Edge Preserving Image smoothing algorithms

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Our project aims to study 3 different Edge-preserving Smoothing algorithms.

For all these 3 methods, we have implemented the code and have done extensive analysis on its performance in presence of noise, time complexity and the effect of parameters.

The first method is the classic, bilateral filtering. Bilateral filtering has been an important contribution in this topic and several variants have been proposed so far to overcome its limitations in different fields.

The second method is based on gradient analysis(paper assigned). This is a local method, which boils down to a kernel that is convoluted with the image.

The third method is called Fast global smoothing based on weighted Least squares. This is a global optimisation method which constraints the distance between the original image and the smoothed image.

BILATERAL FILTERING

A bilateral filter is a non-linear, edge preserving and noise-reducing smoothing filter for images.

In this method we replace each pixel's intensity with a weighted average of intensity pixels from nearby pixels.

The weights depend on both Euclidian distance and on radiometric differences which results in preservation of sharp edges.

Bilateral filter is defined as:

$$I^{filtered}(x) = \frac{1}{W_p}\Sigma_{x_i \epsilon \Omega} I(x_i) f_r(||I(x_i - I(x)||) g_s(||x_i - x||)$$

Where W_p

$$W_p = \Sigma_{x_i \epsilon \Omega} f_r(||I(x_i) - I(x)||) g_s(||x_i - x||)$$

GRADIENT ANALYSIS

Gradient Minimization is an edge preserving and image smoothing technique which enhances fundamental image constituents like edges while diminishing insignificant details.

The main aim of this technique is to globally maintain and possibly enhance the most prominent set of edges by increasing steepness of transition while not affecting the overall image.

The method can be formulated as:

Where weight functi

$$S(p) = \frac{1}{\sum_{q \in N(p)} w(p,q)} \cdot \sum_{q \in N(p)} w(p,q) I(q)$$

$$w(p, q) = [(\cos(\beta)+1)/\alpha] \cdot q.$$

FAST GLOBAL SMOOTHING USING WEIGHTED LEAST SQUARE METHOD

This global optimization method aims to minimise the following weighted least square energy expression:

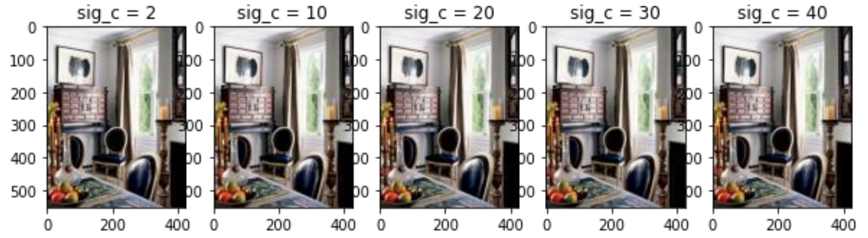
$$J(u) = \sum_{p} \left((u_p - f_p)^2 + \lambda \sum_{q \in \mathcal{N}(p)} w_{p,q}(g)(u_p - u_q)^2 \right)$$

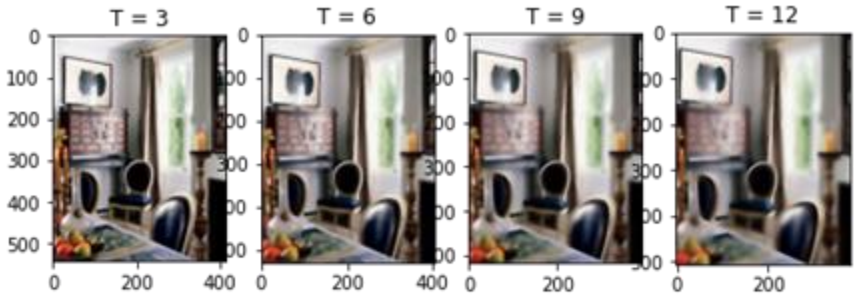
Here u represents the output image, f represents input image, lambda is a parameter that controls the balance between the two terms and w is given by:

$$w_{p,q}(g) = \exp(- \parallel g_p - g_q \parallel / \sigma_c),$$

This optimization problem is solved … tems, specifically over rows and columns on the image. This is done over multiple iterations.

