A Gentle Introduction to Bilateral Filtering and its Applications

Limitation?

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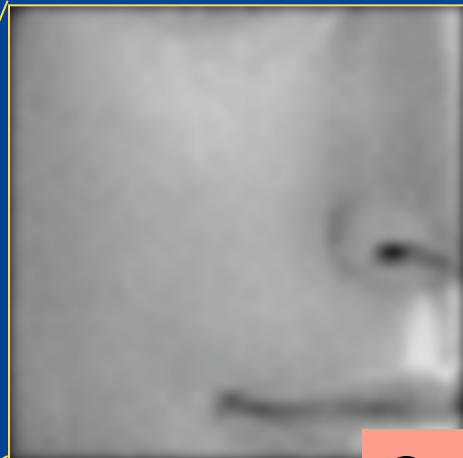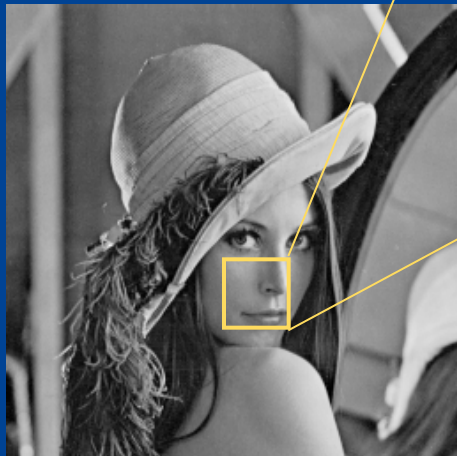0:20

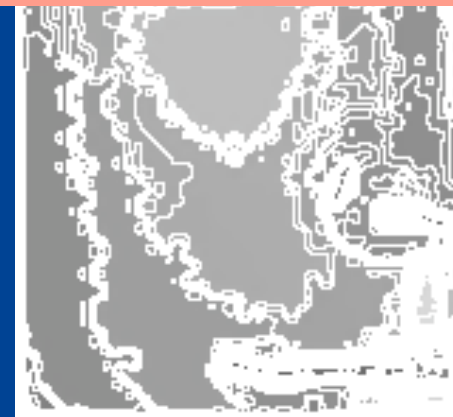# Examples

Soft texture is removed

Input

Bilateral filter

Examples

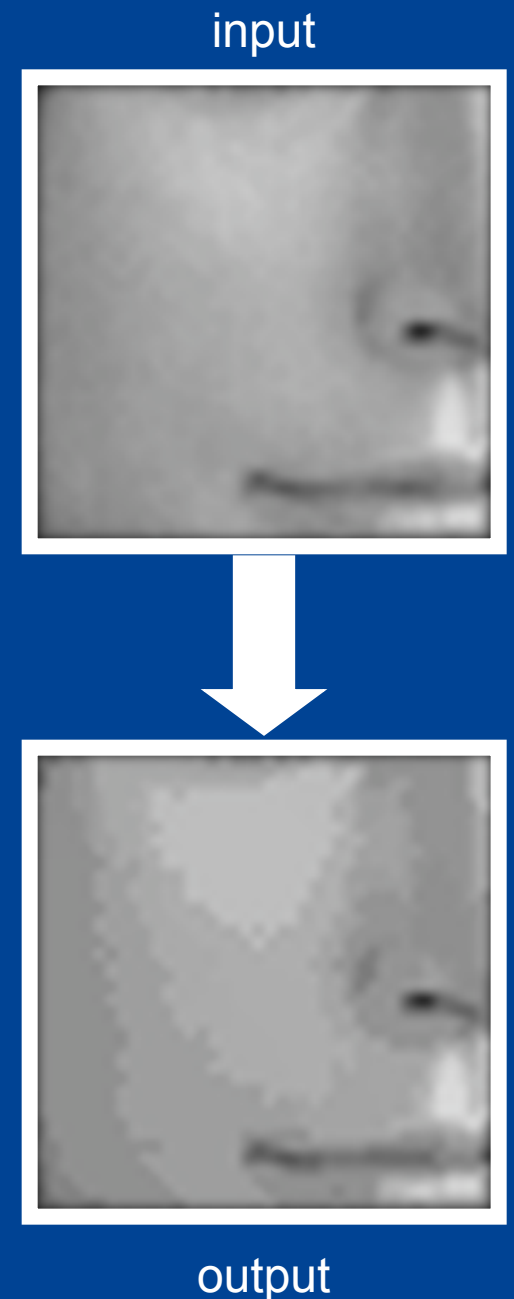Constant regions appear

Input

Bilateral filter
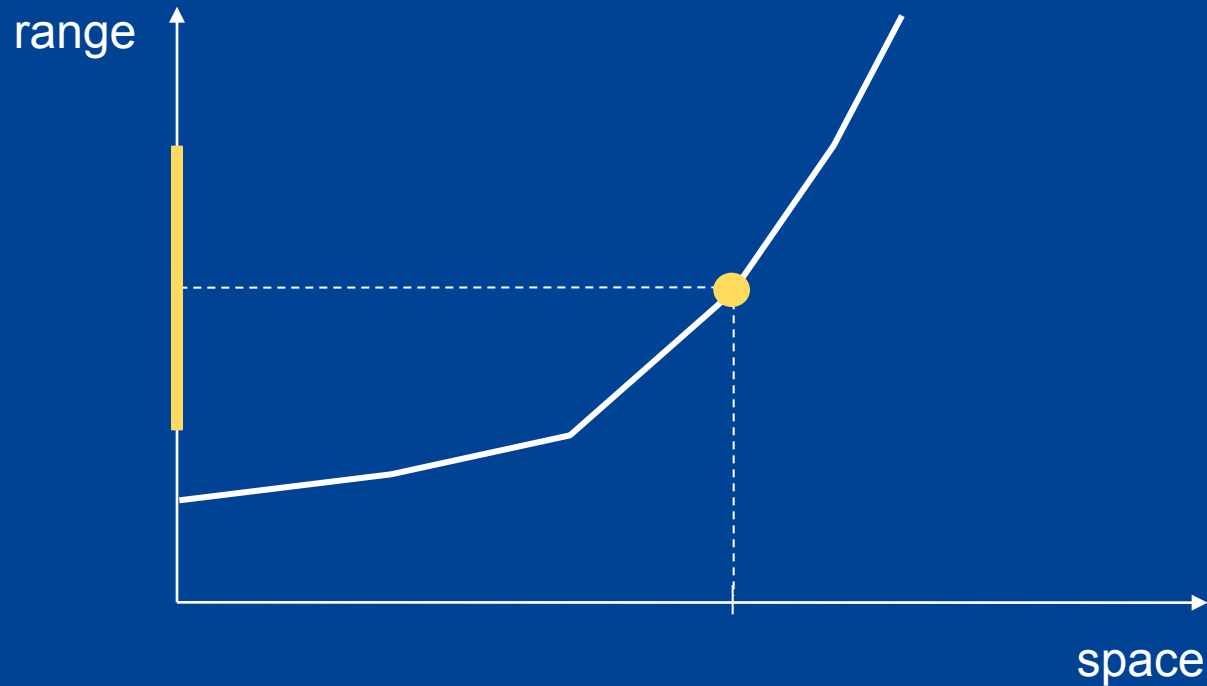
[Buades, Coll, Morel, 2005]

