ECCV '14

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Rolling Guidance Filter

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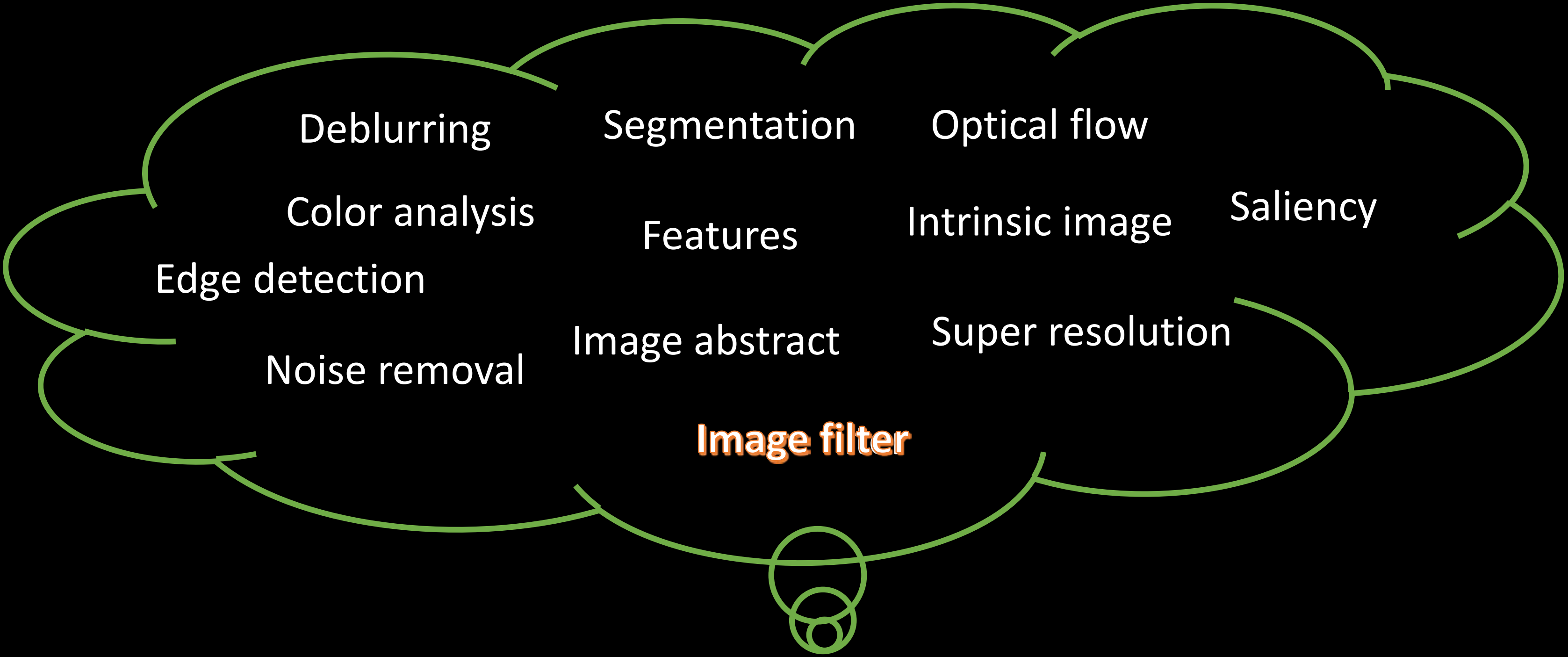


Deblurring

Segmentation

Optical flow

Color analysis

Features

Intrinsic image

Saliency

Edge detection

Image abstract

Super resolution

Noise removal

Image filter

Image Filtering

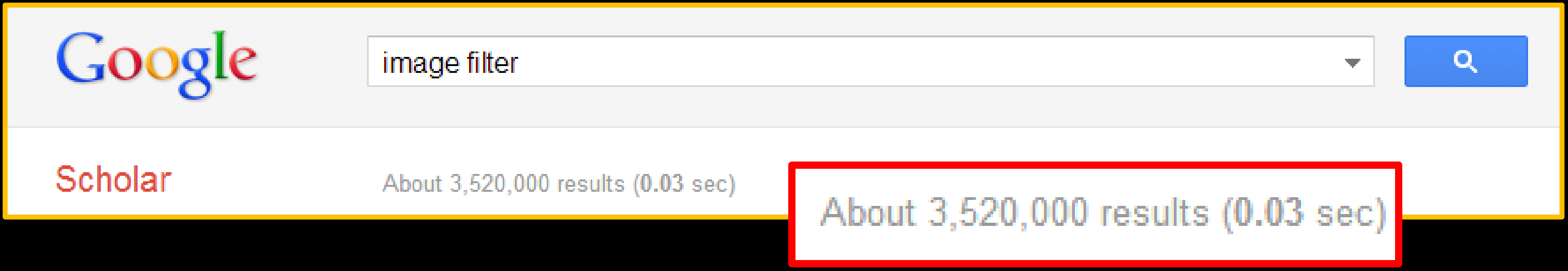


image filter

Scholar

About 3,520,000 results (0.03 sec)

About 3,520,000 results (0.03 sec)

Anisotropic Diffusion

Percentile Filter

Weighted Least Square Filter

Bilateral Filter

Domain Transform Filter

Local Extrema Filter

Local Mode Filter

Gaussian Filter

Guided Filter

Gabor Filter

Laplacian Filter

Min/Max Filter

Geodesic Filter

Sobel Filter

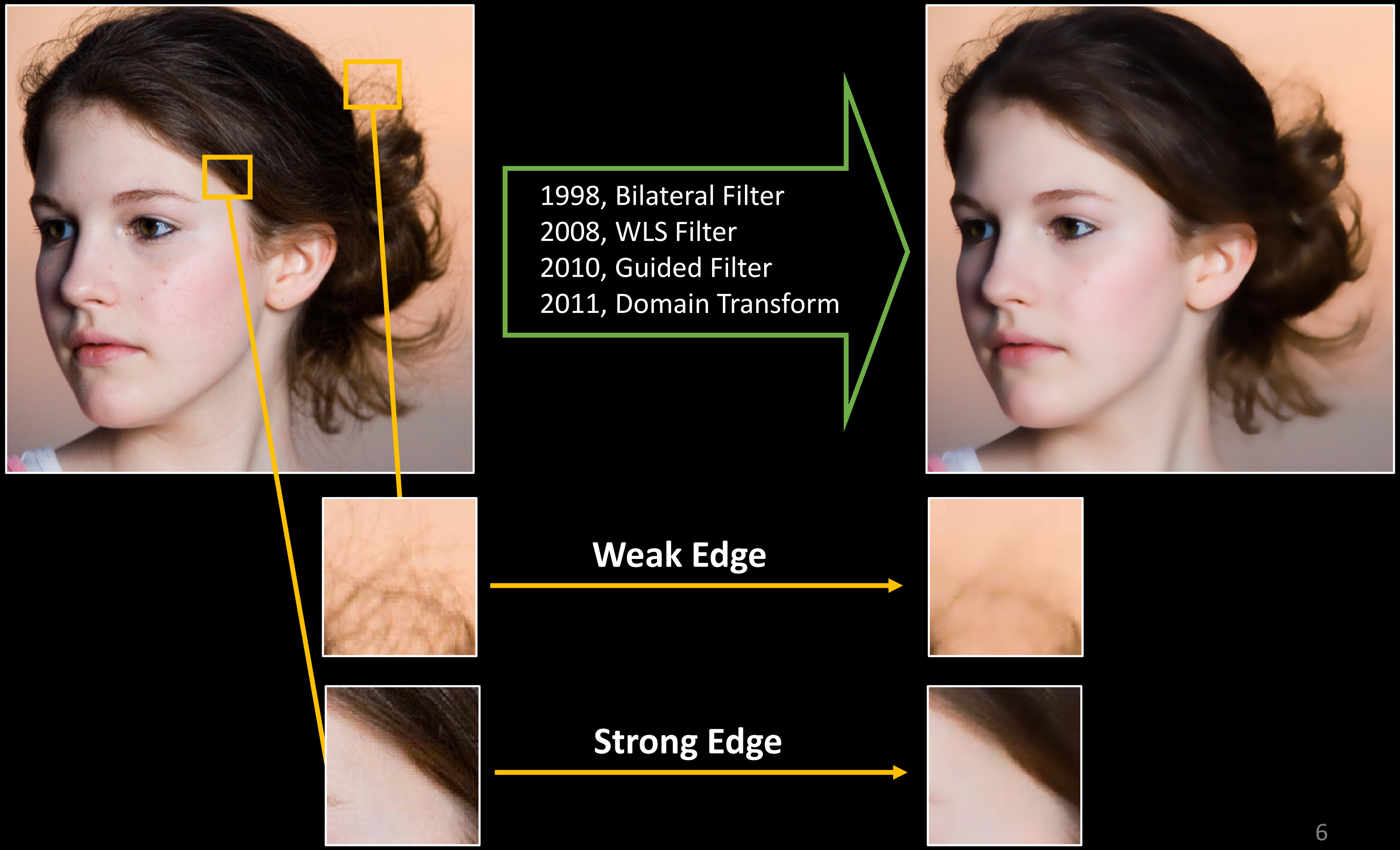
Median Filter

Dominant Filter

Weighted Median Filter

Recursive Bilateral Filter

An Important Steam: Edge Preserving

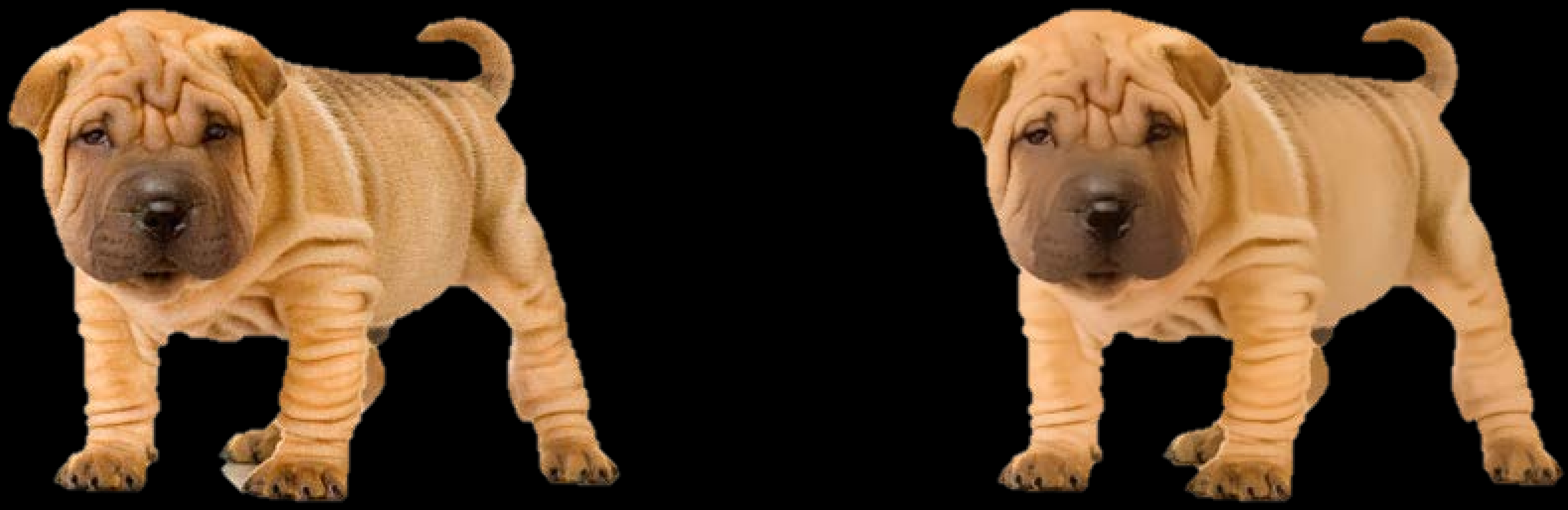


1998, Bilateral Filter
2008, WLS Filter
2010, Guided Filter
2011, Domain Transform