RESULTS AND ANALYSIS





EFFECT OF PARAMETERS: Bilateral

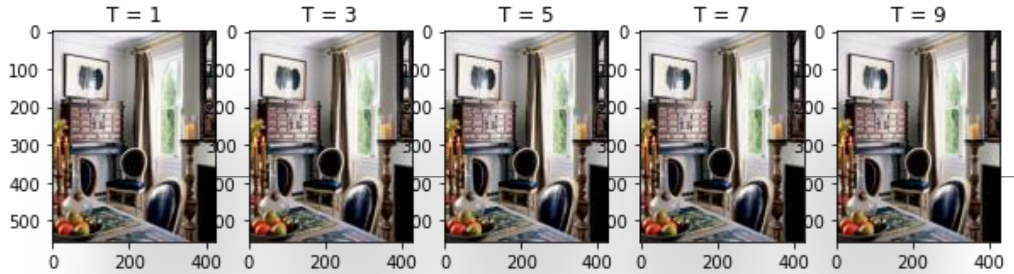
Kernel Size
Increasing the kernel size increases the blurring of the image.

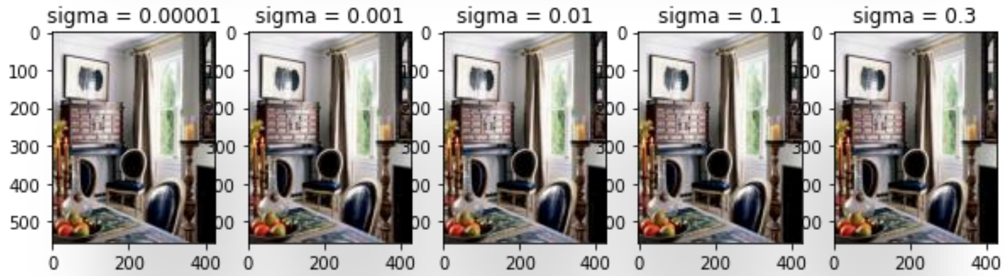
σr
It tries to preserve the edges in the image. Lower the value of σr, sharper the edges will be. For σr -> ∞, bilateral filtering gives similar results as Gaussian blur.

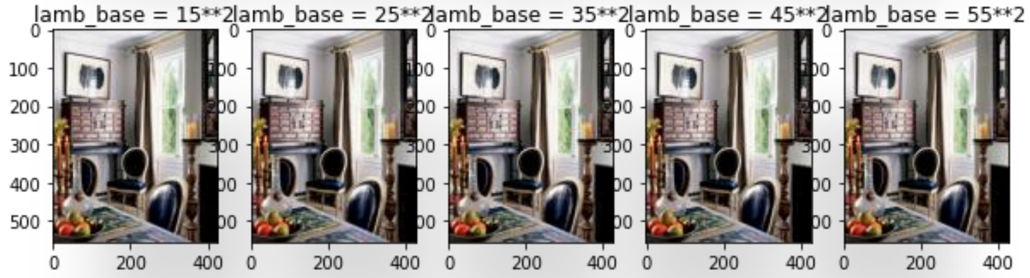
σs
It is responsible for smoothing the image. Increasing σs increases the blurring of the image.

Number of iterations
Repetitively running the algorithm increases the blurring.

EFFECT OF PARAMETERS: FGS







Kernel Size

Increasing the kernel size increases the blurring of the image.