Staircase effect

- Bilateral filter tends to remove texture, create flat intensity regions and new contours

- Questions
  - Why does it occur?
  - Can this be an advantage?
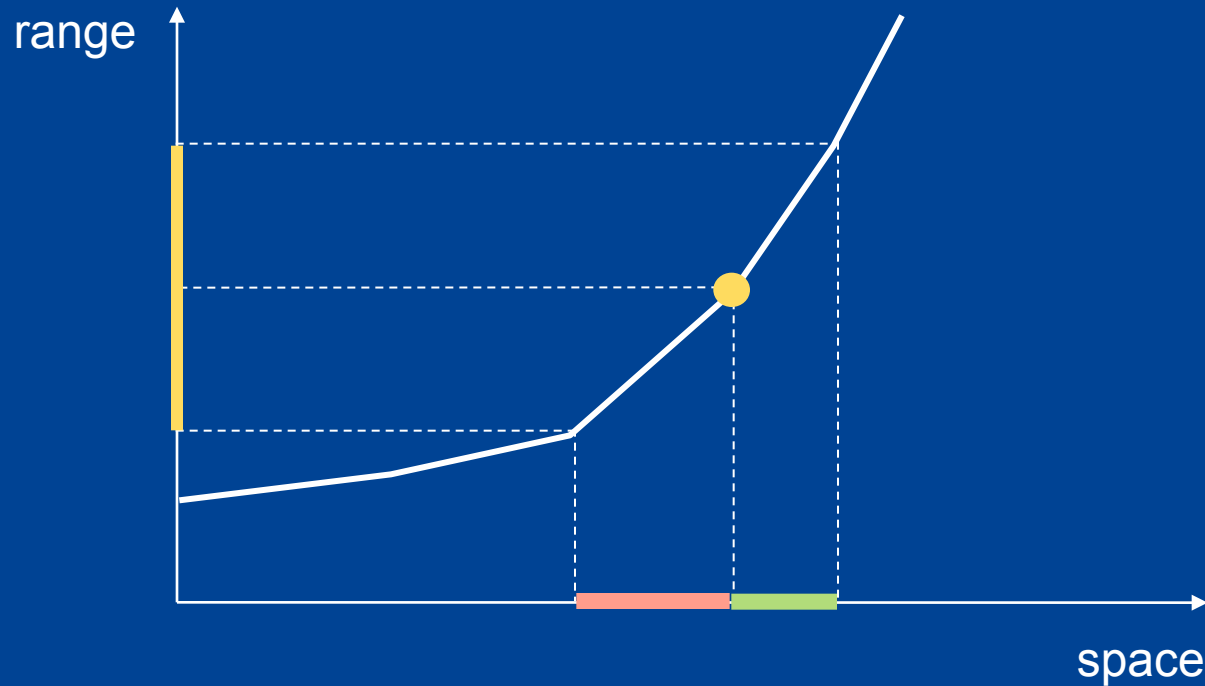 - Otherwise, can we solve this problem?

input

output

Why?

$$G_{\sigma_r}(I_p - I_q)$$

- Bilateral filter is a weighted average of intensities and…

Why?