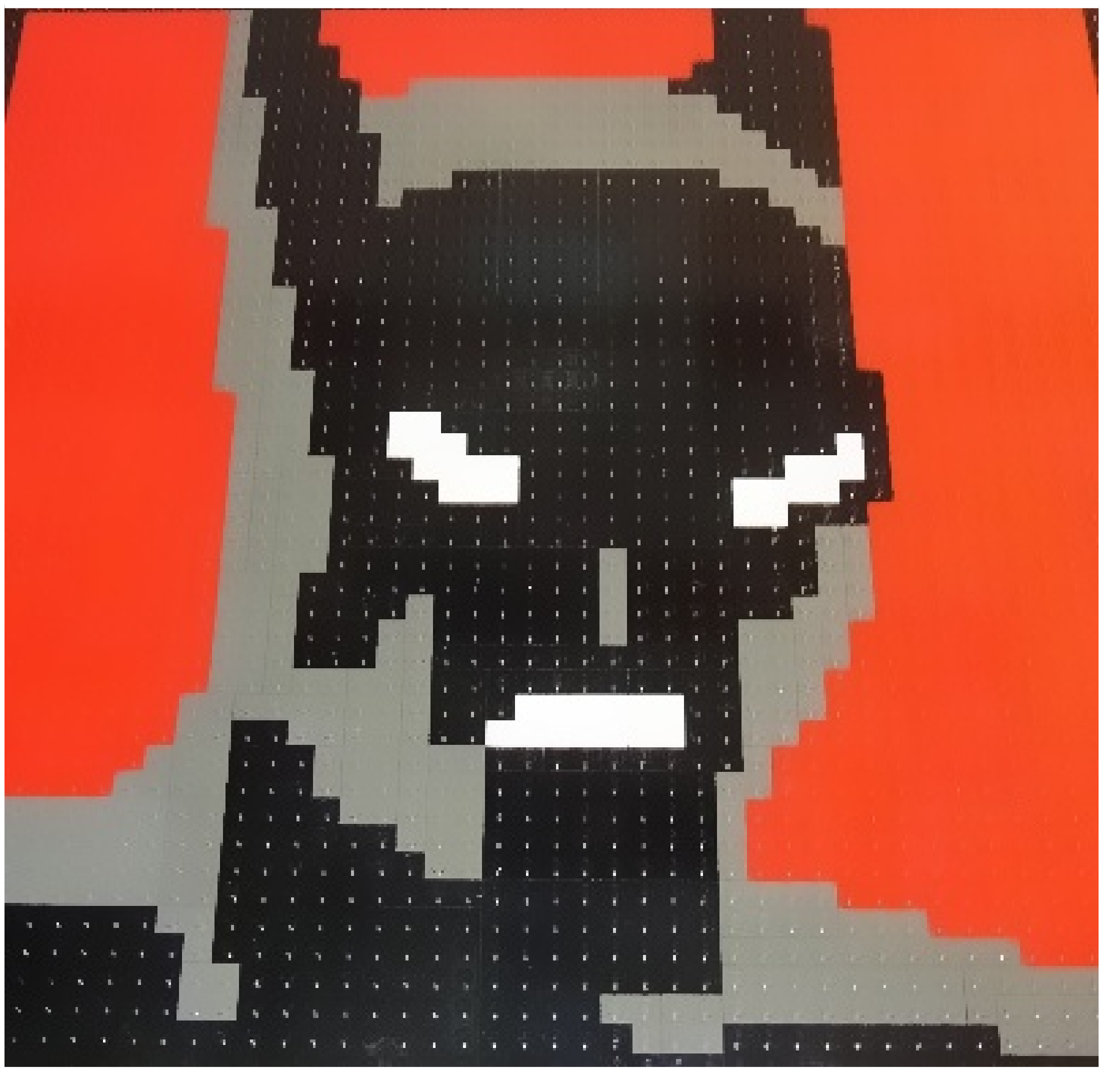
Weak Edge

Strong Edge

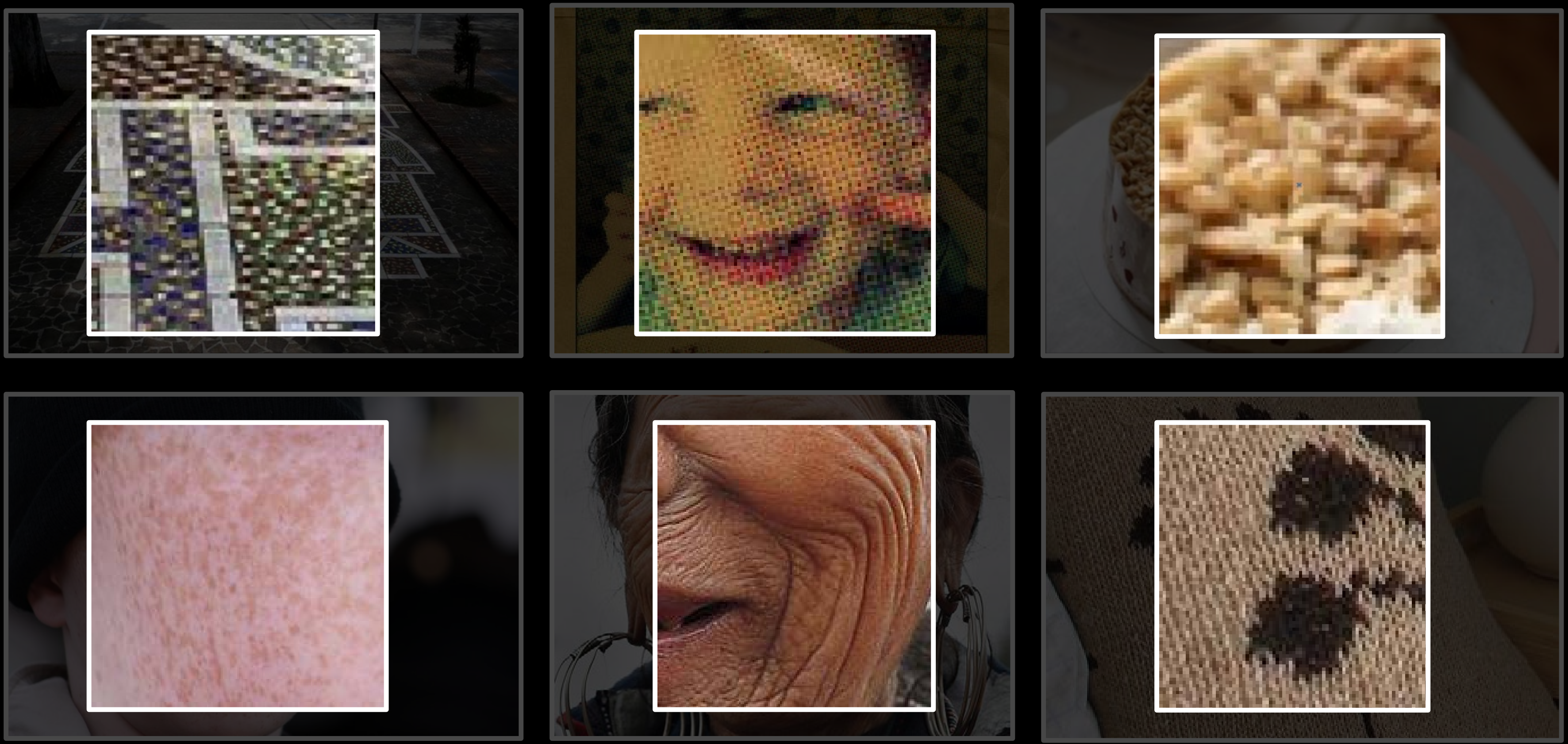
Edge preserving may not work for pet beatification



Edge preserving also fails the batman



Edge-aware filter (bilateral filter)

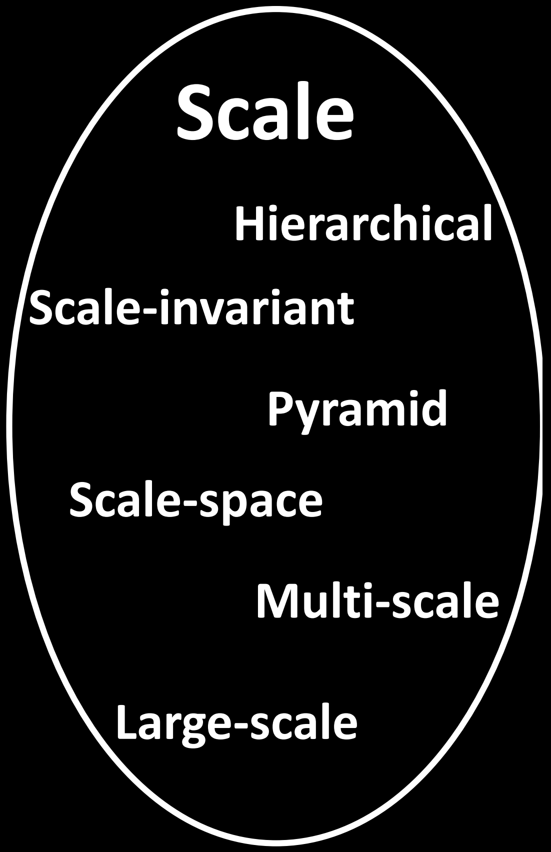


Many tiny contents are strong

What better characters them?

Scale!

Scale in Computer Vision



Scale

Hierarchical

Scale-invariant

Pyramid

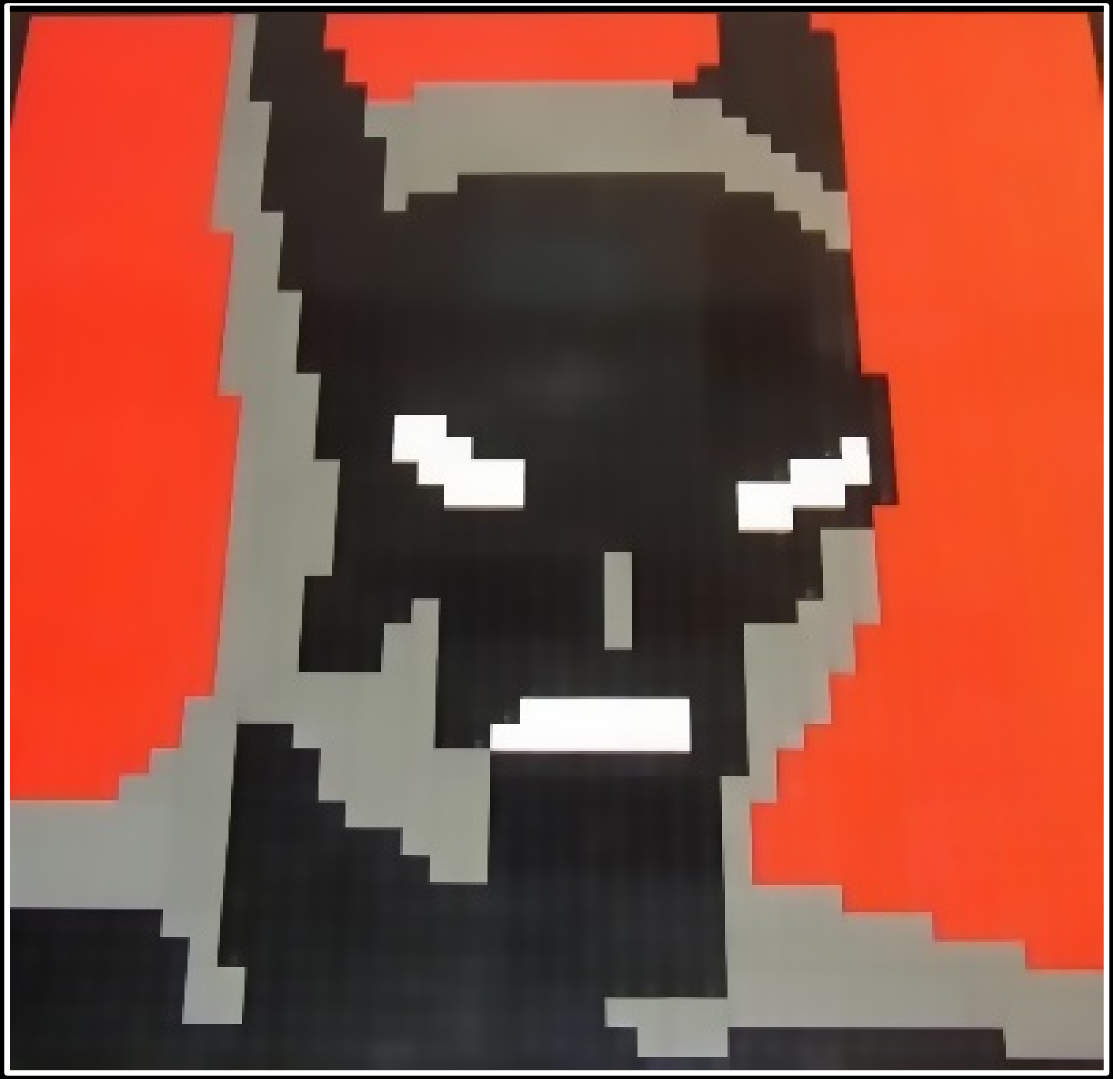
Scale-space

Multi-scale

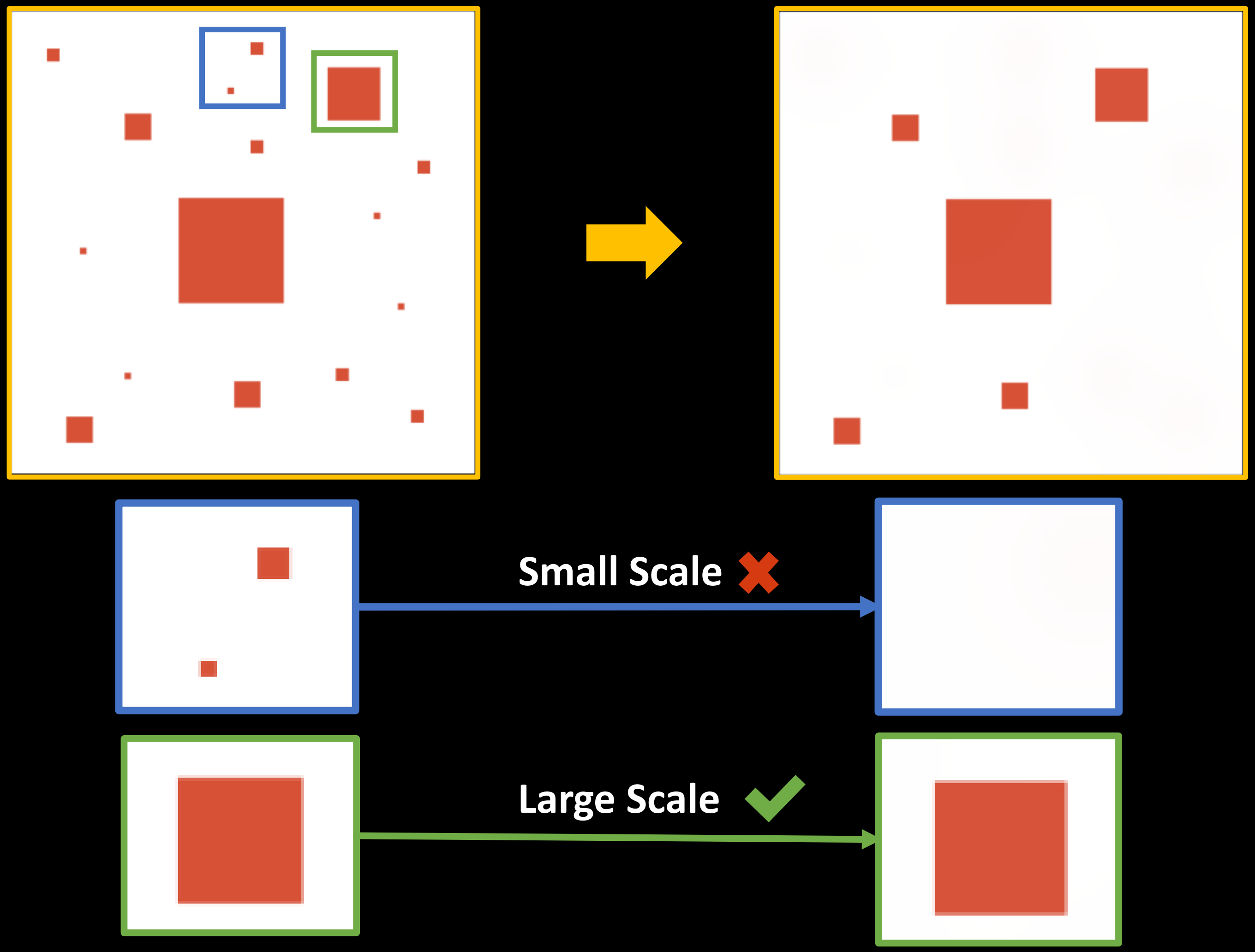
Large-scale

- Segmentation
- Object Detection
- Saliency Detection
- Feature Extraction
- Video Analysis
- Edge Detection
- Optical Flow & Stereo
- Scene Understanding
- Action Recognition
- …

Scale + Image filter = ?



