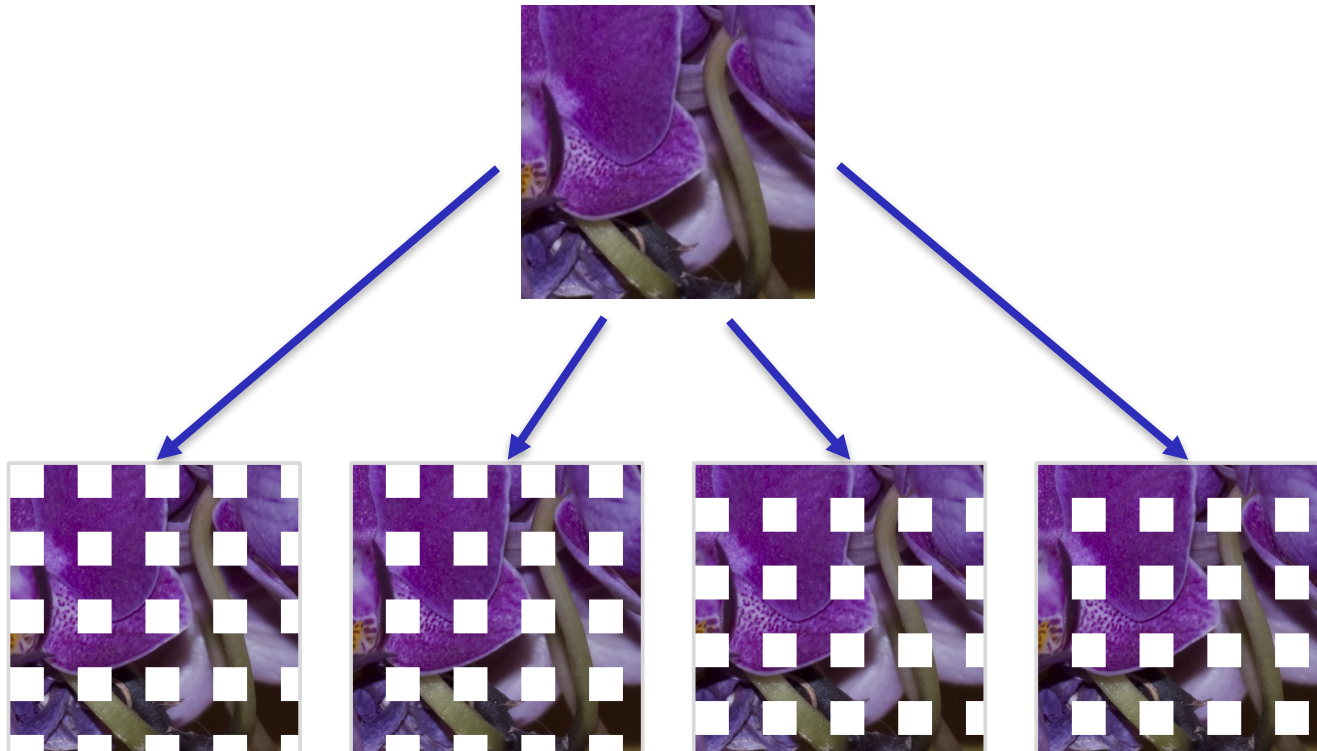
Proposed Algorithm
Block selection

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Proposed Algorithm
Holed images inpainting

- **Inpainting** through **regularized inversion**

$$\arg_{\bar{I}} \min \|S\bar{I} - I\|_F^2 + \mu \|R(\bar{I})\|_p^p$$

I → Regularized inversion → $\bar{I}$

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Proposed Algorithm
Holed images inpainting