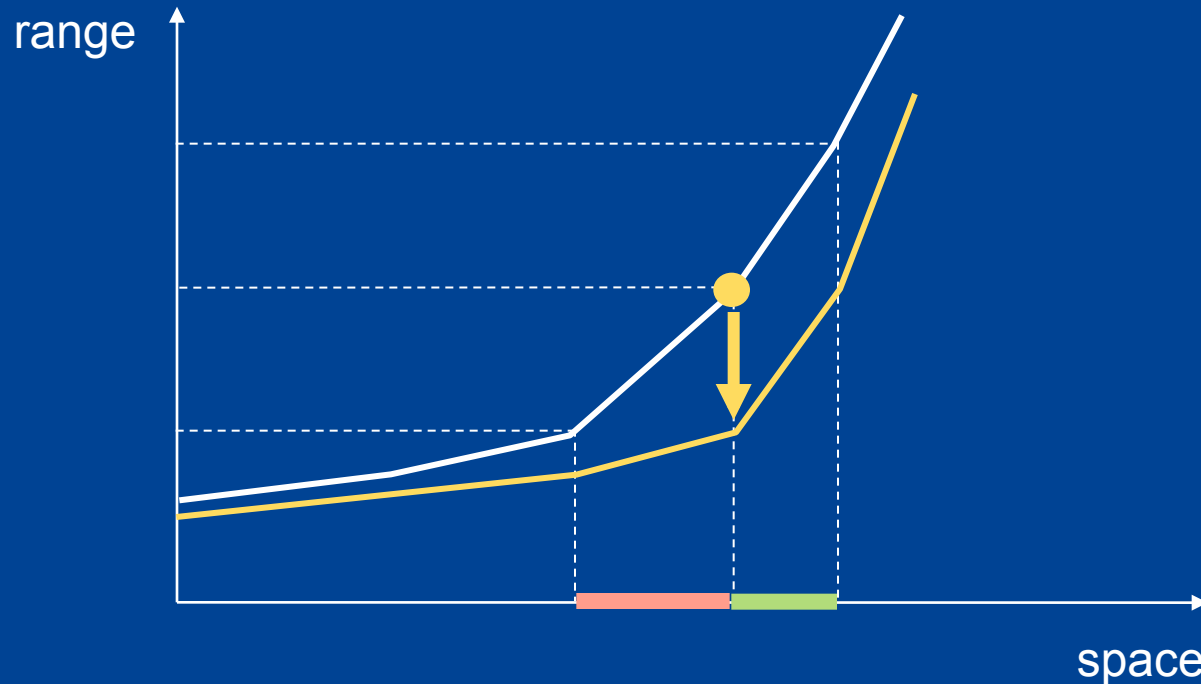$$G_{\sigma_r}(I_p - I_q)$$

- The number of points q satisfying $I_p - h < I_q < I_p$ is larger than the number satisfying $I_p < I_q < I_p + h$.
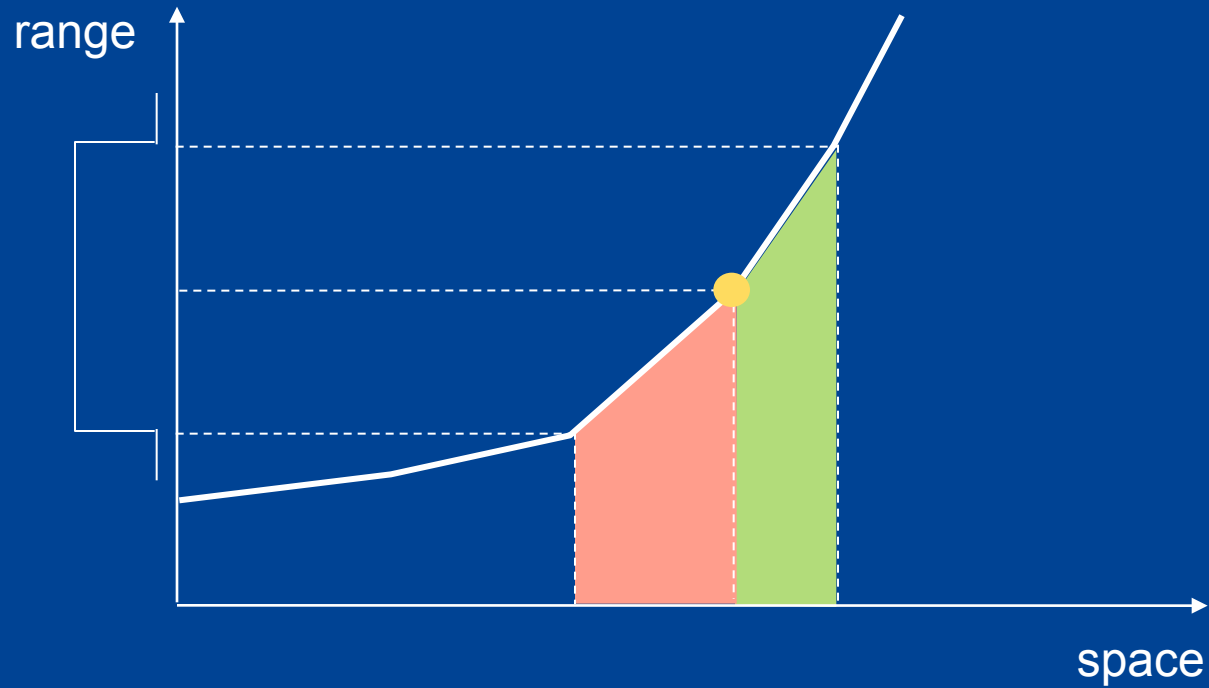
Why?

$$G_{\sigma_r}(I_p - I_q)$$

- Thus the average value is smaller than I_p, enhancing that part of the signal.