Scale-Aware Filtering

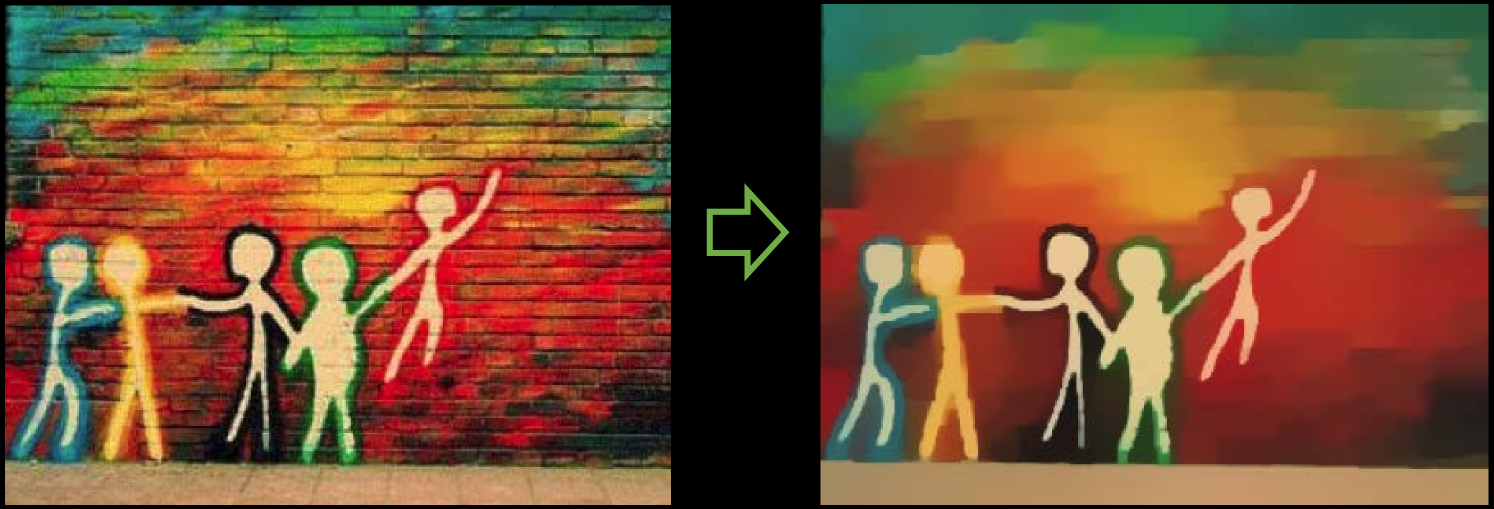


Small Scale ✗

Large Scale ✓

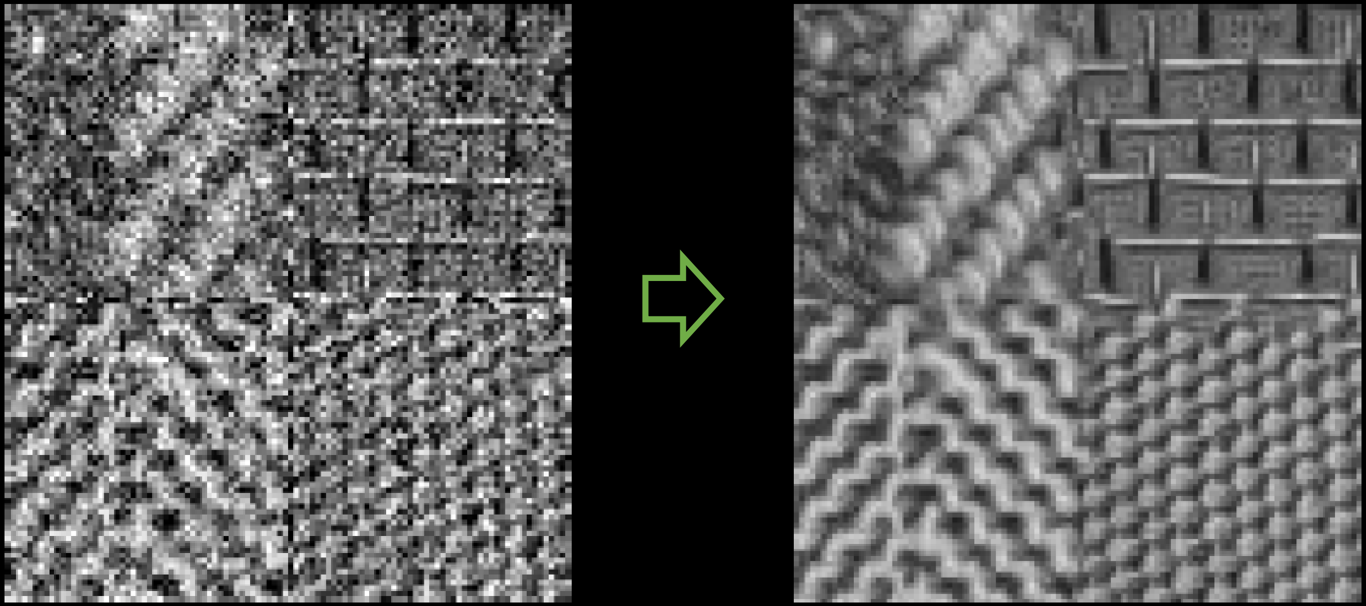
Related Work

- Texture Smoothing
  - Relative Total Variation [Xu et al., 2012]
  - Region Covariance [Karacan et al., 2013]
  - Weighted Median Filter [Zhang et al., 2014]
  - Bilateral Texture Filtering [Cho et al., 2014]



Related Work

- Iterated Filtering Method
  - Iterated Non-local Means (INM) [Brox & Cremers, 2007]



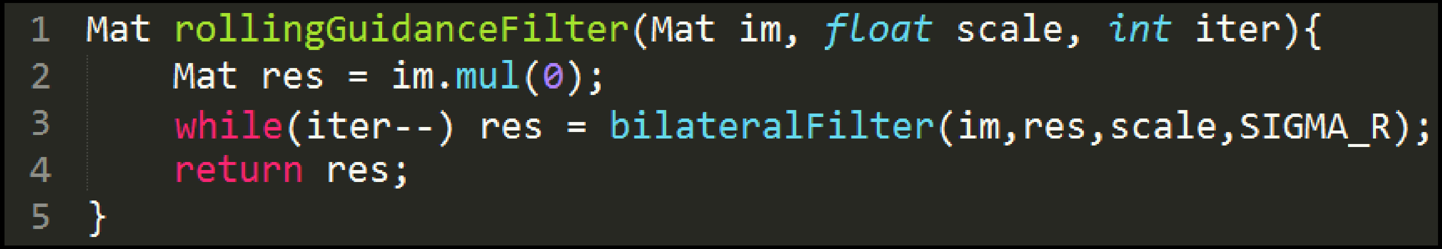
Related Work

- Iterated Filtering Method
  - Iterated Non-local Means (INM) [Brox & Cremers, 2007]

- Comparison
  - Similar **iteration** scheme
  - Different **objective and functionality**
    - **Remove texture** vs **preserve texture**
  - Different **usage of iteration**
    - **Edge recovery** vs **energy minimization**

Interesting Fact

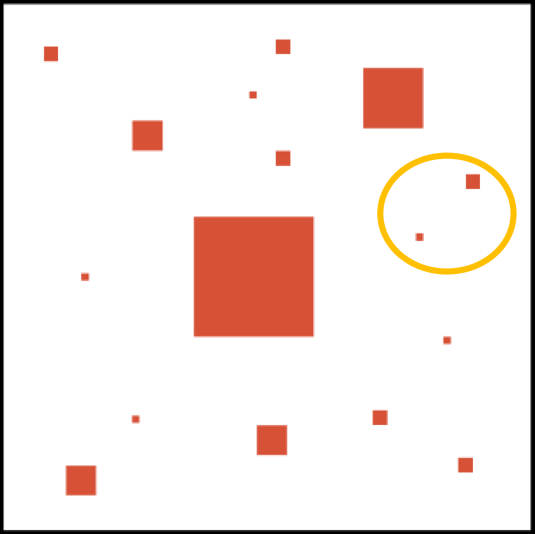
Our main algorithm has only **1 line** of code

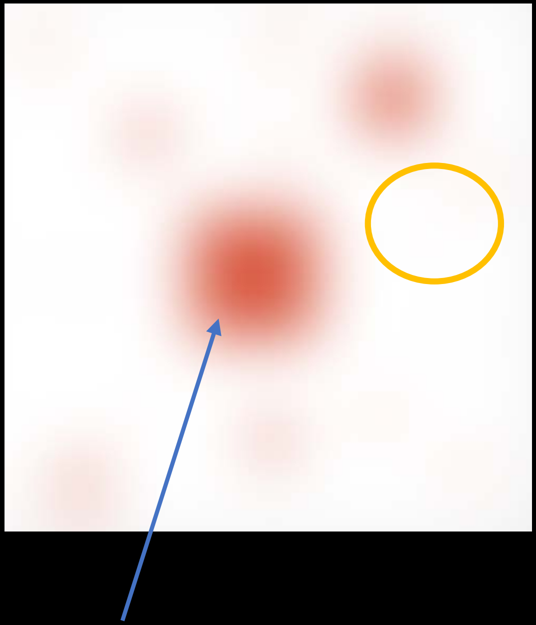


```
Mat rollingGuidanceFilter(Mat im, float scale, int iter){
    Mat res = im.mul(0);
    while(iter--) res = bilateralFilter(im,res,scale,SIGMA_R);
    return res;
}
```

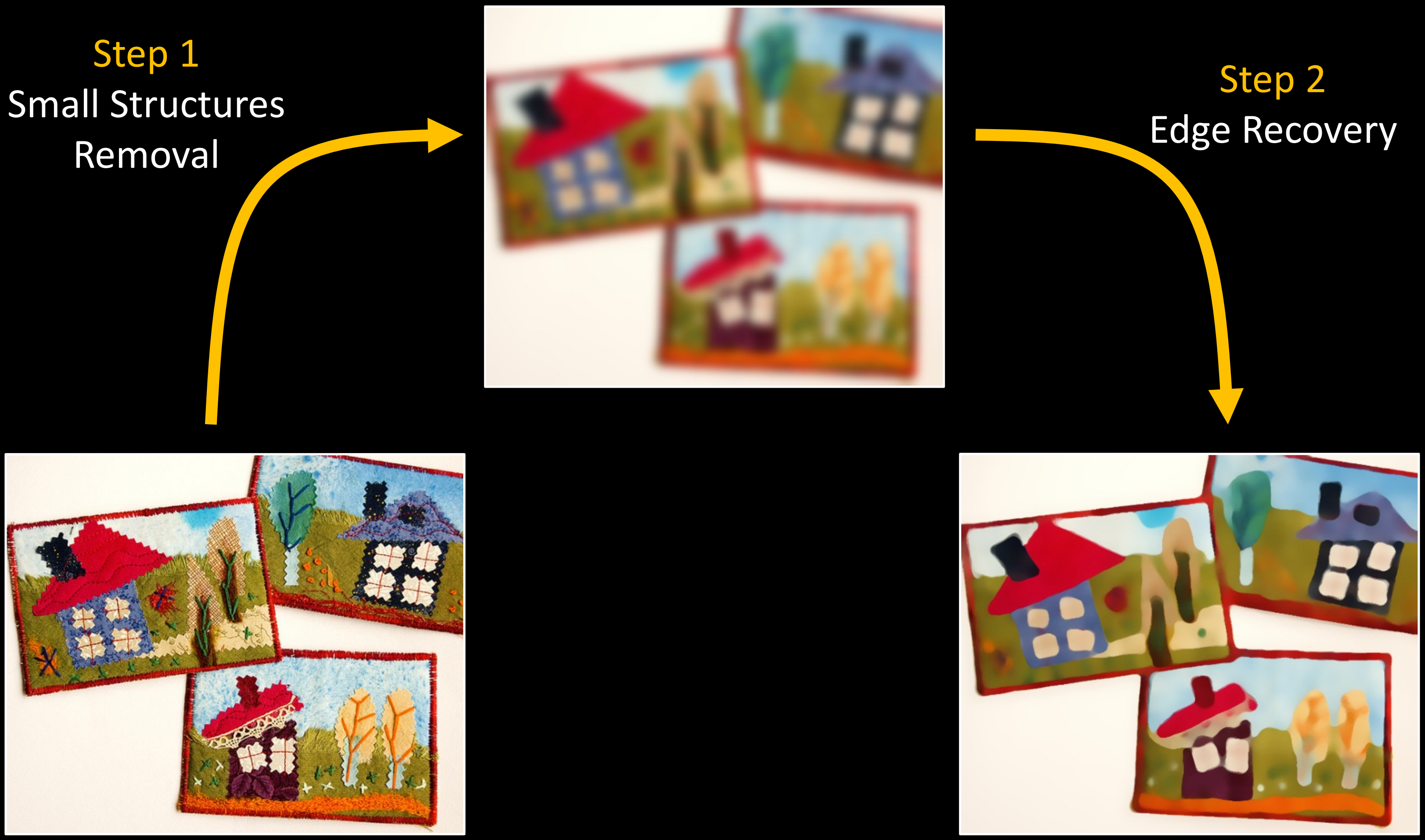
Main Idea

- Scale Space Theory [Lindeberg, 1994]:
  - An object of size t, will be largely smoothed away with Gaussian filter of variance t^2.