- **Inpainting** through **regularized inversion**

$$\arg_{\bar{I}} \min \boxed{\|S\bar{I} - I\|_F^2} + \mu \|R(\bar{I})\|_p^p$$

- Fitting condition on original pixels

$$\|S\bar{I} - I\|_F^2$$

I → Regularized inversion → $\bar{I}$

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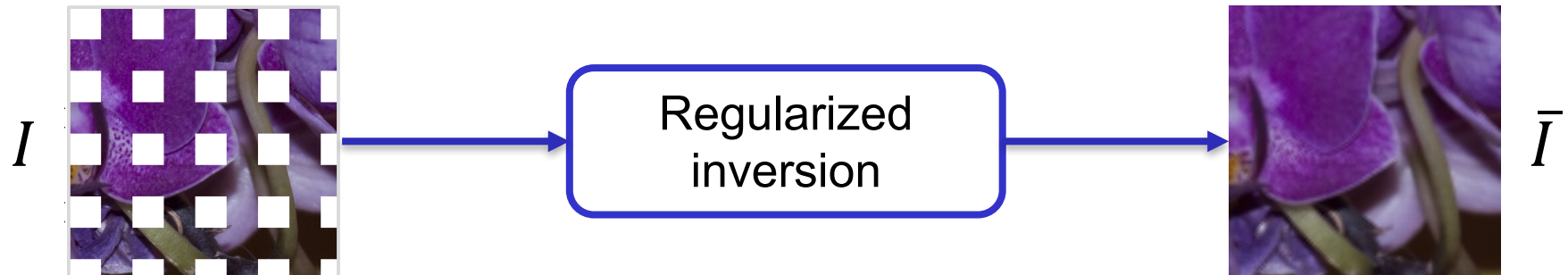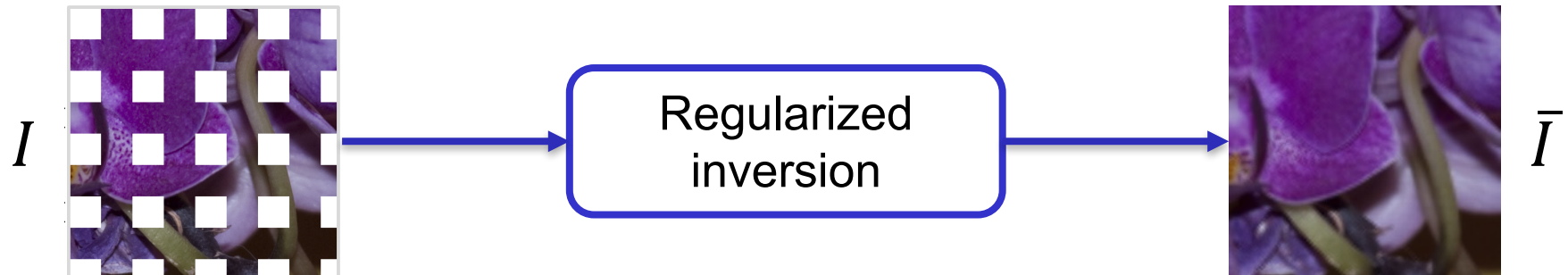
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Proposed Algorithm
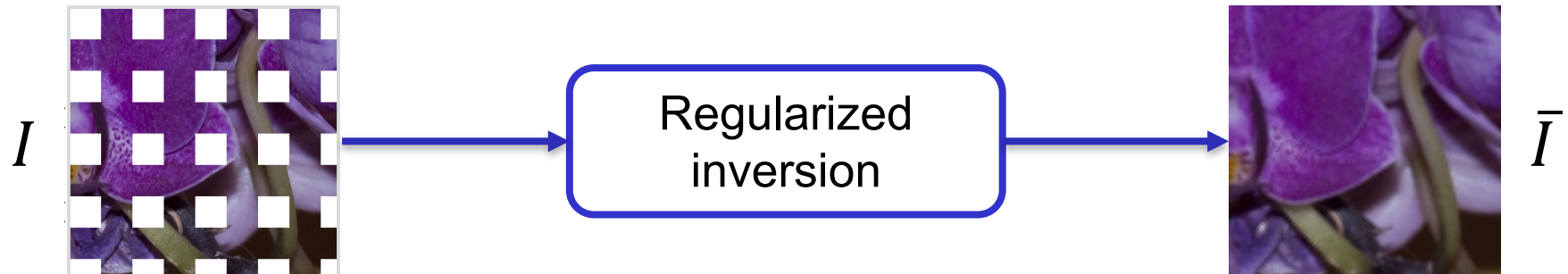## Holed images inpainting

- **Inpainting** through **regularized inversion**

$$\arg_{\bar{I}} \min \|S\bar{I} - I\|_F^2 + \mu \boxed{\|R(\bar{I})\|_p^p}$$

- Fitting condition on original pixels

$$\|S\bar{I} - I\|_F^2$$

- Regularization term to impose smoothness
  - First derivative operator
  - L1 (Total Variation) and L2 norm (Tikhonov)

$$\|R(\bar{I})\|_p^p$$

I → Regularized inversion → $\bar{I}$

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Proposed Algorithm
Block merging