Note: Of course, opposite reasoning the the concave case

And Gaussians don't change anything

range
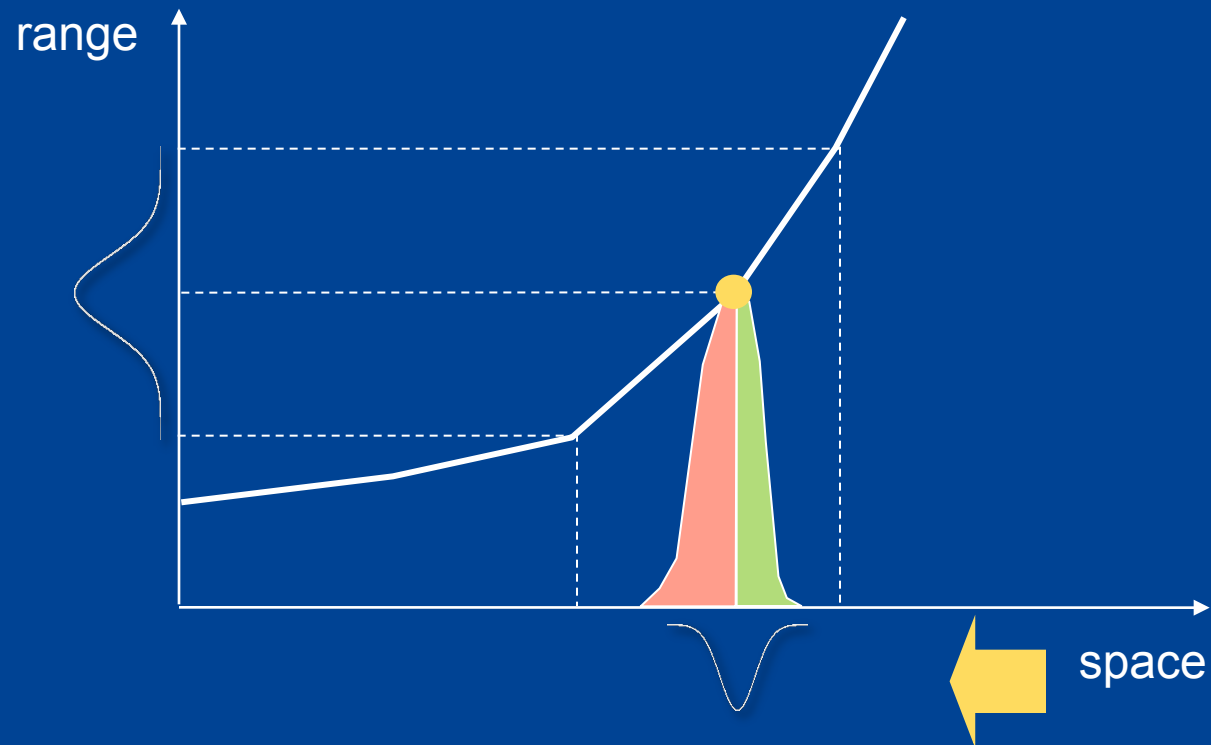
space

$$(I_p - I_q)$$

And Gaussians don't change anything

$$G_{\sigma_r}(I_p - I_q)$$

And Gaussians don't change anything

$$G_{\sigma_s}(p - q)$$

So… Can this be an advantage?

- Yes! Since we obtain cartoon-like pictures, let us do cartoons!...

Input

Output

I said cartoons?

Few words about the approach

[Winnemoller, Olsen, Gooch, 2006]

[Winnemöller, Olsen, Gooch, 2006]

And you can do more!

- Real-time video abstraction

- To know more

  http://www.cs.northwestern.edu/~holger/Research/VideoAbstraction/

You want to see some example?

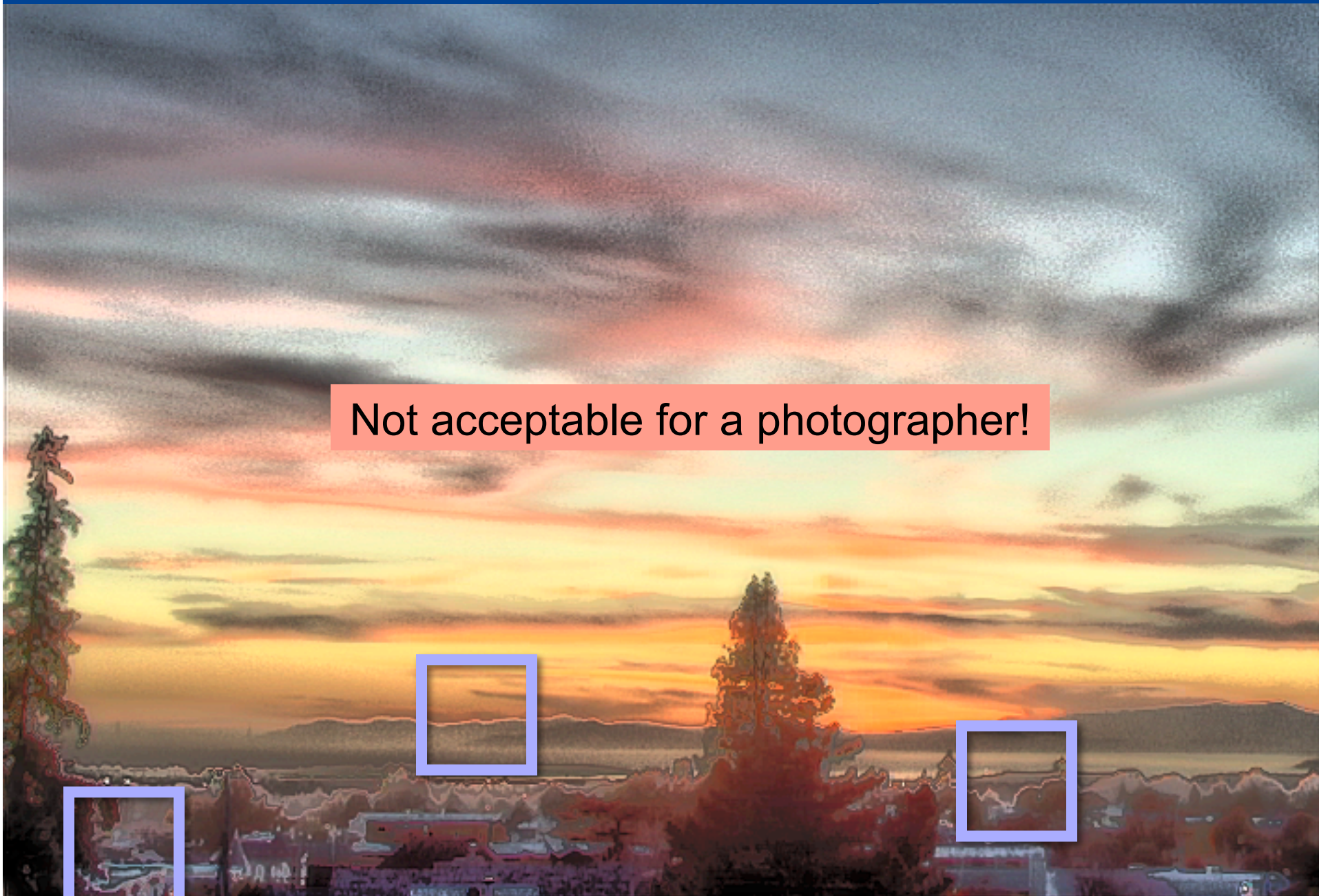# But…

- We don't always want to have this kind of rendering

- When bilateral filter is used some side effects car appear

HDR input

Tone mapping with look transfer [Bae, Paris and Durand, 2006]

Not acceptable for a photographer!