Our Scale-aware Filter



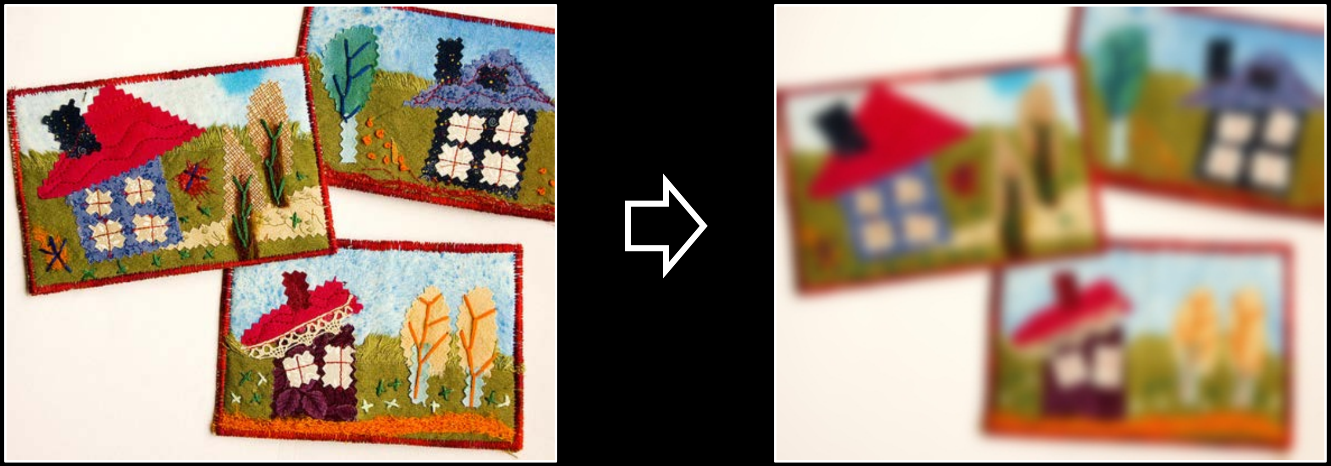
Step 1
Small Structures
Removal

Step 2
Edge Recovery

Step 1: Small Structures Removal

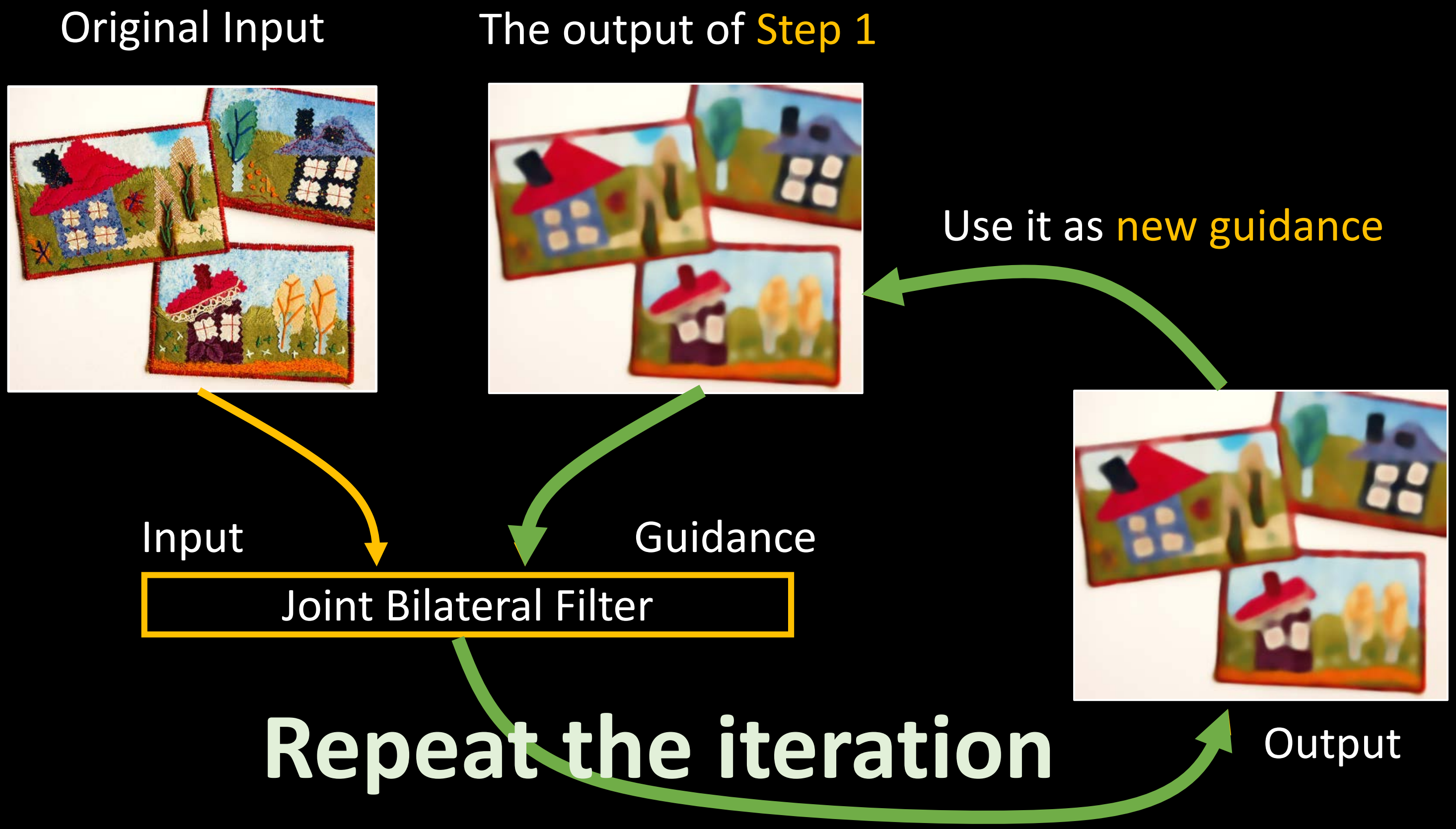
Gaussian Filter

$$J(p) = \frac{\sum_{q \in R(p)} \exp(-\frac{|p-q|^2}{2\sigma_s^2}) \cdot I(q)}{\sum_{q \in R(p)} \exp(-\frac{|p-q|^2}{2\sigma_s^2})}$$