σ

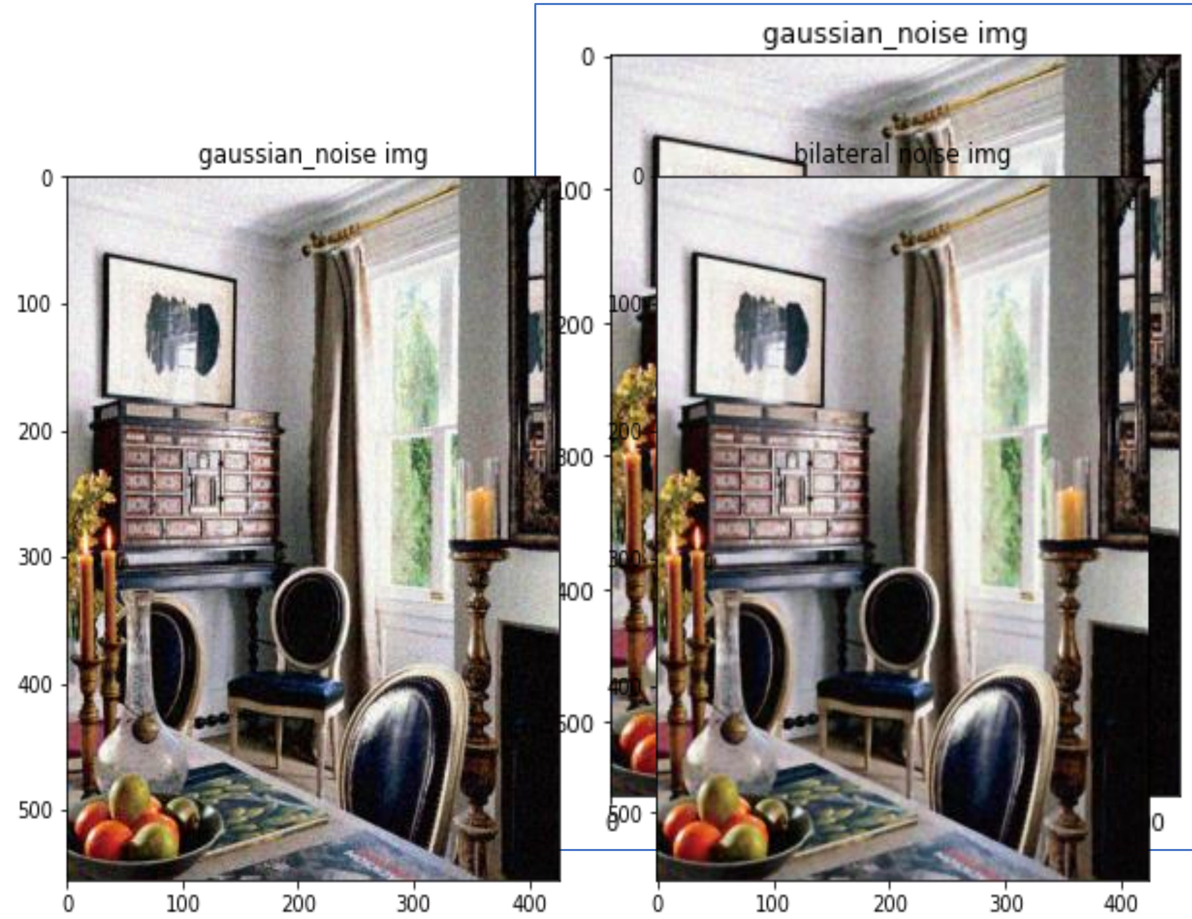
It is responsible for smoothing the image. Increasing σ increases the smoothing of the image.

λ

It is the weightage given to the Gaussian term in the equation. It increases the blurring of the image.