Result **without** correcting the BF output

Can we avoid this defect?

Yes!

"Gradient manipulation"

Solution 1

[Bae, Paris and Durand, 2006]   *Goal of the paper was to control photographic look and transfer a "look" from a model photo*
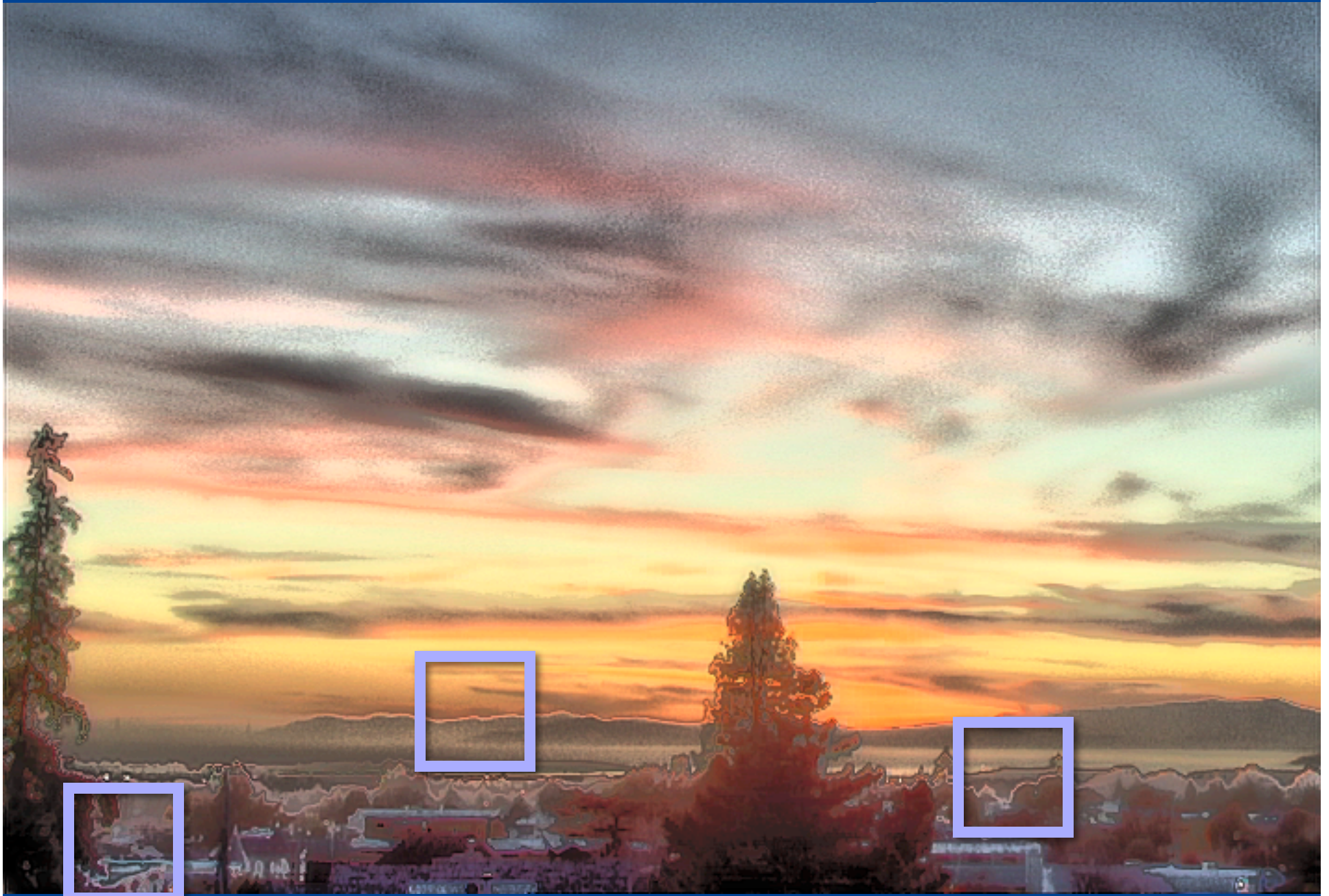
1. In the **gradient domain**:

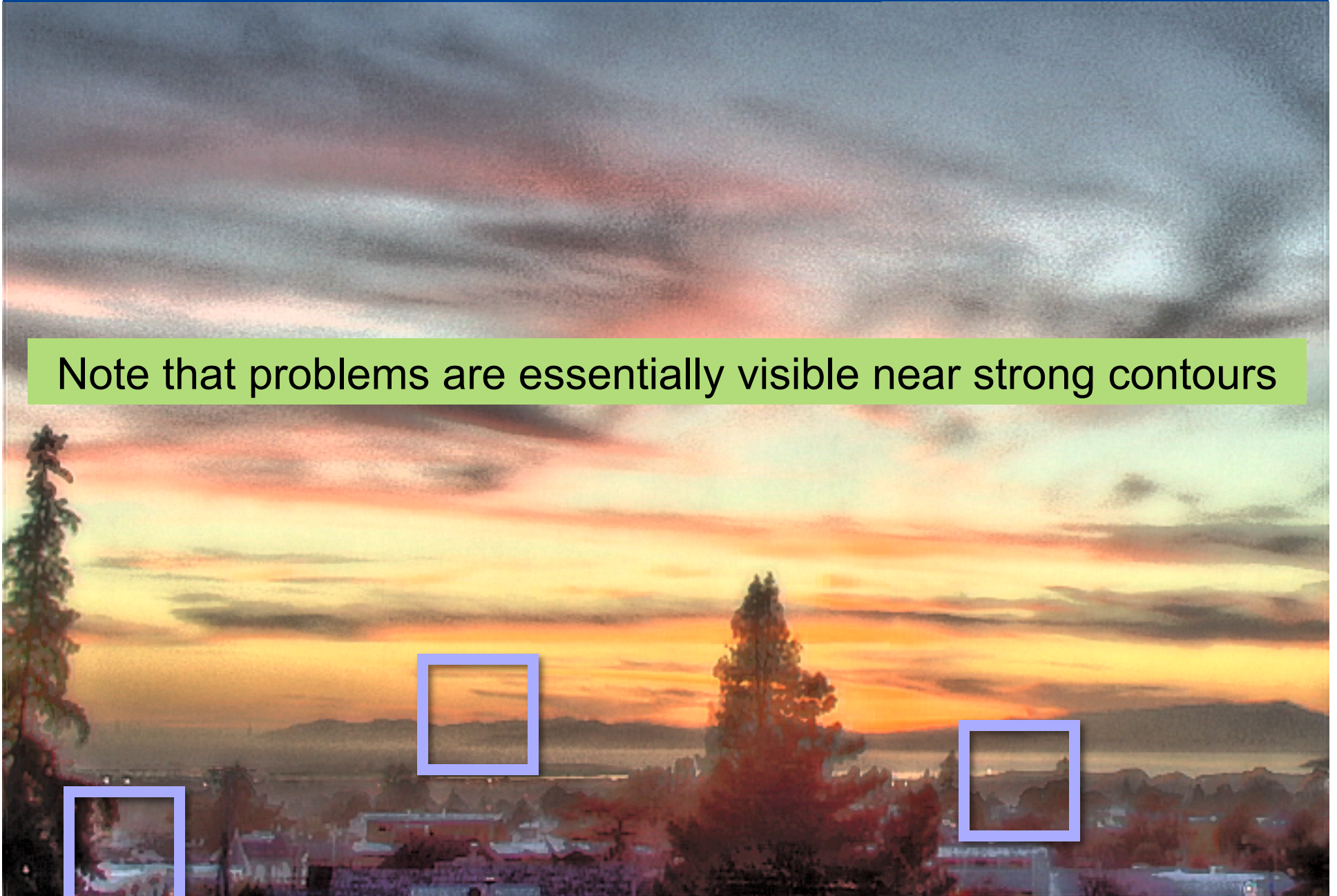   – Compare gradient amplitudes of input and current

   – Prevent increase

3. Solve the **Poisson equation**

   See [Perez etal, 2003] on Poisson image editing
   See [Agarwala, 2007] on solving Poisson equation for large images

Tone mapping with look transfer [Bae, Paris and Durand, 2006]

Result **without** correcting the BF output

Tone mapping with look transfer [Bae, Paris and Durand, 2006]

Note that problems are essentially visible near strong contours

Result **with** corrected BF output

Edge Blending

[Durand and Dorsey, 2002]   *Goal of the paper was the display of high-dynamic-range images*

- With a single iteration, staircase effects is visible only at edges.

- Edges detected with normalization factor (see also [Smith and Brady, 1997])

- Blend edges with smoothed version of input to counteract staircase effect

  (Combination between BF and Gaussian results at strong contours locations)
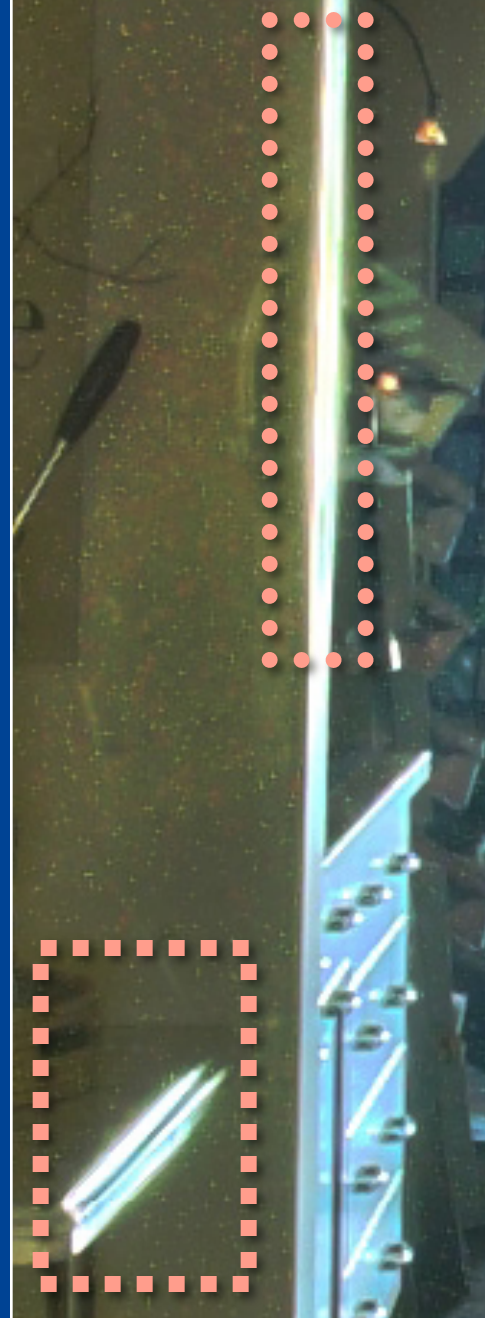
Tone Mapping
[Durand 02]

Result without correction

Result with correction

"Linear interpolation"

Solution 3

[Buades, Coll, Morel, 2005]

Goal of the paper was to establish the link between integral formulations and differential operators

- We saw that bilateral filter behaves like Perona-Malik and thus creates flat zones

- They proposed to replace the simple average by a linear regression

- How?