Step 2: Edge Recovery

- A rolling guidance



Original Input

The output of Step 1

Use it as new guidance

Input

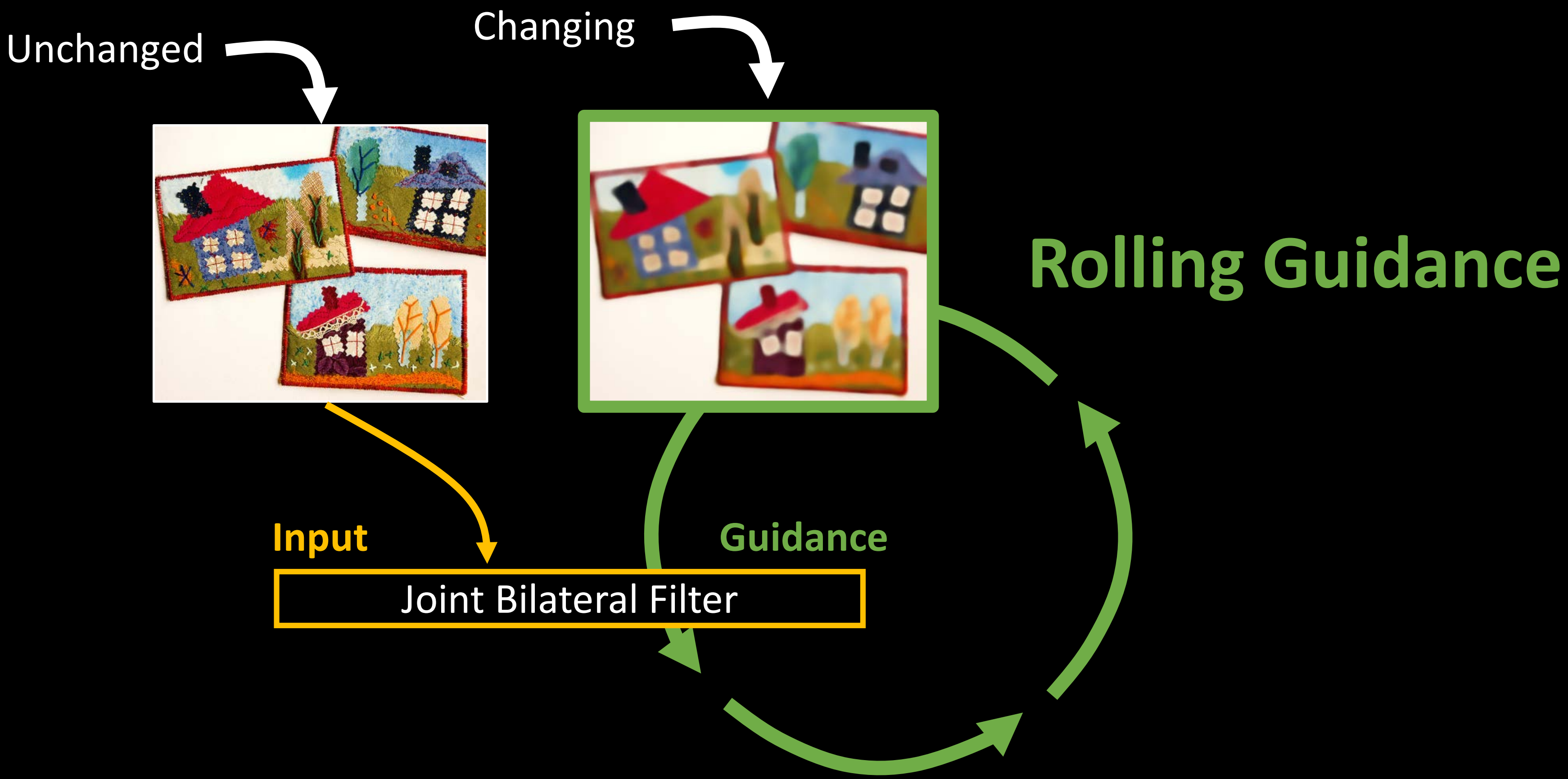
Guidance

Joint Bilateral Filter

Output

Repeat the iteration

Rolling Guidance



Unchanged

Changing

Rolling Guidance

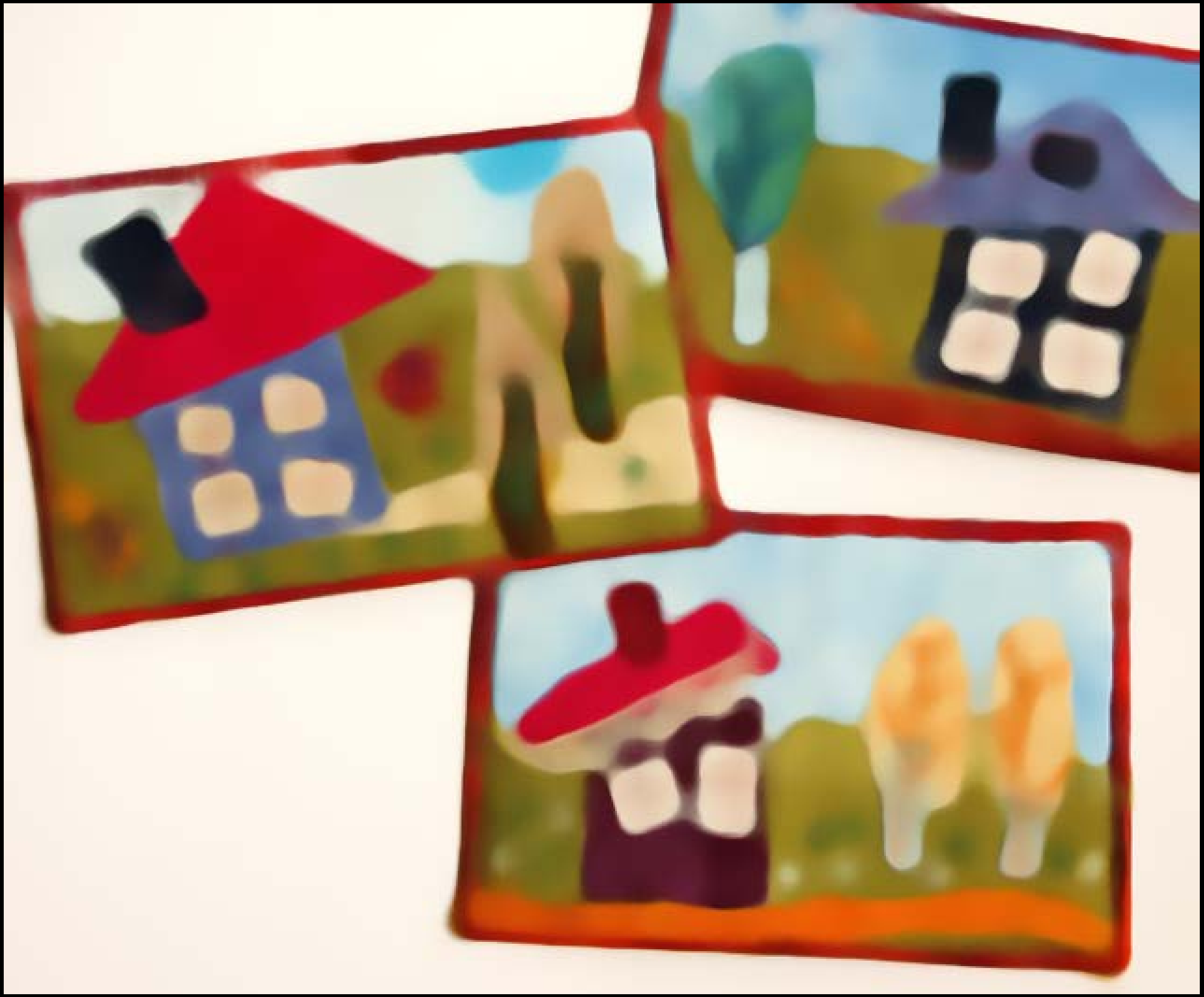
Input

Guidance

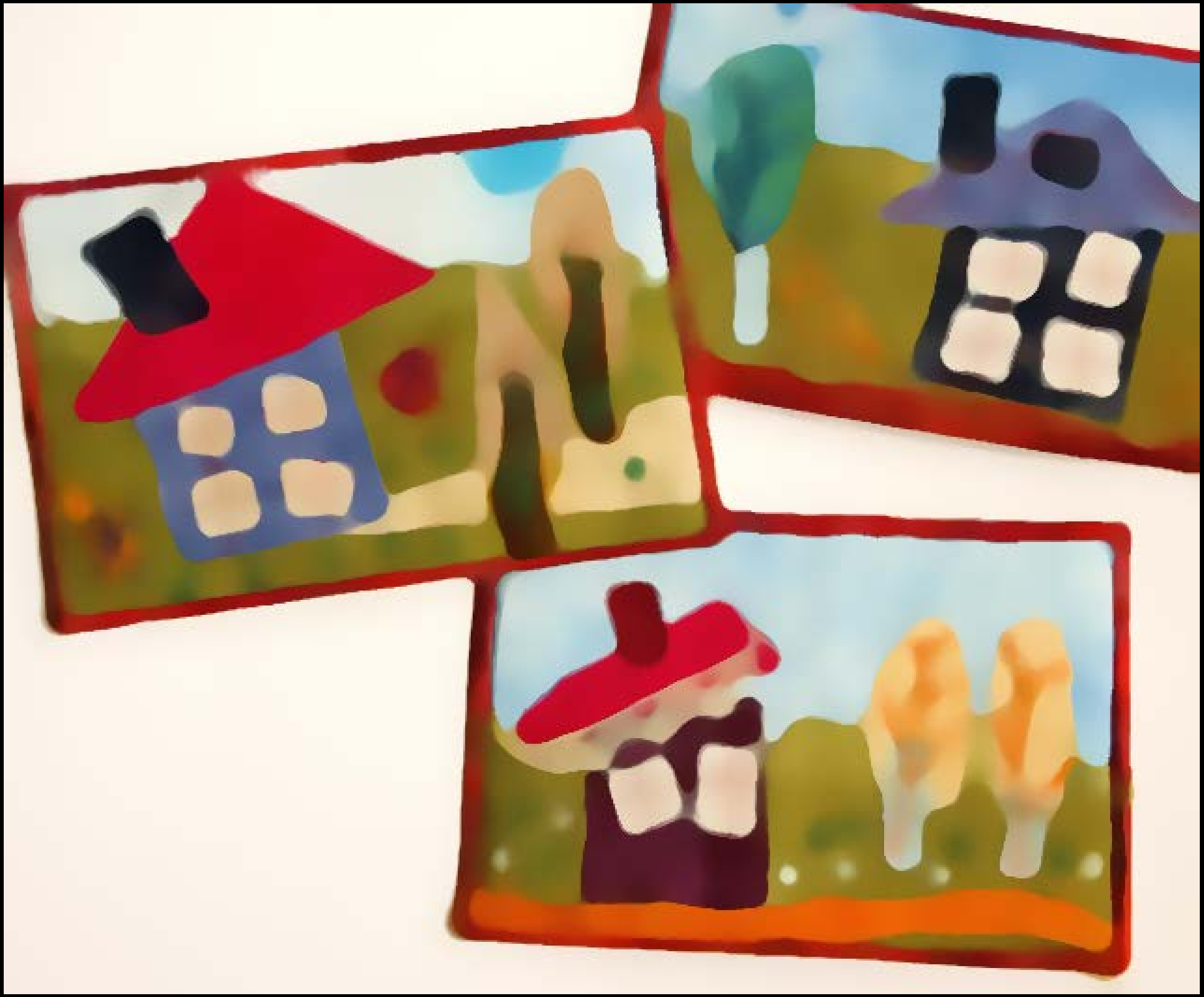
Joint Bilateral Filter

Guidance for the 1st iteration

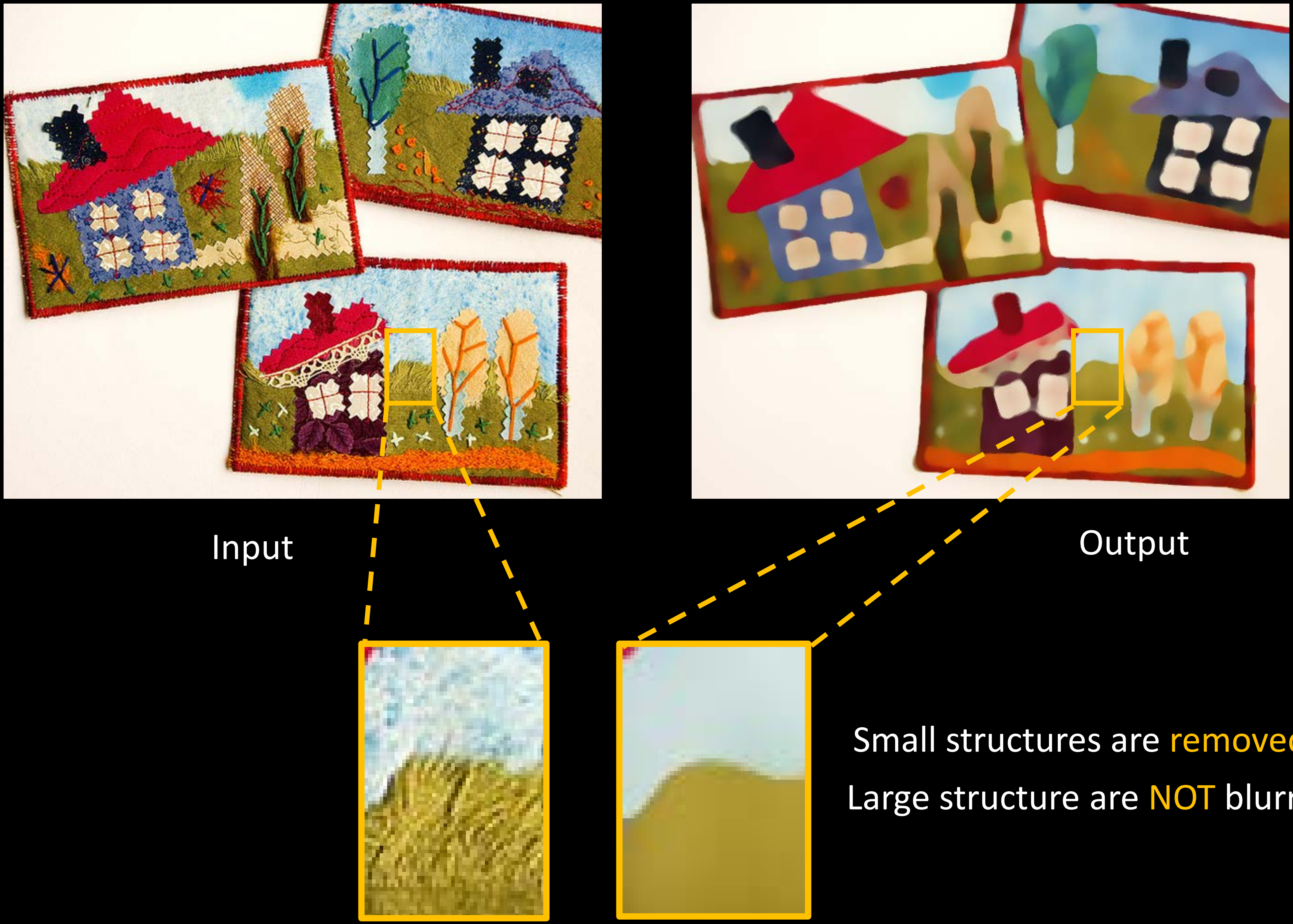
Guidance for the 2nd iteration



Guidance for the 3rd iteration



Guidance for the 5th iteration



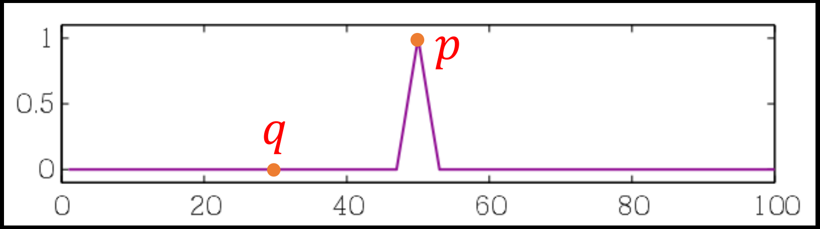
Small structures are removed.

Large structure are NOT blurred.

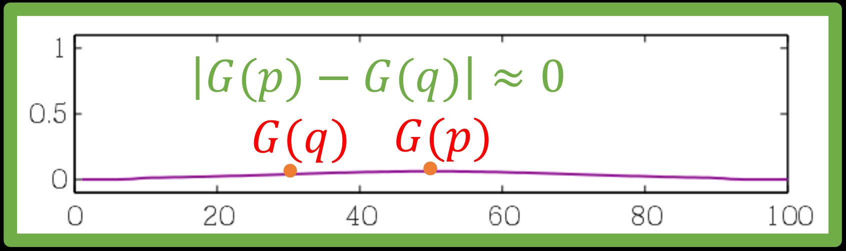
Why does rolling guidance work?

Small Structure

Input I



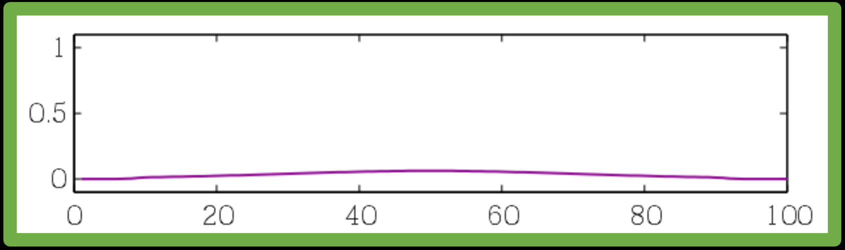
Guidance G (output of step 1)



$$J(p) = \frac{1}{K_p} \sum_{q \in R(p)} \boxed{\exp(-\frac{|p-q|^2}{2\sigma_s^2})} \cdot I(q)$$

It becomes a Gaussian filter

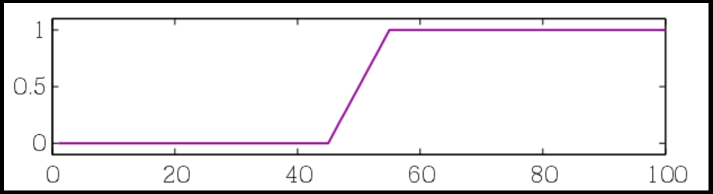
Joint Bilateral Filter



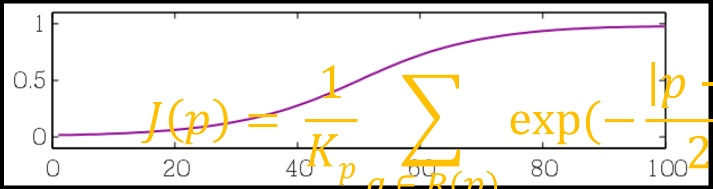
Same

Large Structure

Input Image



Result of Step 1

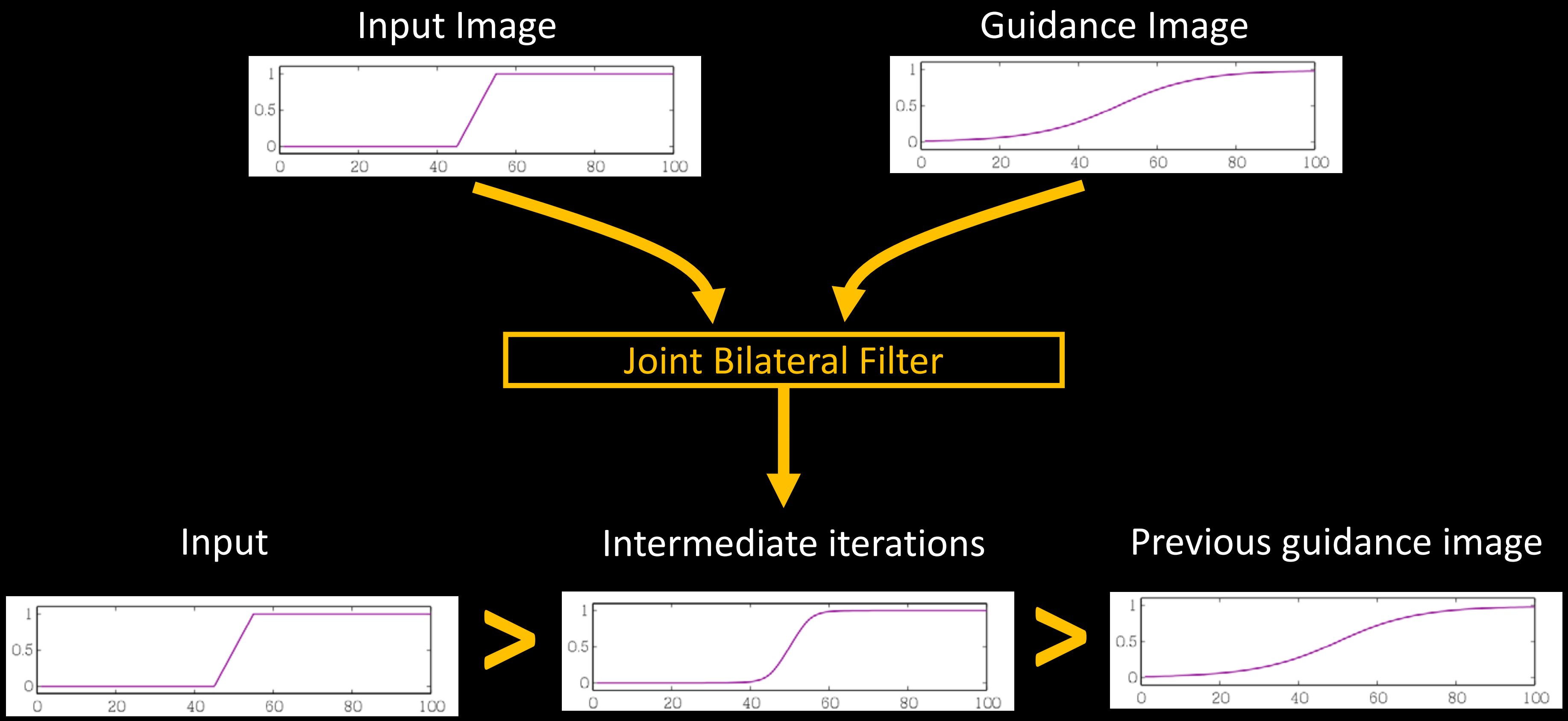


$$J(p) = \frac{1}{K_p} \sum_{q \in R(p)} \exp(-\frac{|p-q|^2}{2\sigma_s^2}) \cdot \boxed{\exp(-\frac{|G(p)-G(q)|^2}{2\sigma_r^2})} \cdot I(q)$$

$\neq 1$

Due to this range weight

It generates **sharper** results than Gaussian!