- Merge selecting **only reconstructed pixels**

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Proposed Algorithm
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Proposed Algorithm
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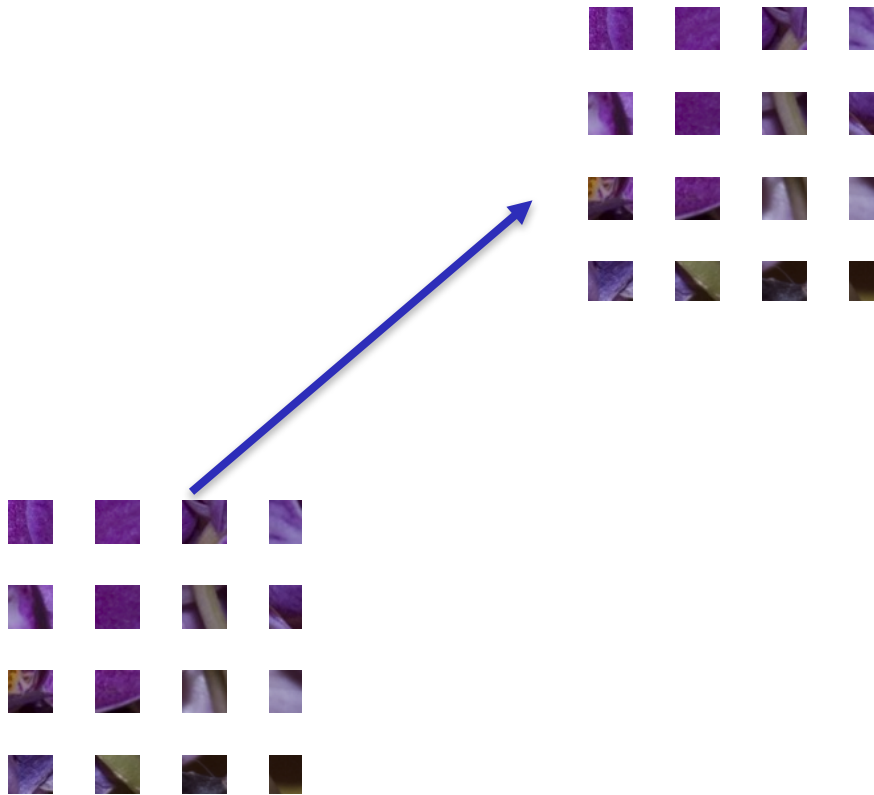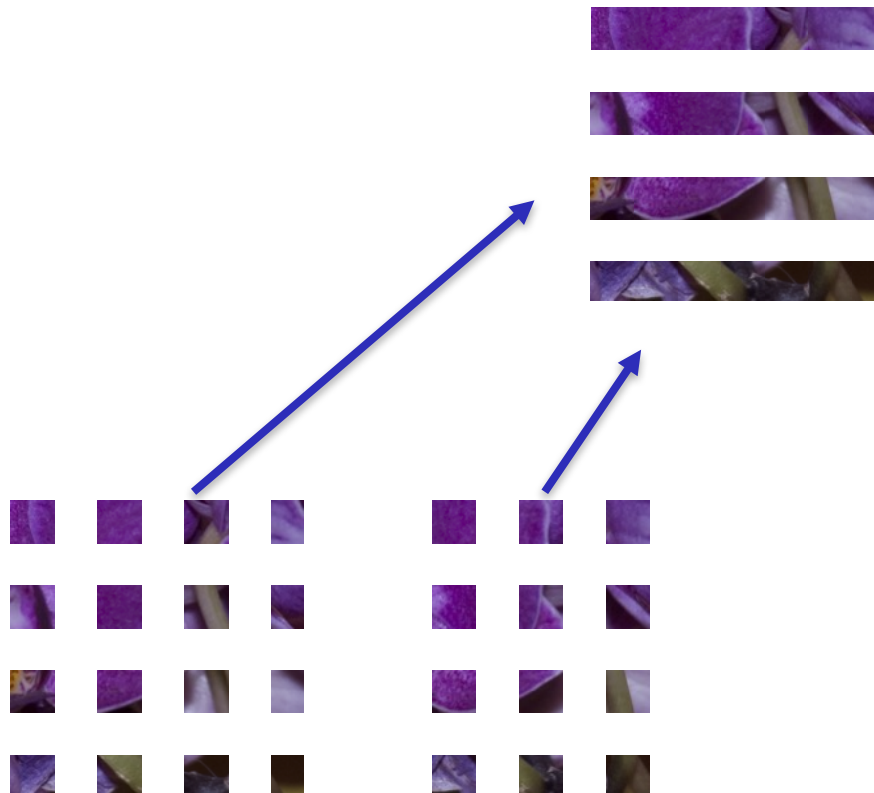