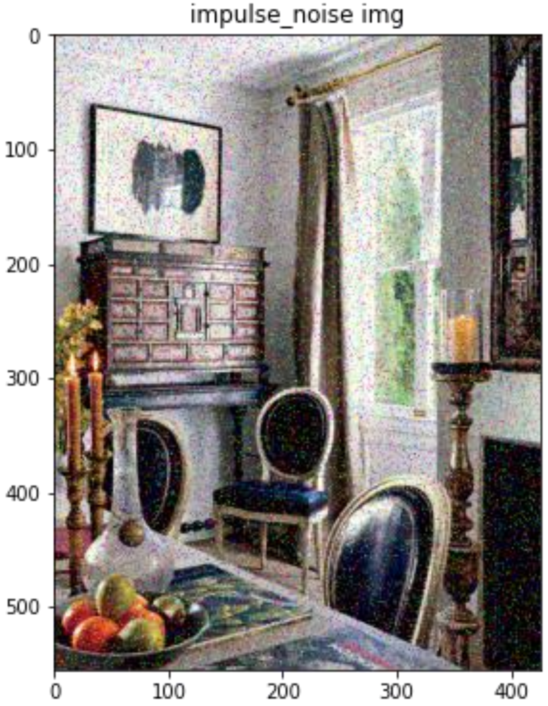
EFFECT OF NOISE

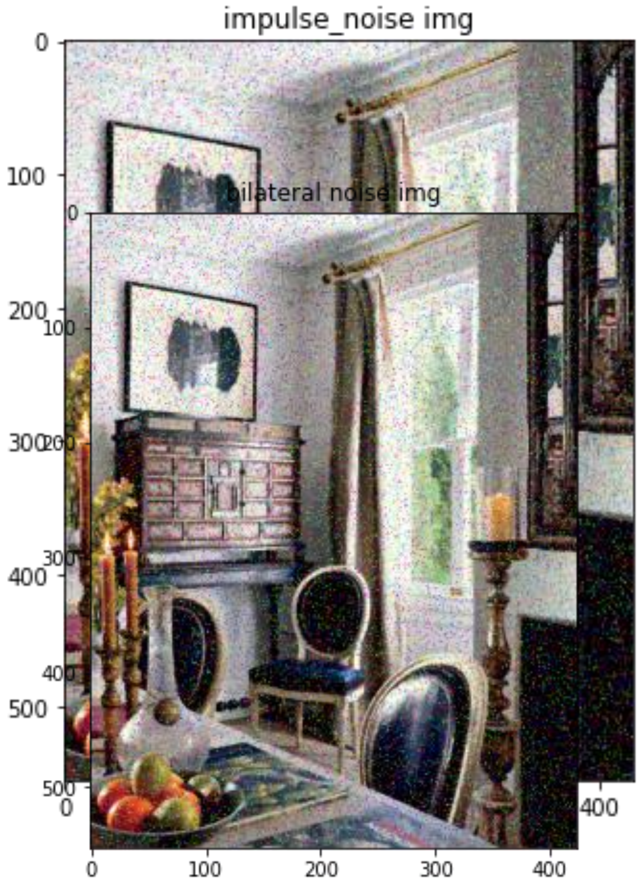
- Gaussian Noise
- Laplacian Noise
- Impulse Noise
- Poisson Noise
- Uniform Noise