Input Image

Guidance Image

Joint Bilateral Filter

Input

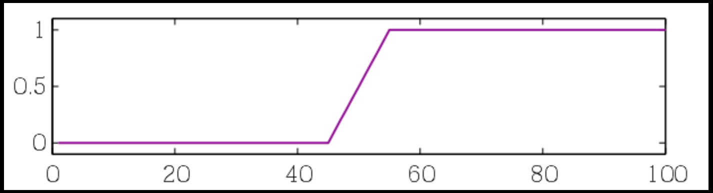
Intermediate iterations

Previous guidance image

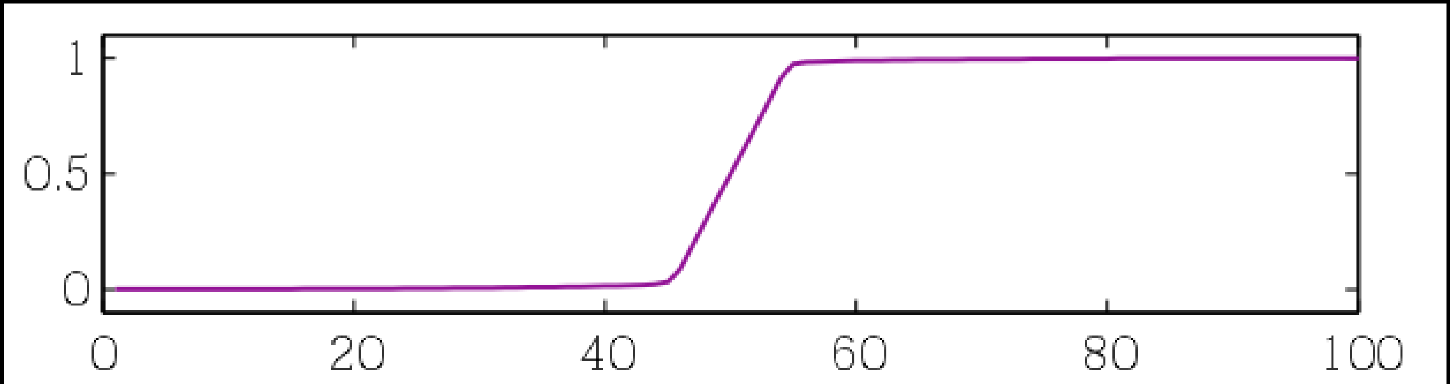
Smoothing

Range weight

Input Image



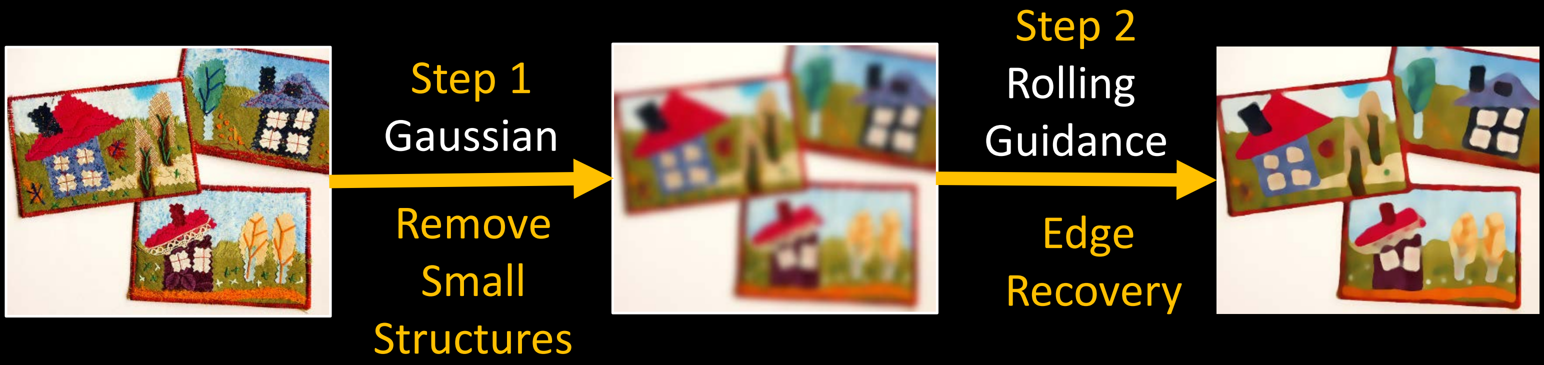
Guidance Image



1st Iteration

2nd Iteration

Rolling Guidance Filter



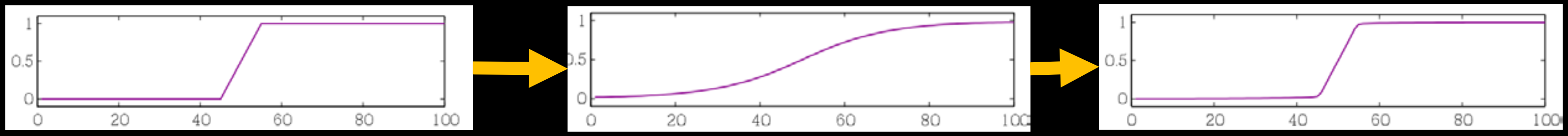
Step 1
Gaussian

Remove
Small
Structures

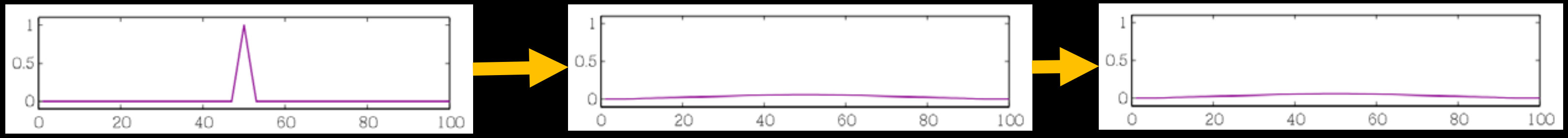
Step 2
Rolling
Guidance

Edge
Recovery

Large Structure



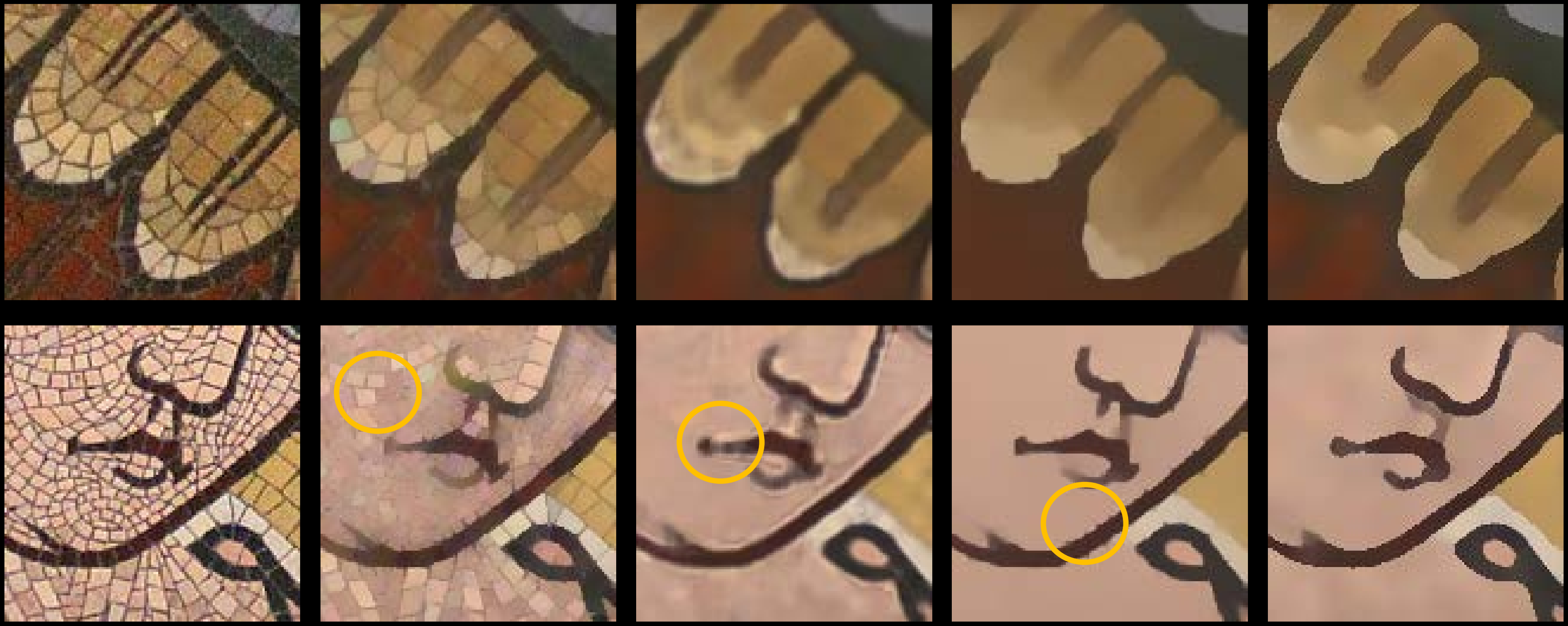
Small Structure



Comparison

Result Comparison

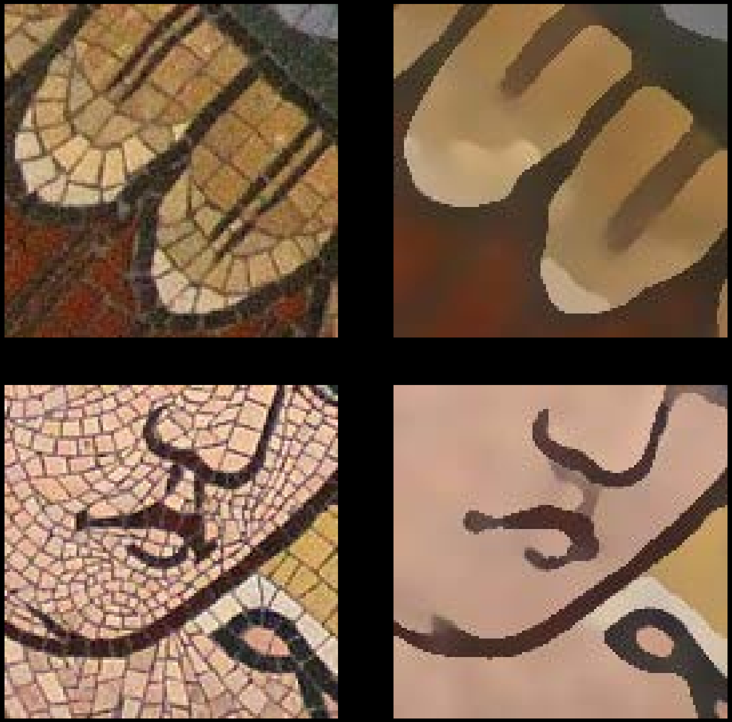
- Result comparison with related work



Input [Subr et al.] [Karacan et al.] [Xu et al.] Ours

Performance Comparison

- Performance comparison with related works



Input

Ours

For 4 Megapixel Image

2

seconds

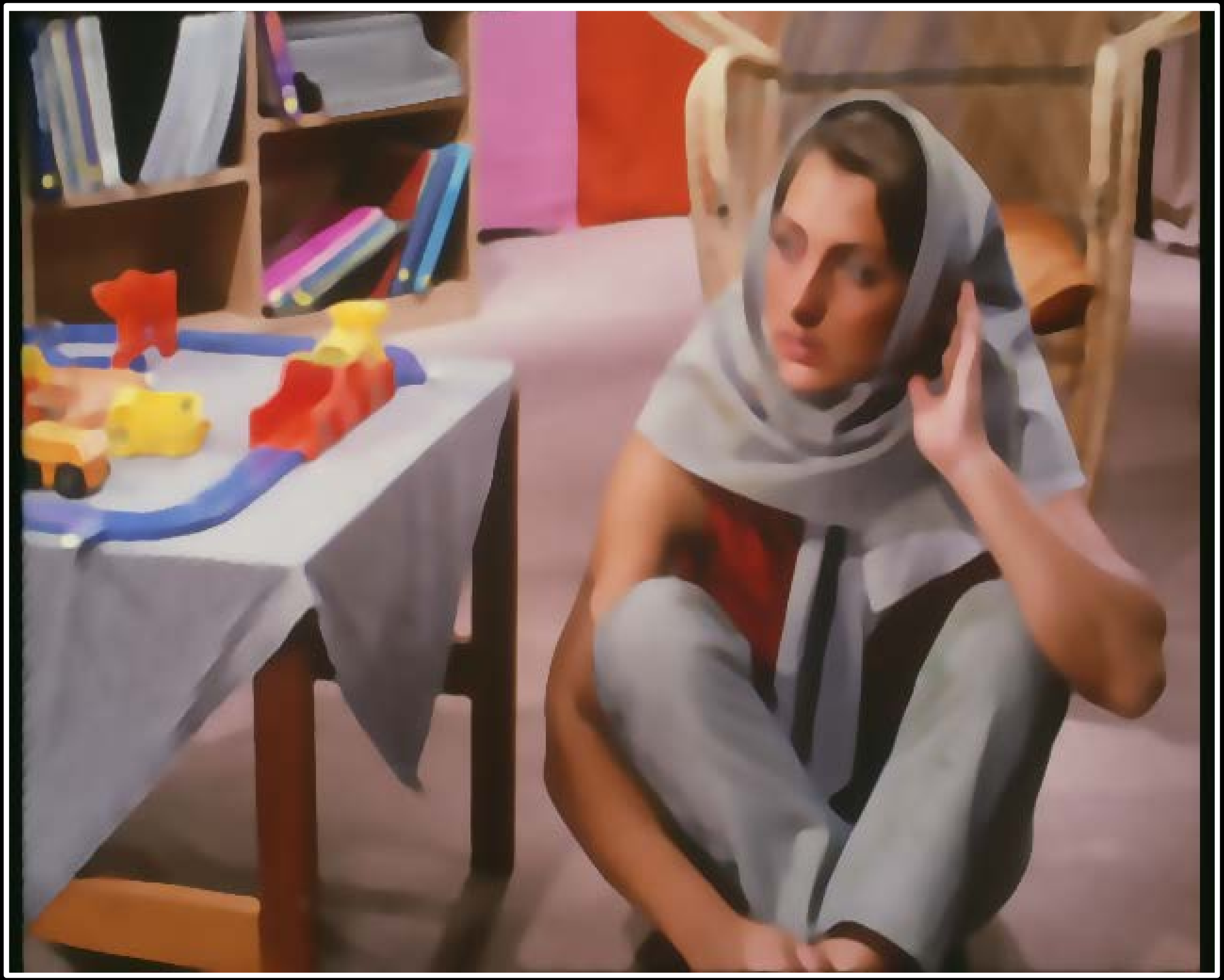
Performance Comparison

- Performance comparison

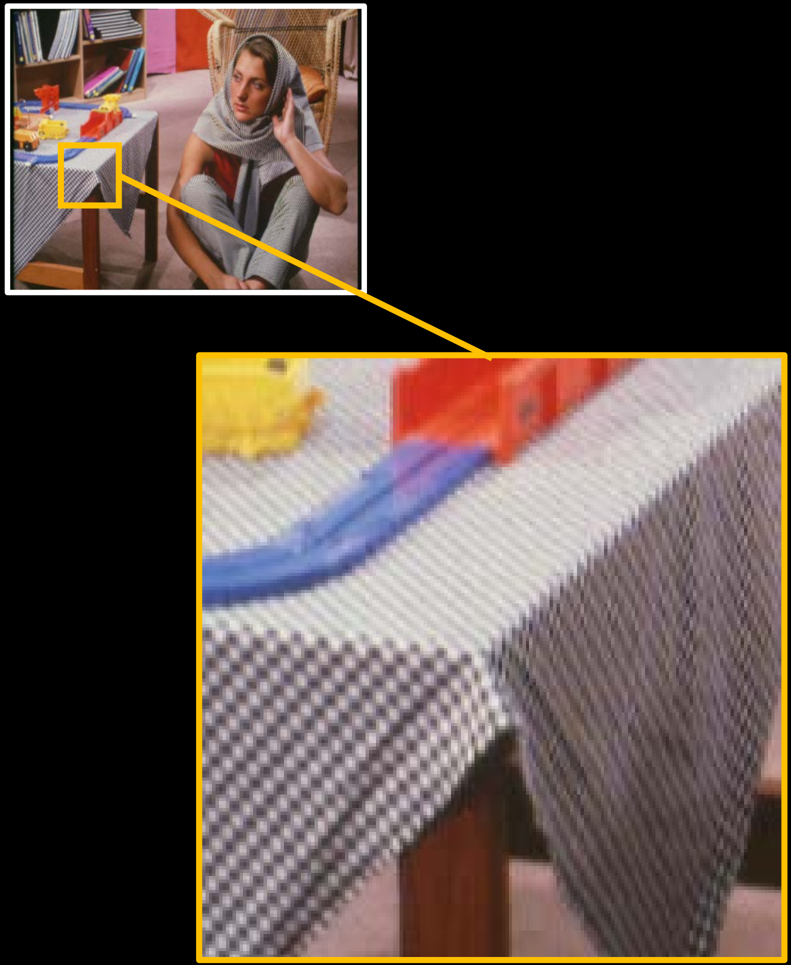
Algorithms	Time (seconds/Megapixel)
Local Extrema [Subr et al., 2009]	95
RTV [Xu et al., 2012]	14
Region Covariance [Karacan et al., 2013]	240
Ours	0.05 (Real-time)