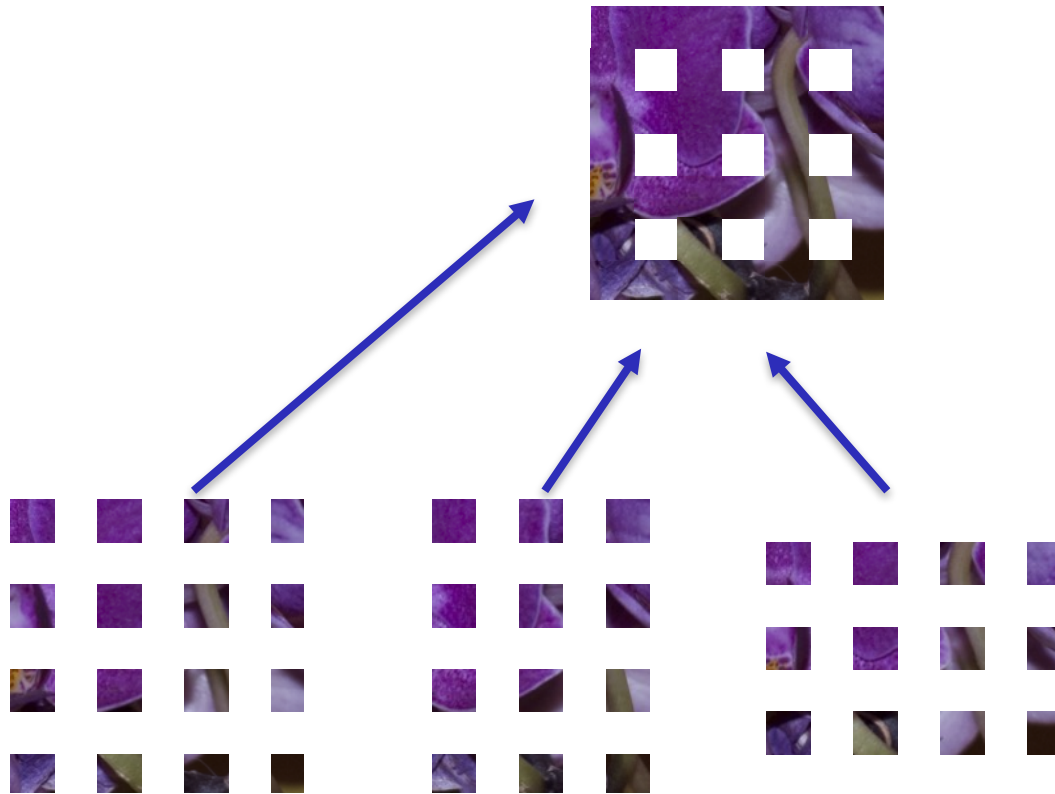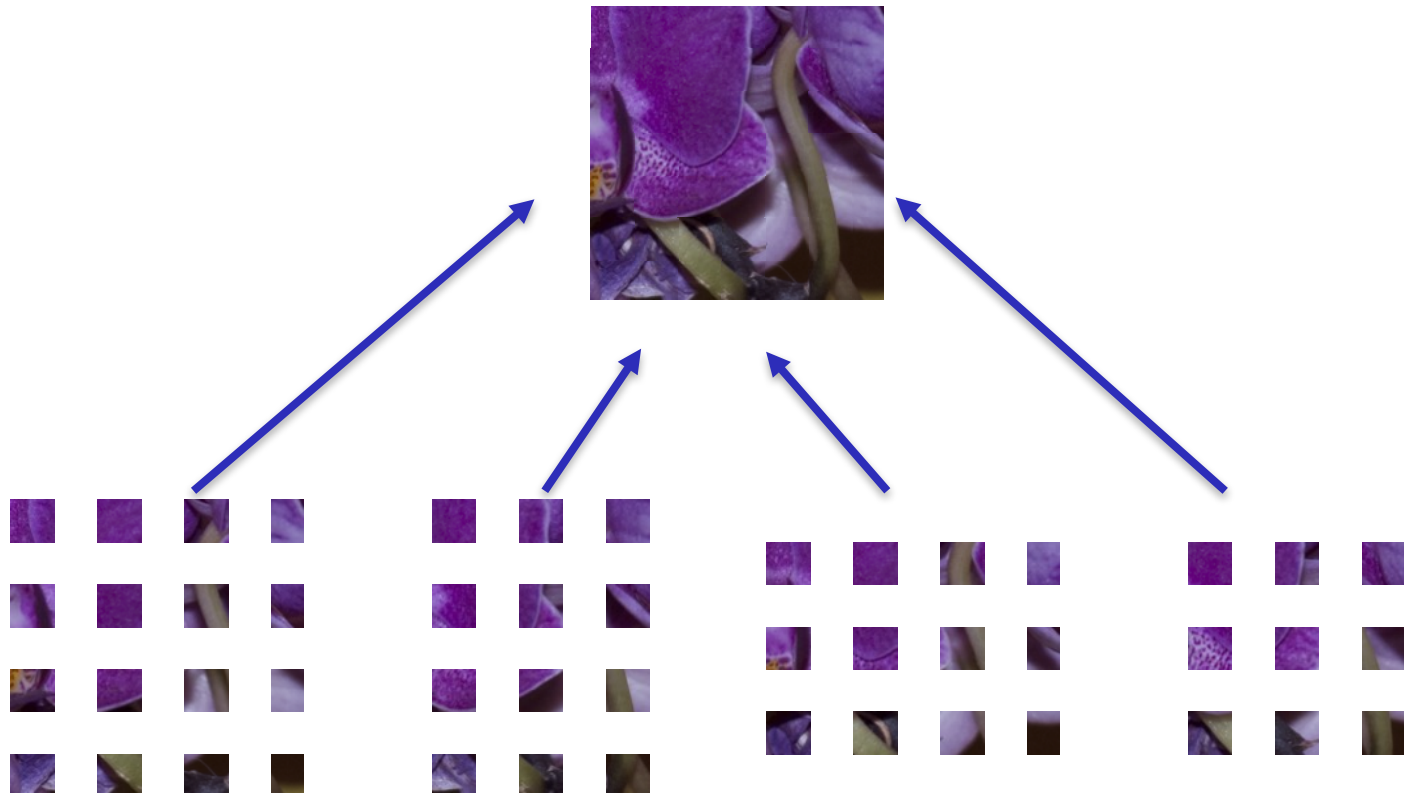
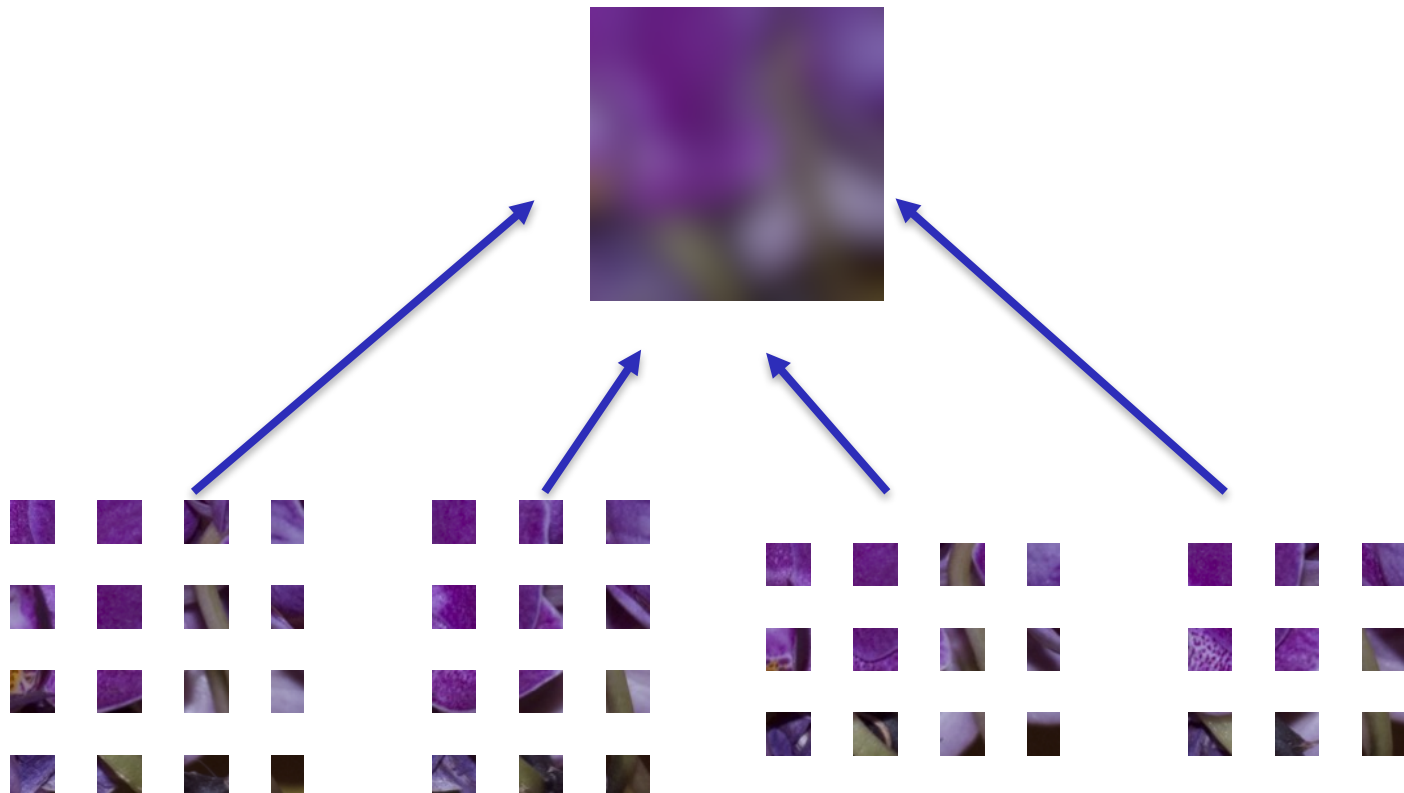# Proposed Algorithm
Block merging