Gradient Analysis

Gradient Analysis





Gradient Analysis


poisson_noise img
0 100 200 300 400 500
0 100 200 300 400


bilateral noise img
0 100 200 300 400 500
0 100 200 300 400

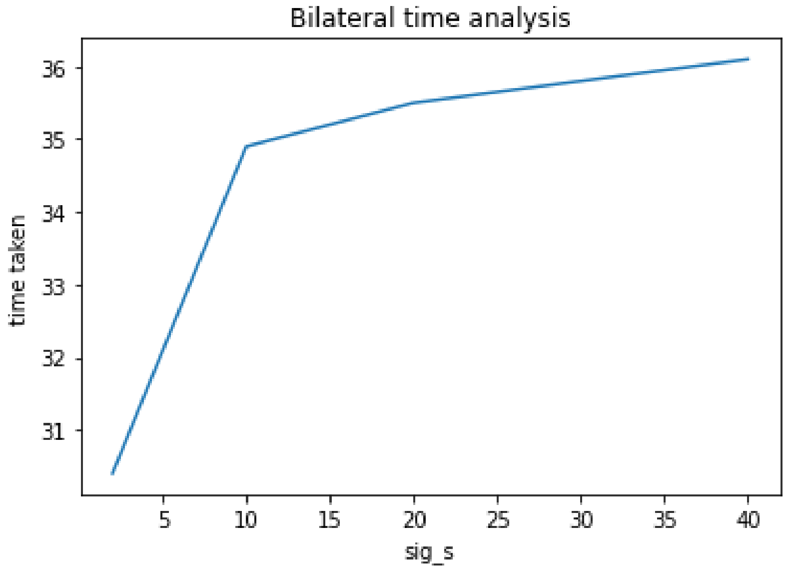

FGS noise img
0 100 200 300 400 500
0 100 200 300 400

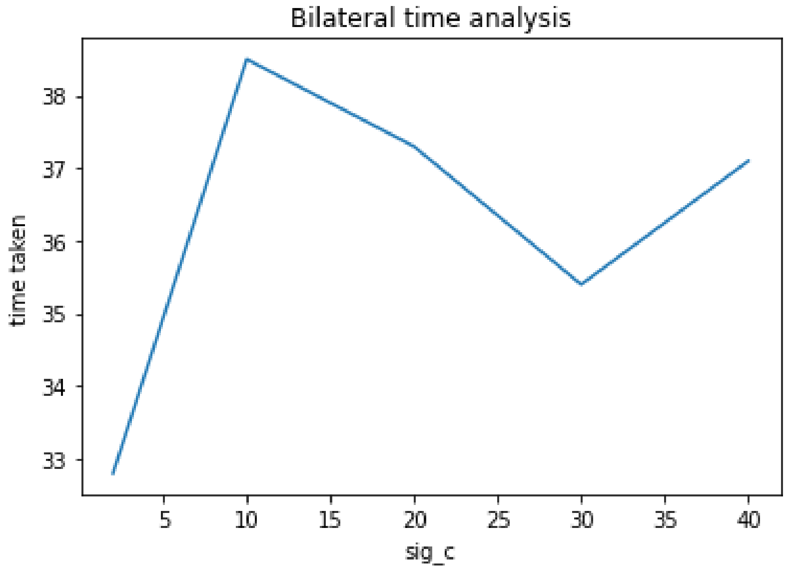

Gradient Analysis
0 100 200 300 400 500
0 100 200 300 400

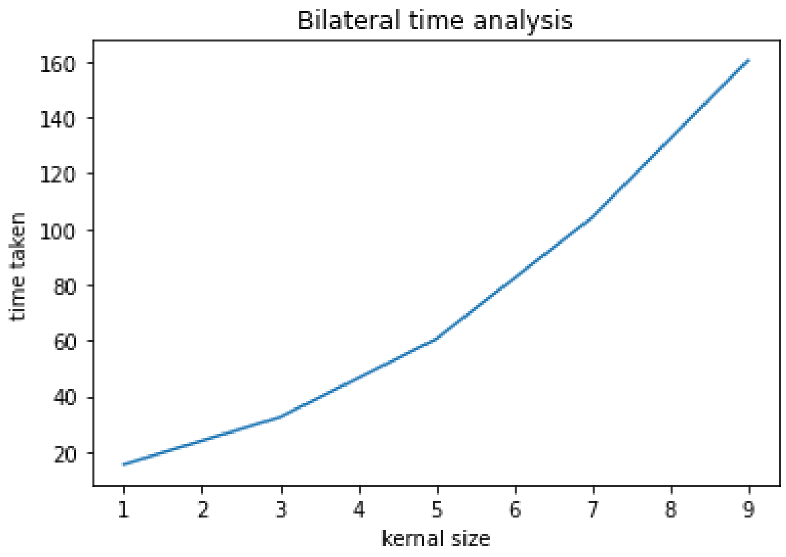

uniform_noise img
bilateral noise img
uniform_noise img
FGS noise img
Gradient Analysis

TIME ANALYSIS:BILATERAL FILTERING

Time complexity:



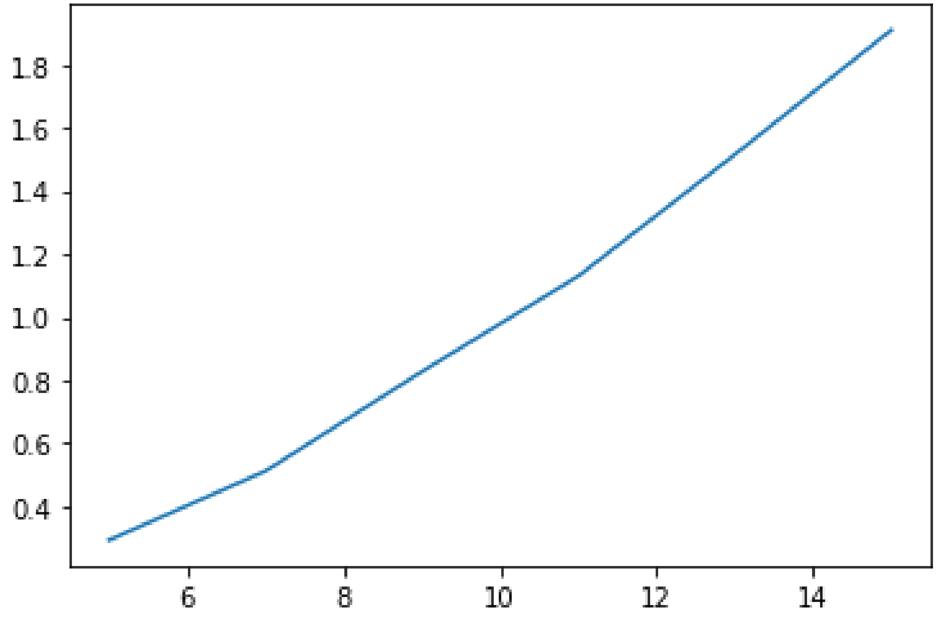




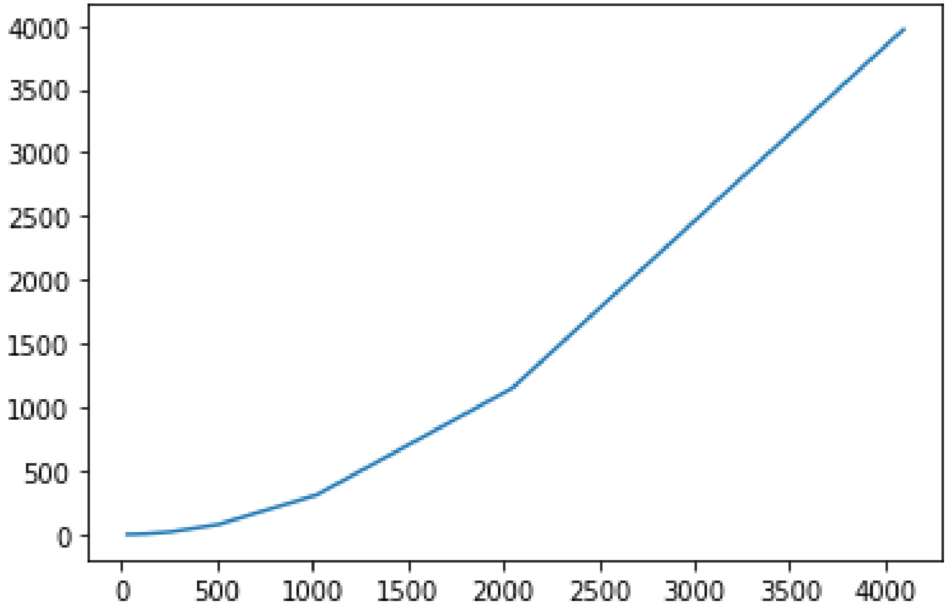
TIME ANALYSIS:GRADIENT ANALYSIS

Time Complexity:

Time vs input size

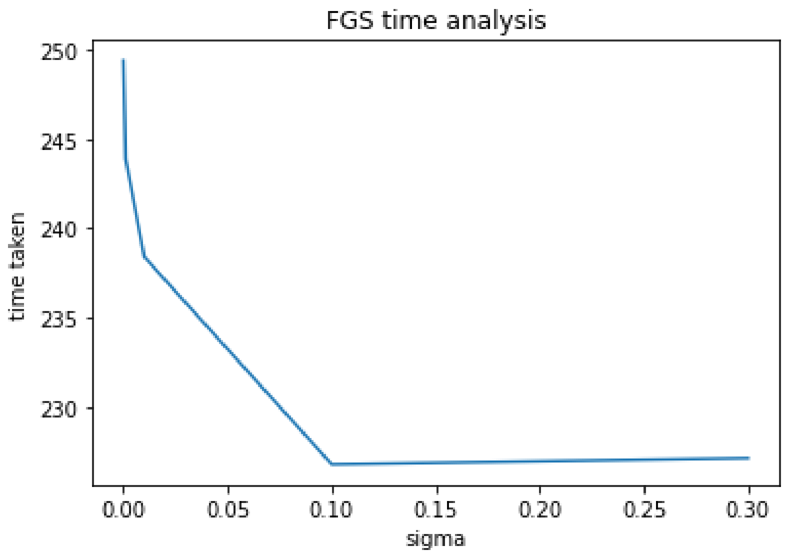


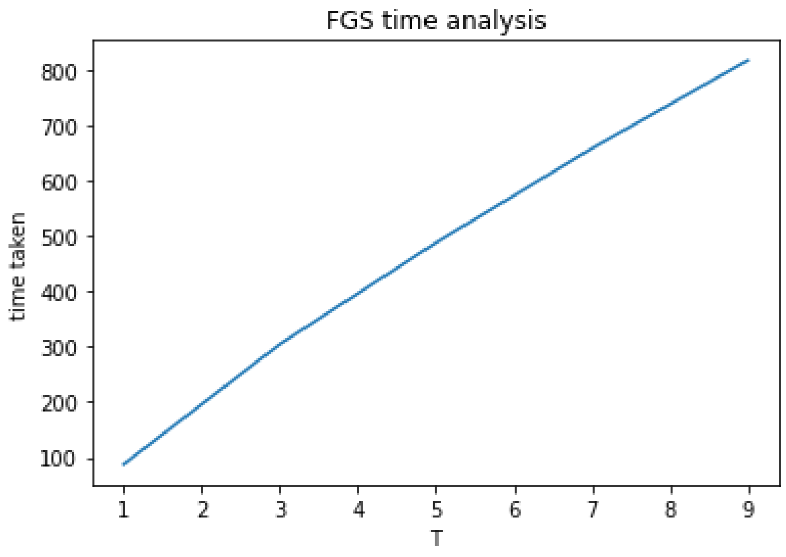
Time vs kernel size

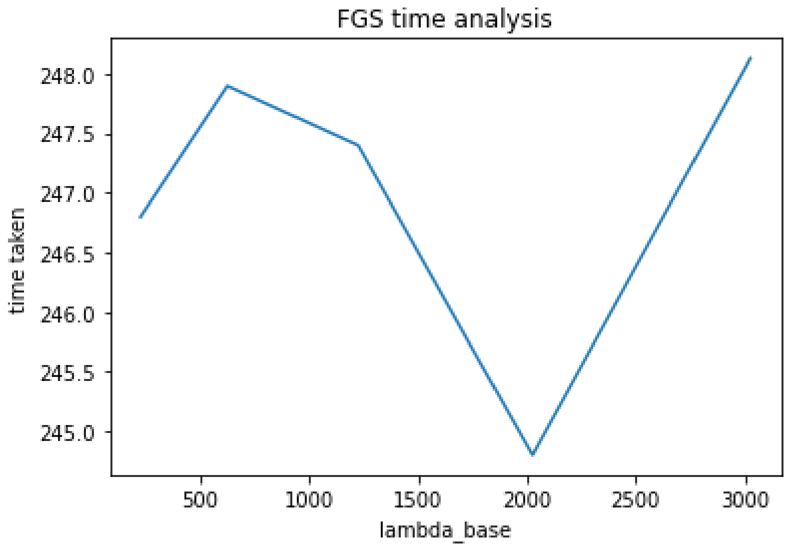


TIME ANALYSIS: FAST GLOBAL SMOOTHING

Time complexity:







GUI Demo

DATASET AND EVALUATED RESULTS

We have added all the aforementioned noise to a set of 14 images. These resulted in a total of 84 images. Each of the algorithms: bilateral filter, gradient method and fast global smoothing have been run on this dataset of 84 images.

To access results of bilateral filter : click here

To access results of gradient method : click here

REFERENCES

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C. Tomasi and R. Manduchi, “Bilateral filtering for gray and color images,” in Computer Vision, 1998. Sixth International Conference on. IEEE, 1998, pp. 839–846

D. Min, S. Choi, J. Lu, B. Ham, K. Sohn, and M. N. Do, “Fast global image smoothing based on weighted least squares,” IEEE Transactions on Image Processing, vol. 23, no. 12, pp. 5638–5653, 2014

A Benchmark for Edge-Preserving Image Smoothing Feida Zhu, Student Member, IEEE, Zhetong Liang, Student Member, IEEE, Xixi Jia, Student Member, IEEE,Lei Zhang, Fellow, IEEE, and Yizhou Yu, Fellow, IEEE