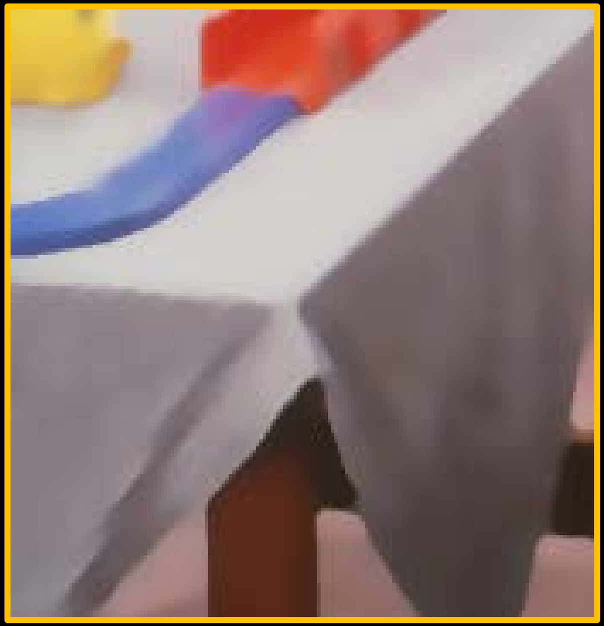
Results & Application

Texture Removal

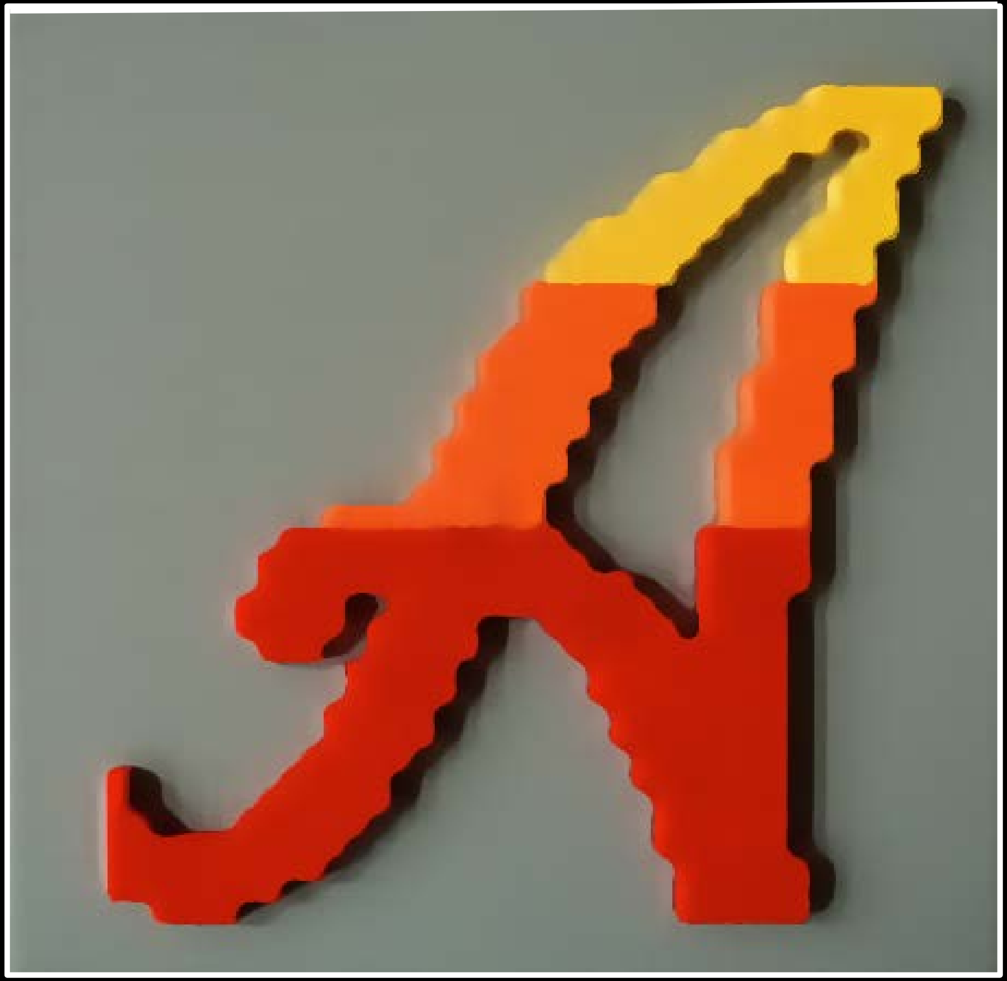


Texture Removal



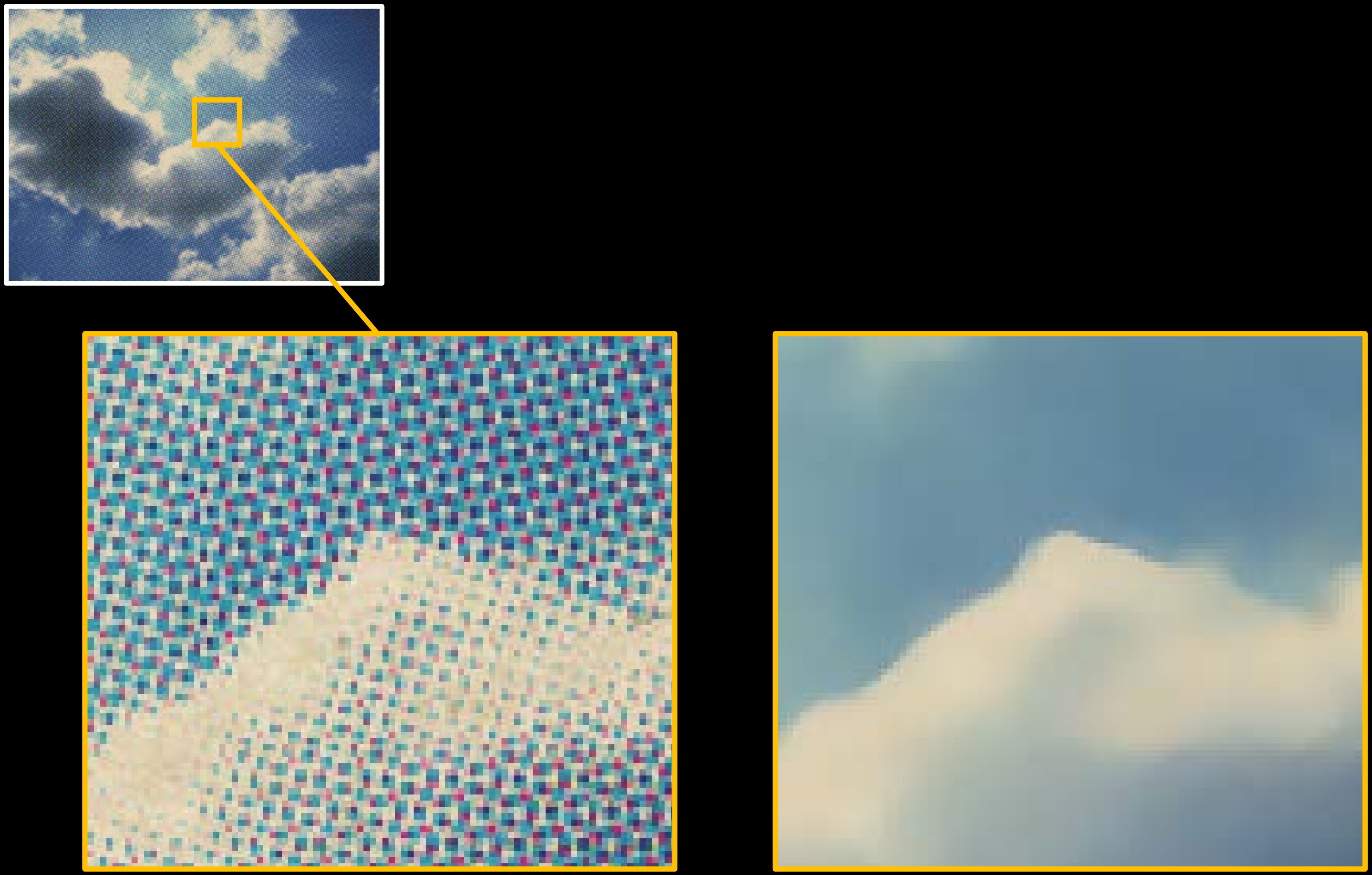


Texture Removal

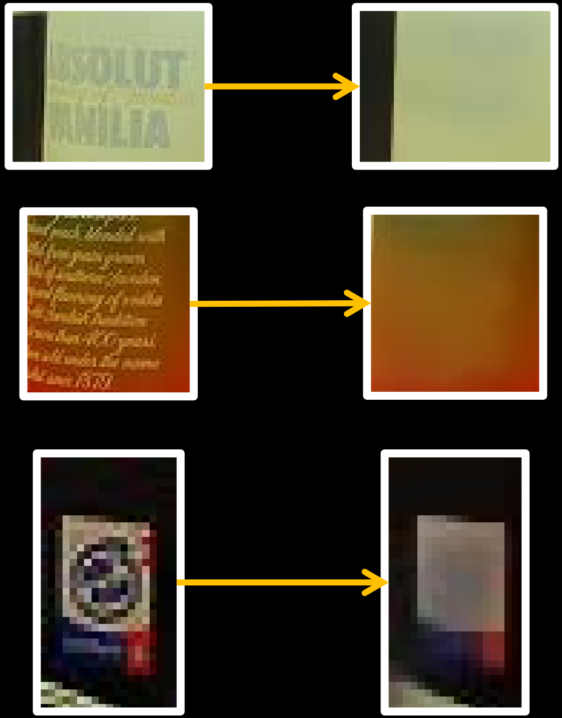


Halftone Image

Halftone Image

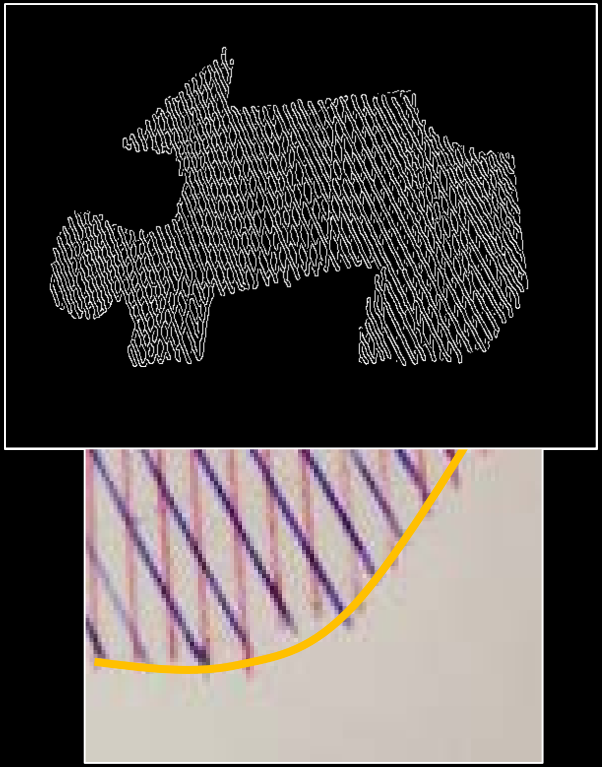


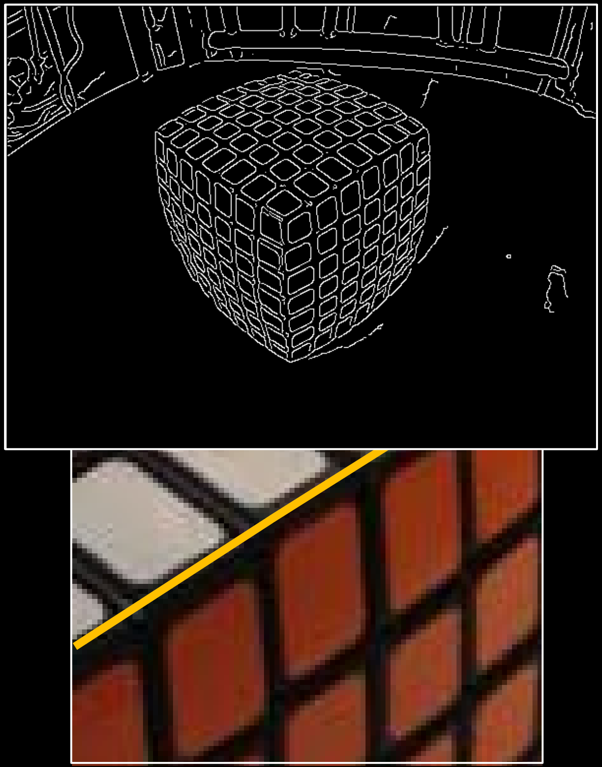
Small Text Removal

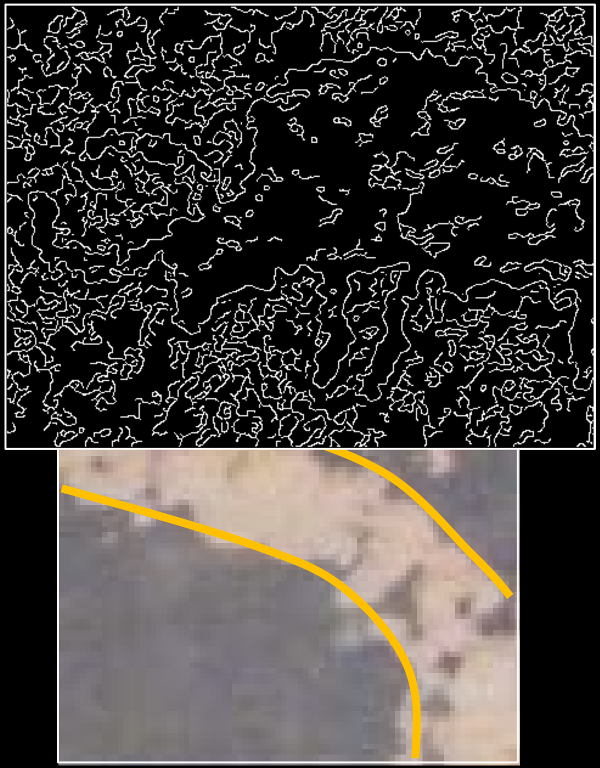


Remove Text

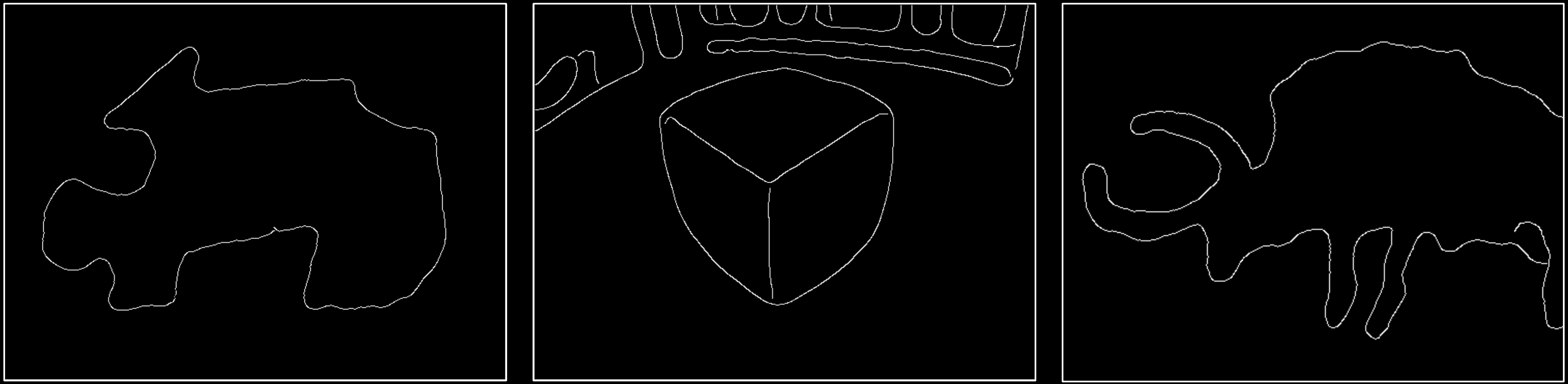
Virtual Edge Detection







Virtual Edge Detection



Natural Images

- Usable for
  - Segmentation
  - Saliency
  - Scene understanding
  - Background subtraction
  - Layer separation
  - Outlier removal
  - …