"Linear interpolation"

- Bilateral filter can be expressed by

$$\sum_i \qquad \qquad \qquad \frac{-i}{}$$

- If you derive, you obtain

$$\sum_i$$

"Linear interpolation"

- Bilateral filter can be expressed by

$$i \qquad\qquad \underline{-i}$$

- [Buades, Coll, Morel, 2005] changed the constant model by an affine model
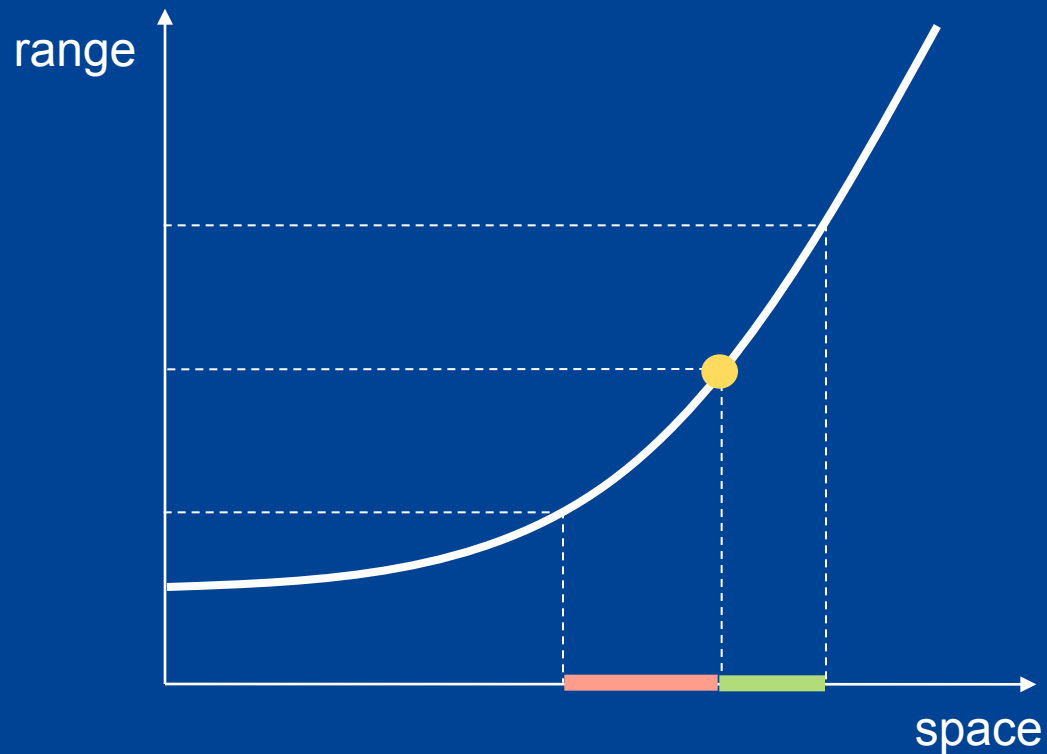
$$a, b, c \qquad\qquad \underline{-aq_1 - bq_2 - c}$$
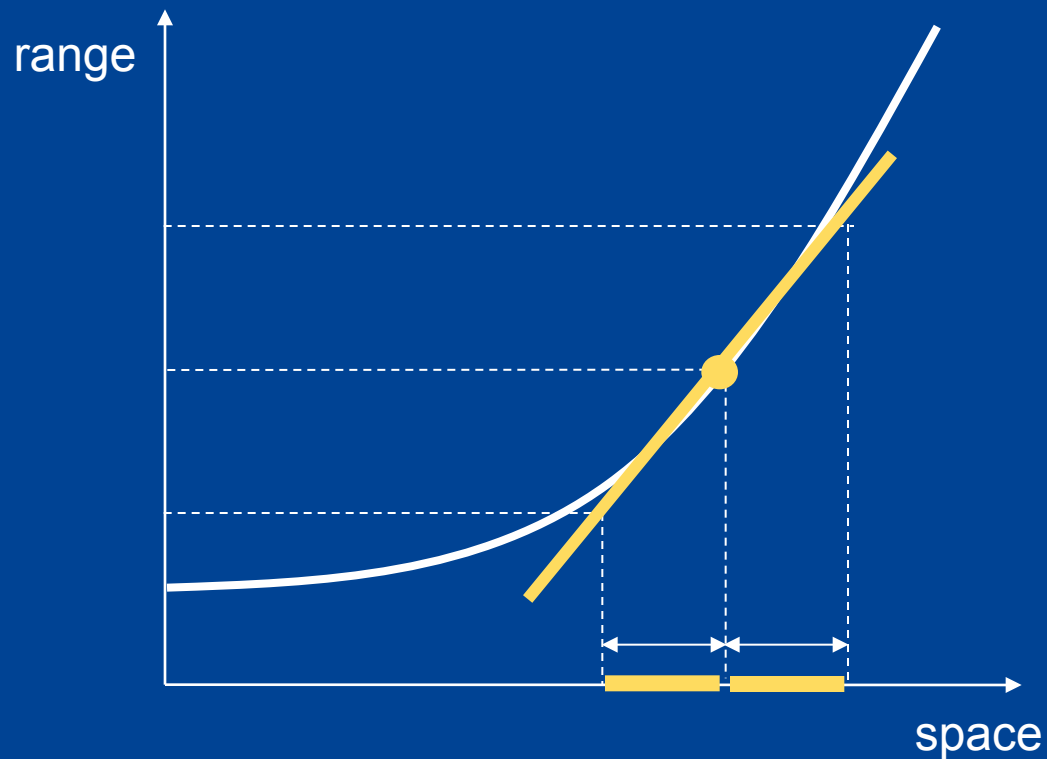
- New value at p will be

"Linear interpolation"