- Merge selecting **only reconstructed pixels**

- Drawback: **quality loss**

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Proposed Algorithm
Edge Reconstruction

- Canny **edge detector** on original image

- Edge **dilation**

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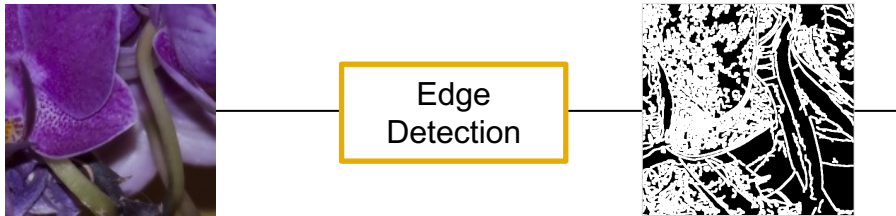
Proposed Algorithm
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denoised edges

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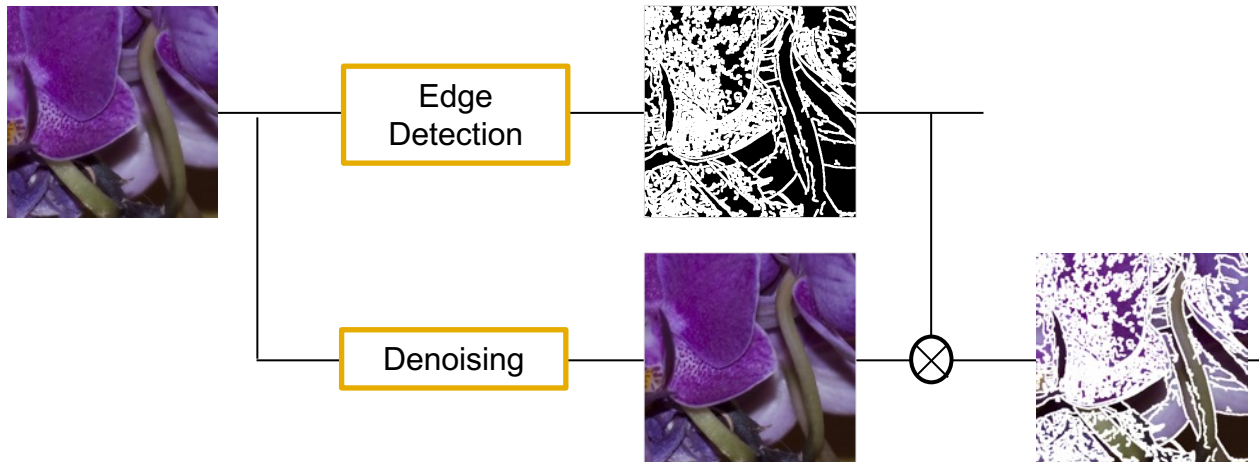
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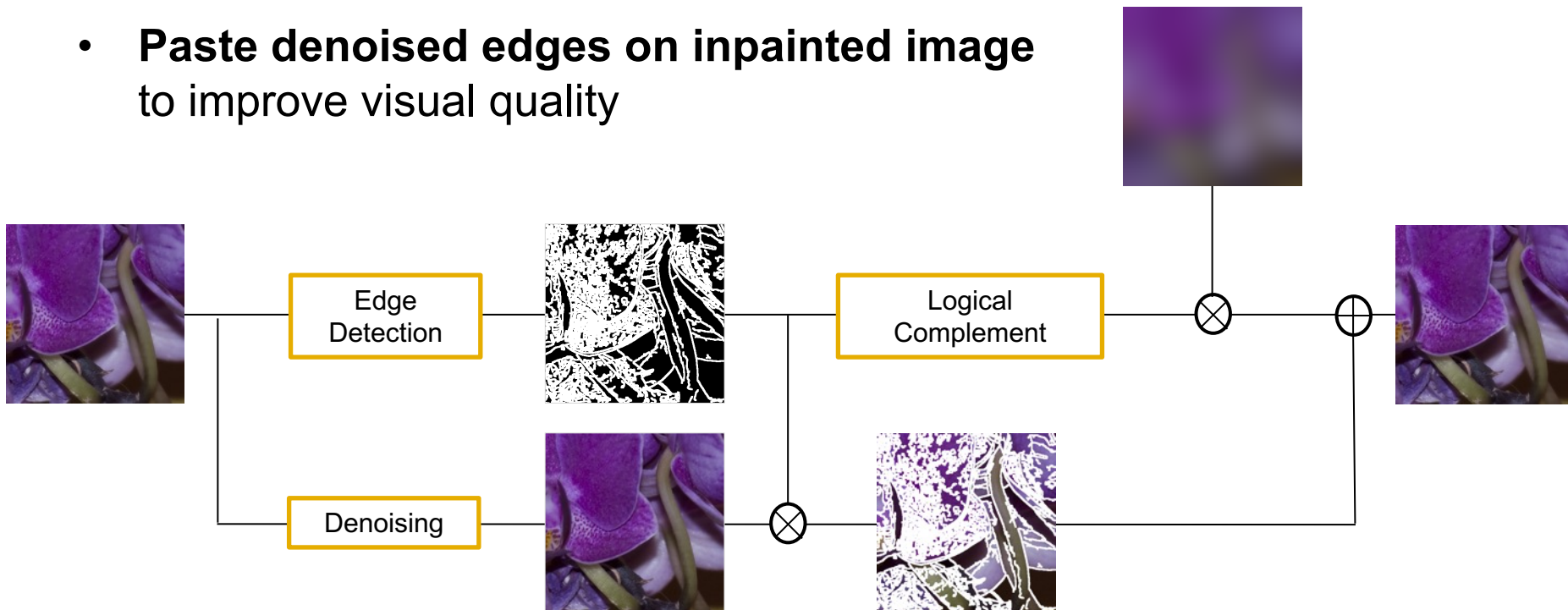
Proposed Algorithm
Edge Reconstruction