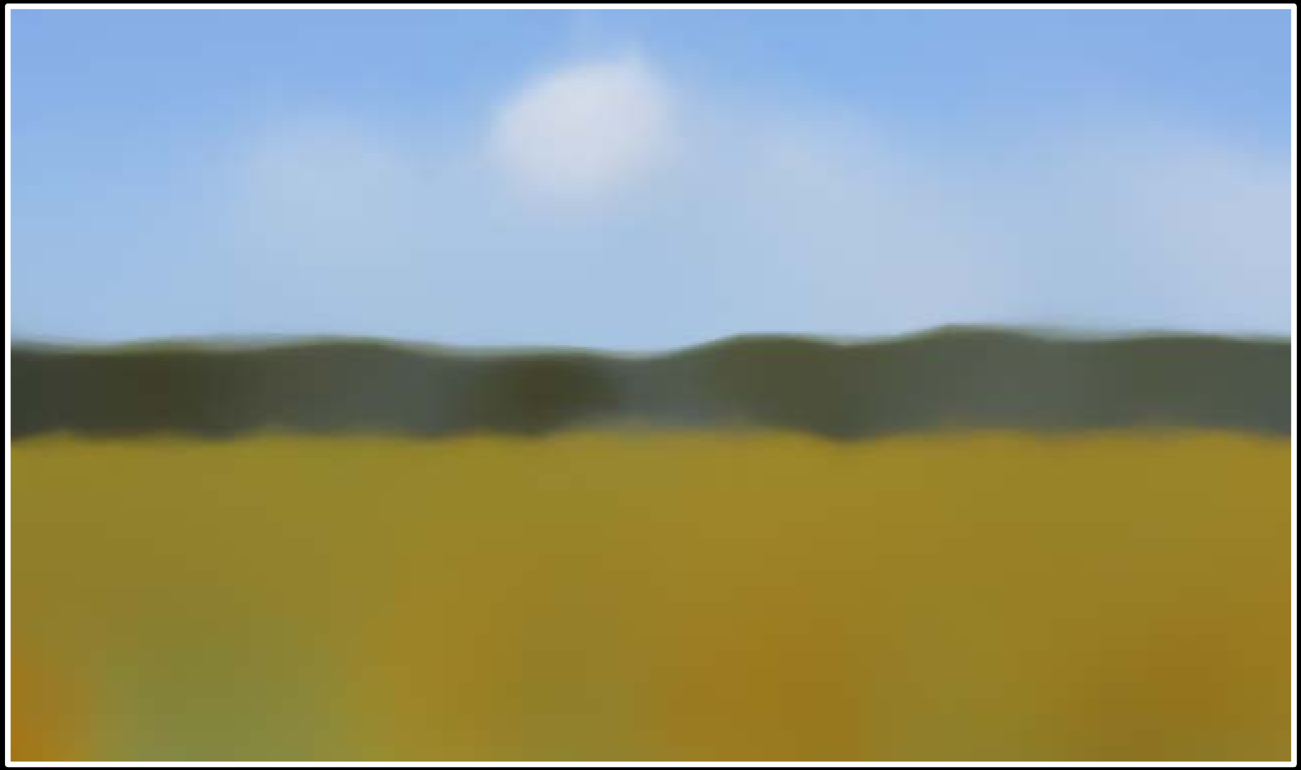
Determining Scales

Step 1 $$J(p) = \frac{1}{K_p} \sum_{q \in R(p)} \exp(-\frac{|p-q|^2}{\boxed{2\sigma_s^2}}) \cdot I(q)$$ Gaussian

Step 2 $$J(p) = \frac{1}{K_p} \sum_{q \in R(p)} \exp(-\frac{|p-q|^2}{\boxed{2\sigma_s^2}}) \cdot \exp(-\frac{|G(p)-G(q)|^2}{2\sigma_r^2}) \cdot I(q)$$ Joint filter

σ_s determine the scale.

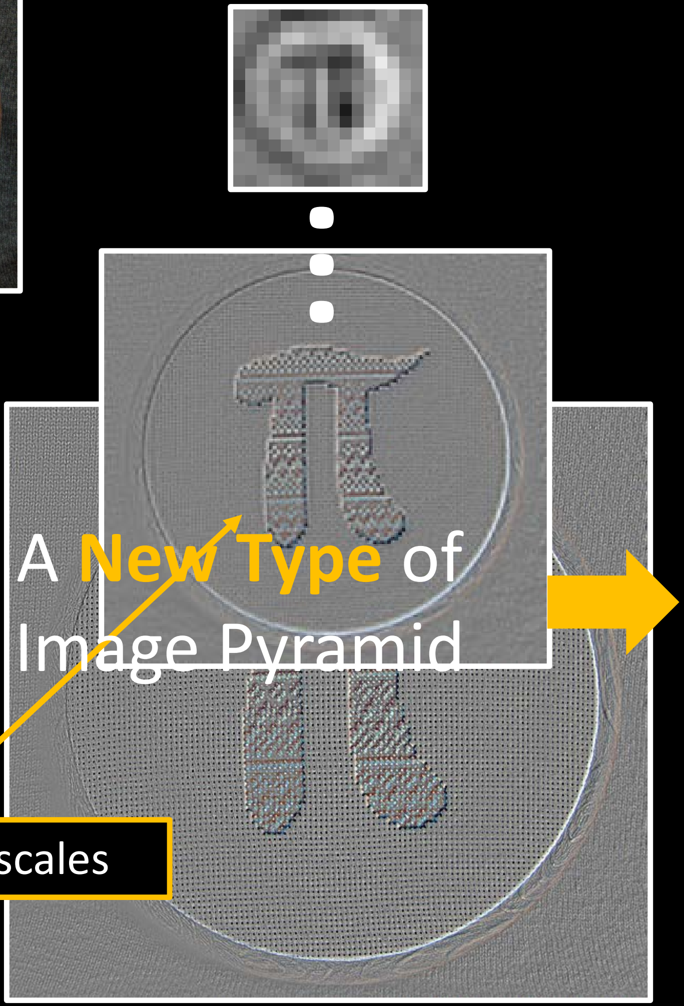
Multi-Scale Filtering



σ_s = 30

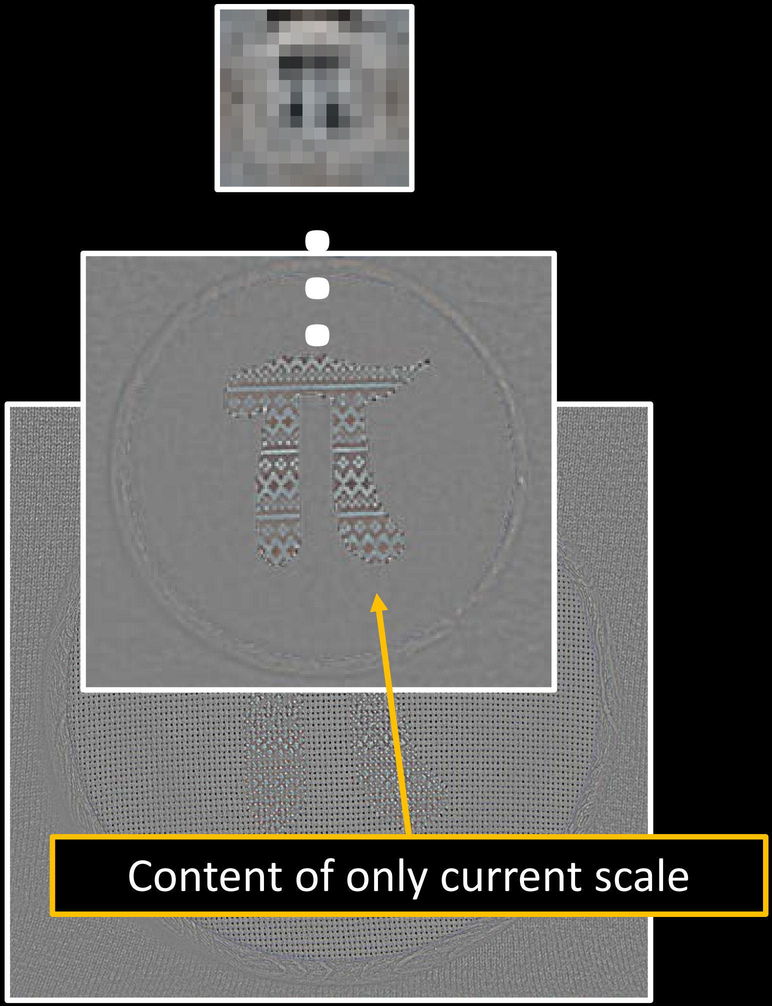
A New Type of Image Pyramid

Input



Content of all scales

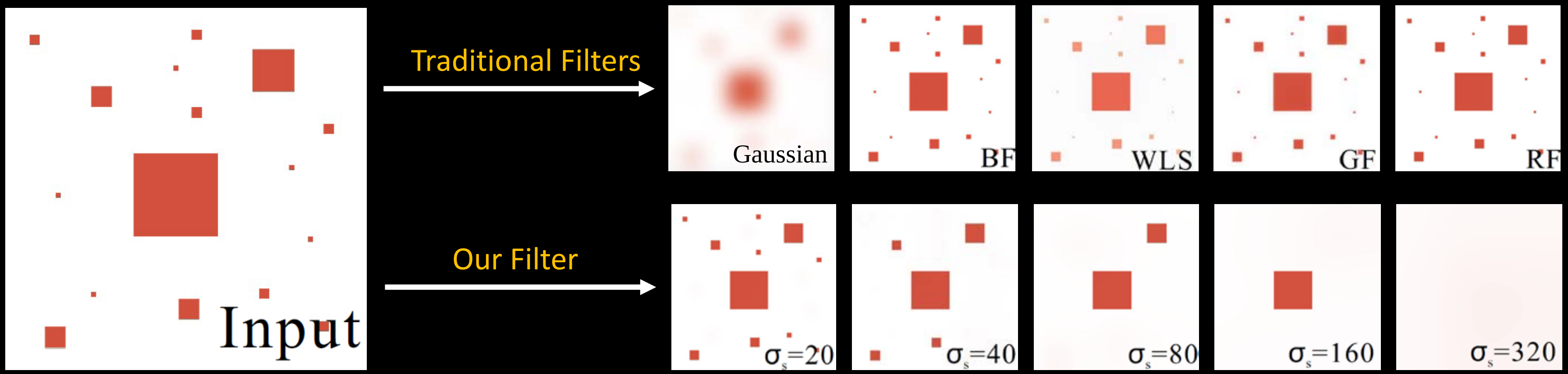
Laplacian Pyramid
(generated with Gaussian)

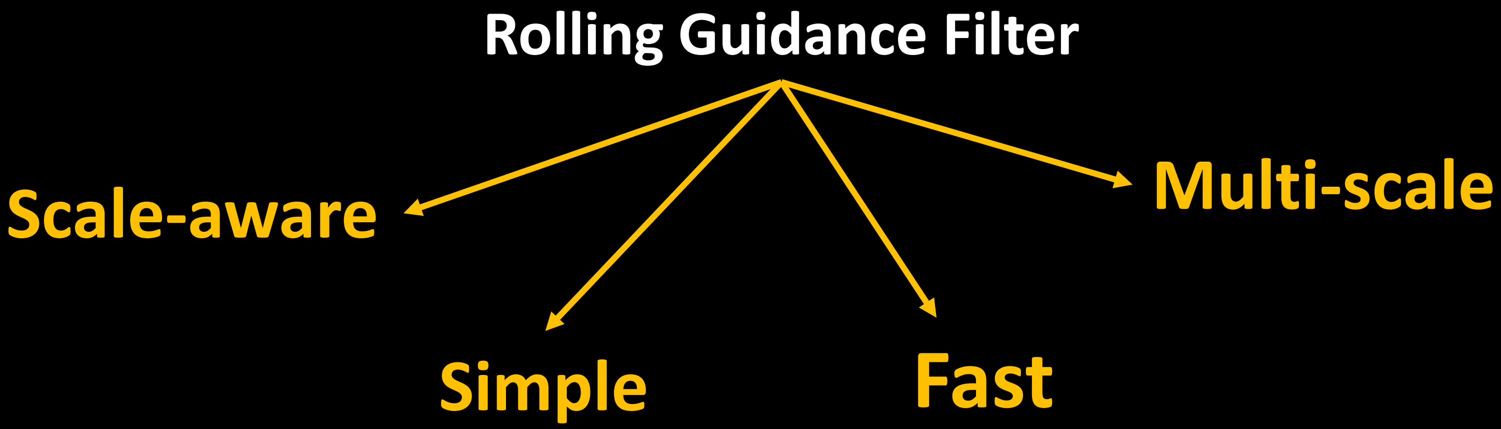


Content of only current scale

Texture Pyramid
(generated with Rolling Guidance Filter)

Summary





Rolling Guidance Filter

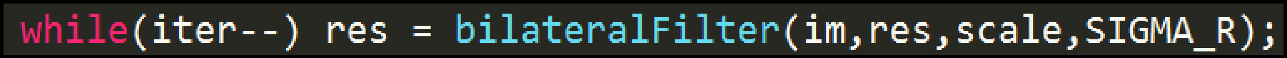
Scale-aware

Simple

Fast

Multi-scale

Code Available Online



```
while(iter--) res = bilateralFilter(im,res,scale,SIGMA_R);
```

Thank You

Limitations

- Sharp corners could be rounded
  - It is because sharp corner presents high frequency change.
  - In other words, sharp corners are small-scale structures.