Geometrical interpretation

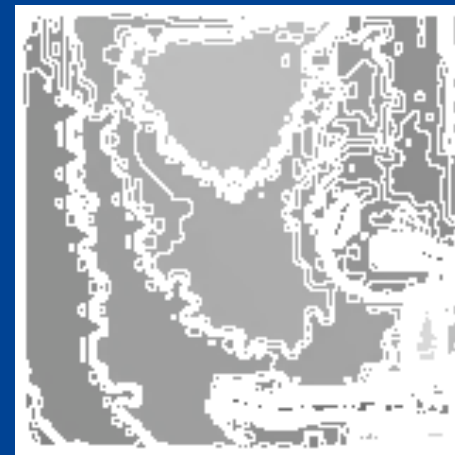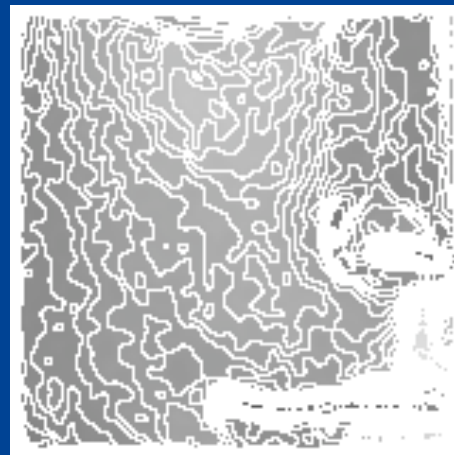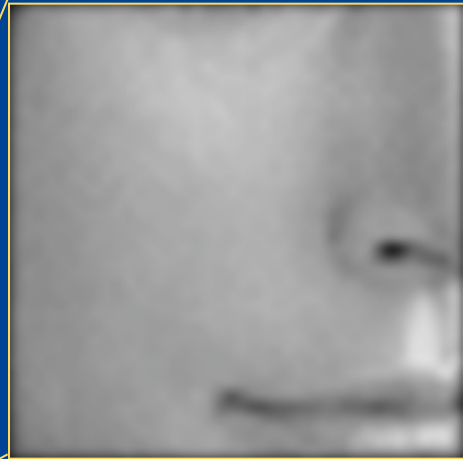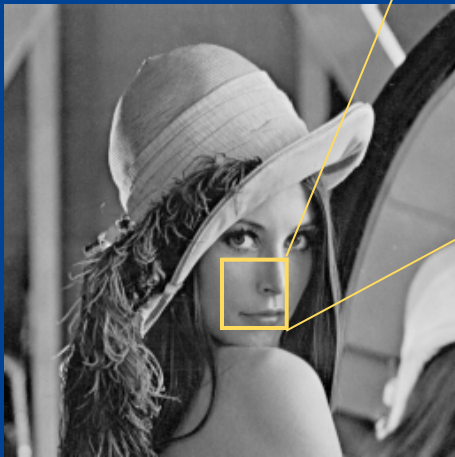- Remember, the problem was that lower values were more taken into consideration

"Linear interpolation"

Geometrical interpretation

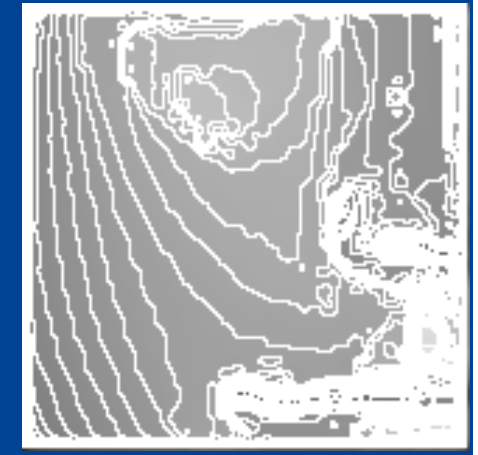- Now, left and right-hand side parts have the same influence
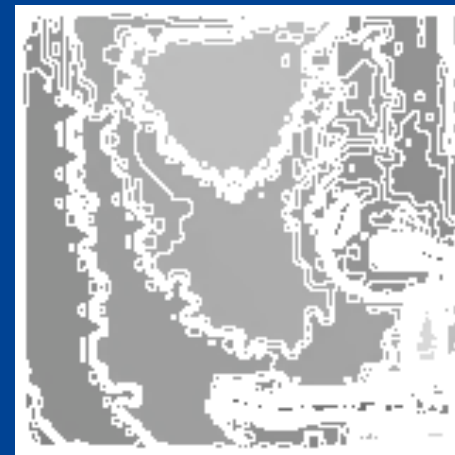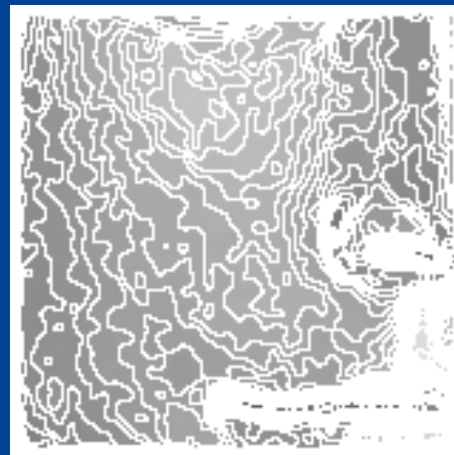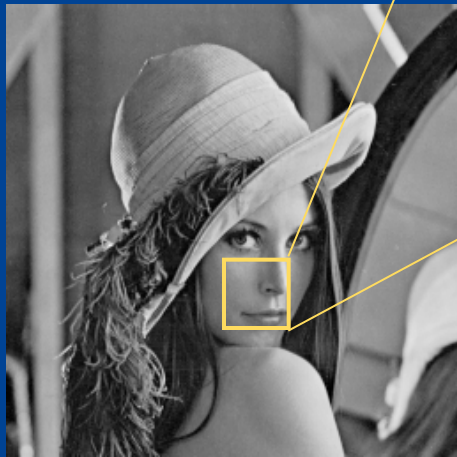
Staircase effect

Input

Bilateral filter

With linear interpolation…

Input   Bilateral filter   modified

[Buades, Coll, Morel, 2005]

Also…

- This new operator is also related to differential operators, i.e., PDEs!

- In this paper, you will also find extensions of bilateral filter, called non local filter.

→

Average when
similar intensities

Average when
similar patch around
(correlation of neighborhood)

[Buades, Coll, Morel, 2005]

How to choose?

- Two methods which correct afterward defects of bilateral filter, mainly visible on boundaries.

  Efficient

  Correction of an existing problem

- One method which solves the problem by adapting the bilateral filter.

  Directly address the problem

  Computationally expensive

Summary

- Bilateral filter produces staircase effect

- It has been used as a tool for many applications such as texture extraction

- By itself, it has some interest too!

- Staircase effect can be controlled

- The link with PDEs is again appearing

Questions?

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