- Canny **edge detector** on original image

- Edge **dilation**

- **Paste denoised edges on inpainted image** to improve visual quality

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Experiments and results
Setup

- Dataset
  - 600 RAW uncompressed images
  - 512 x 512 pixels
  - Dresden Image Dataset

- Wavelet denoising
  - Camera PRNU estimation
  - Image noise residuals

- Performance evaluation in terms of
  - Receiver-Operating-Characteristic
  - Area-Under-Curve vs SNR
  - TPR vs SNR (at fixed FPR)

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Experiments and results
ROC

L2 norm
3 pixel holes

L2 norm
5 pixel holes

L1 norm
3 pixel holes

L1 norm
5 pixel holes

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L2 norm
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Experiments and results
Comparison with SOTA

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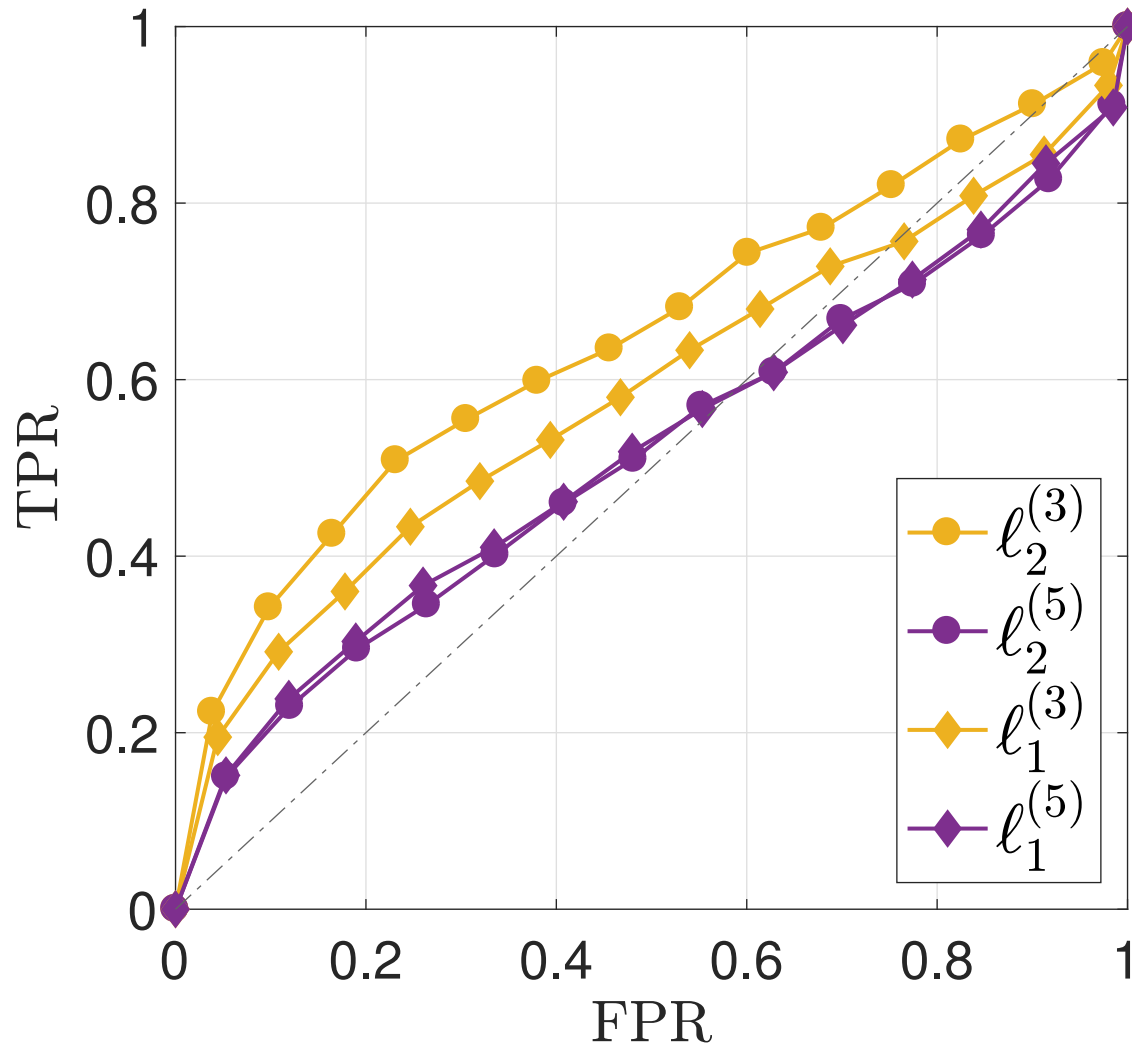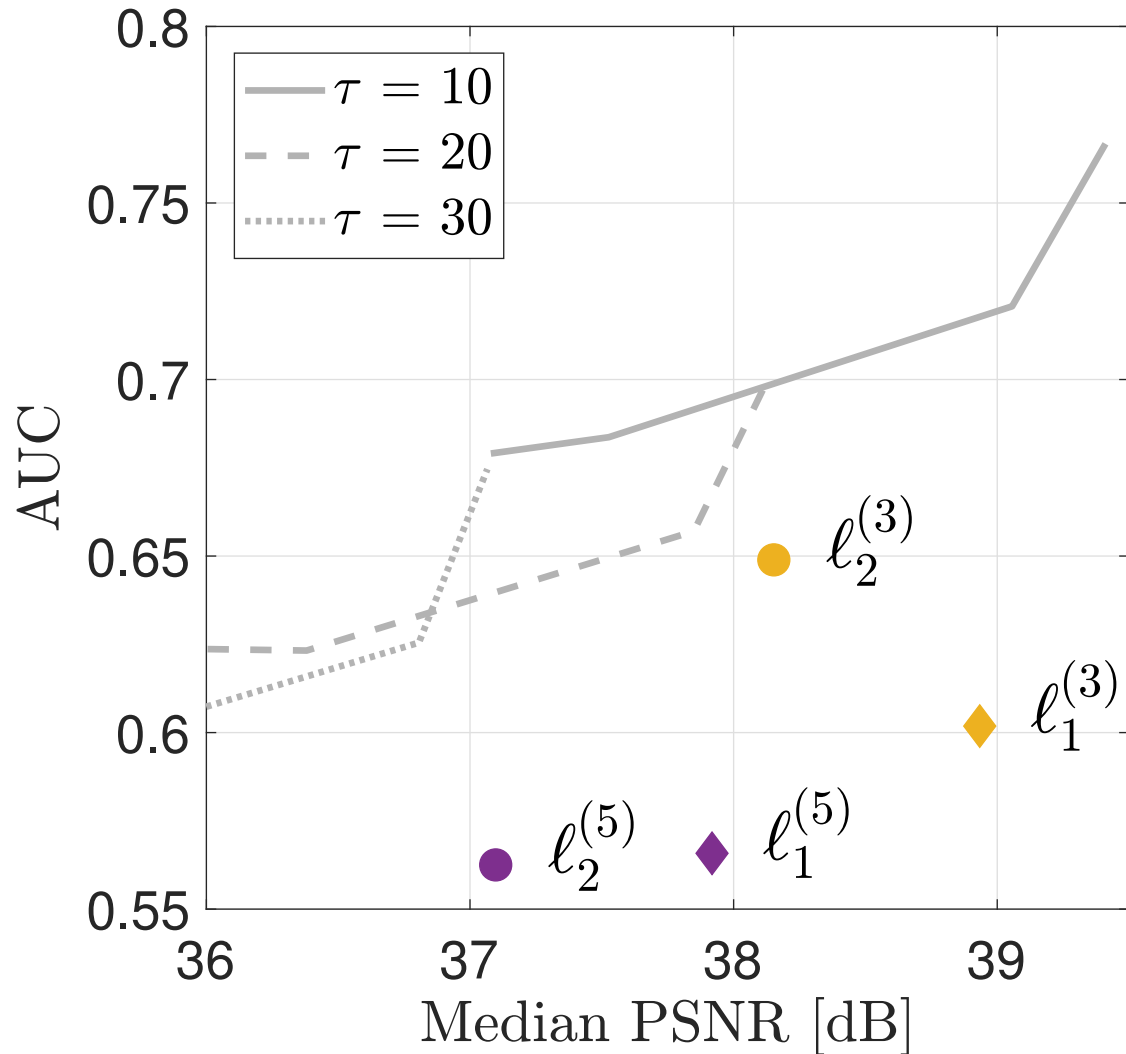
Conclusions

- *So far*
  - **Simple** anonymization strategy
  - Block-wise inpainting is easily **parallelizable**

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- *So far*
  - **Simple** anonymization strategy
  - Block-wise inpainting is easily **parallelizable**

- *The future*
  - Investigate more **sophisticated** solutions
    - Take care of edge reconstruction at inpainting phase
  - Effectiveness on **JPEG** compressed images

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ICIP 2017

IEEE International Conference on Image Processing
September 17-20, 2017, Beijing, China

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Integrity Analytics
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Physical Integrity
Semantic Integrity
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