Team reVision

Image Denoising Using Non-Linear Aggregation of Image Filters

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Introduction

Noise: Might be introduced due to various factors.

- Capture Conditions: poor lighting, blurring etc.
- Sensor: sensor temperature, data transmission error, approximations during digitization etc.

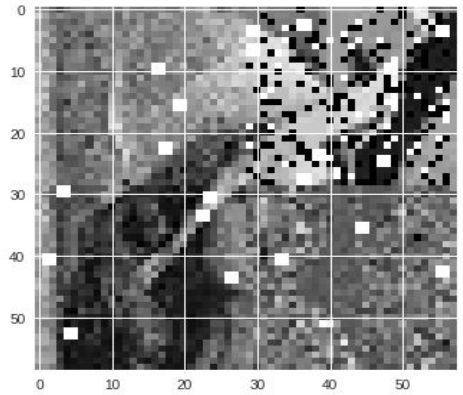
Image Denoising: Fundamental problem in image processing.

- **Aim**: Improve quality of image by removing noisy information
- **Challenge:** Removing noise while preserving existing image structure

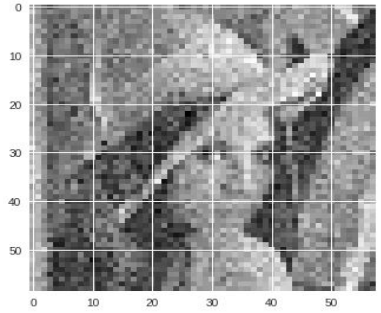
Existing Solutions: Suffer from a few limitations

- **Smoothening**: Images tend to be too smooth. Details are lost.
- **Blurring**: Edges are less sharp

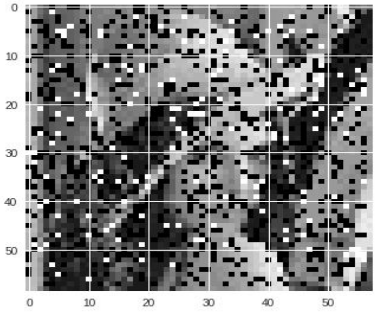
Noise Models in Digital Image Processing



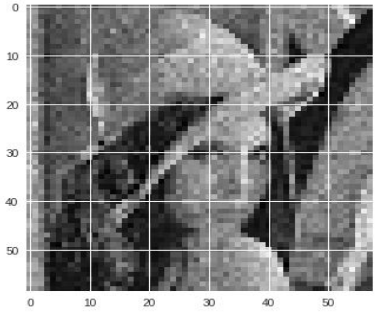
Original Image



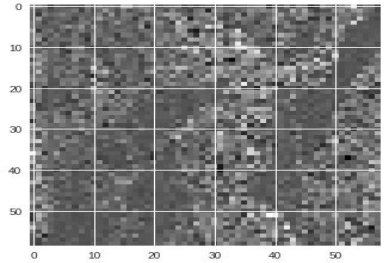
Gaussian Noise



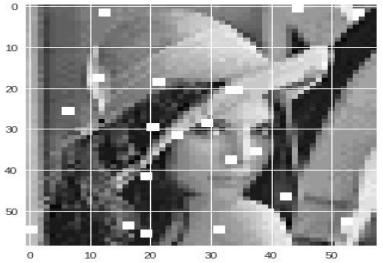
Salt and Pepper Noise



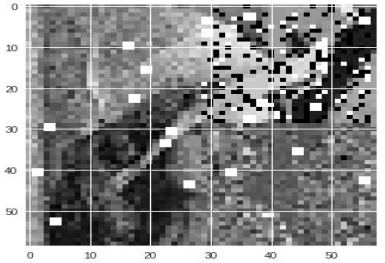
Poisson Noise



Speckle Noise



Patch Suppression



Multi Noise

Solution: (Outline)

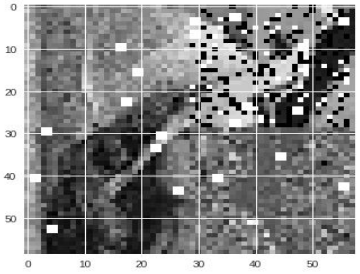
Idea: Use a combination of existing algorithms

- Each *classical* method has its pros and cons.
- Different methods work better for different kinds of noises
- For example, Salt - Min Filtering, Pepper - Max Filtering
- Make the best out of each method's strong points

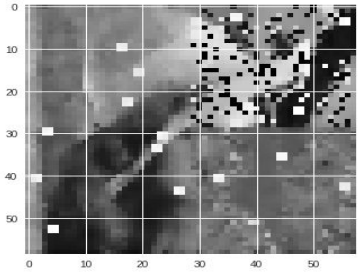
Strategy: Inspired from COBRA algorithm

- COBRA: COmBined Regression Alternative
- Uses non-linear aggregation of image filters
- Several predictions of the noisy pixel are obtained; best is chosen

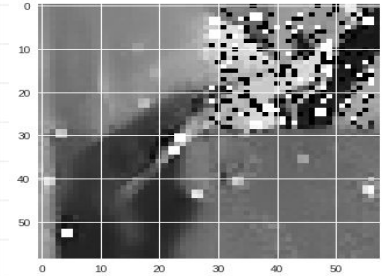
Preliminary Image Denoising Algorithms



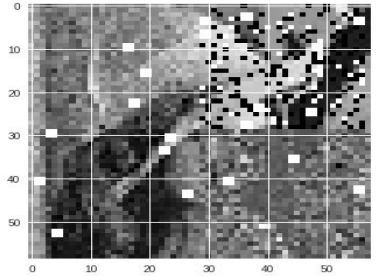
Multi Noise Image



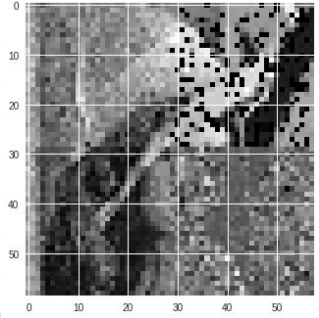
Bilateral Filtering



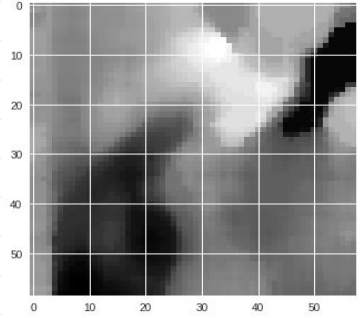
Non-local Means



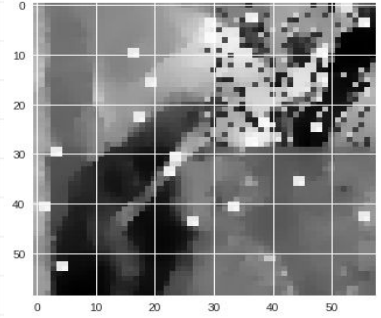
Gaussian Filtering



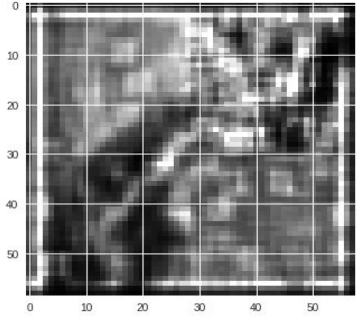
Inpainting



Median Filtering



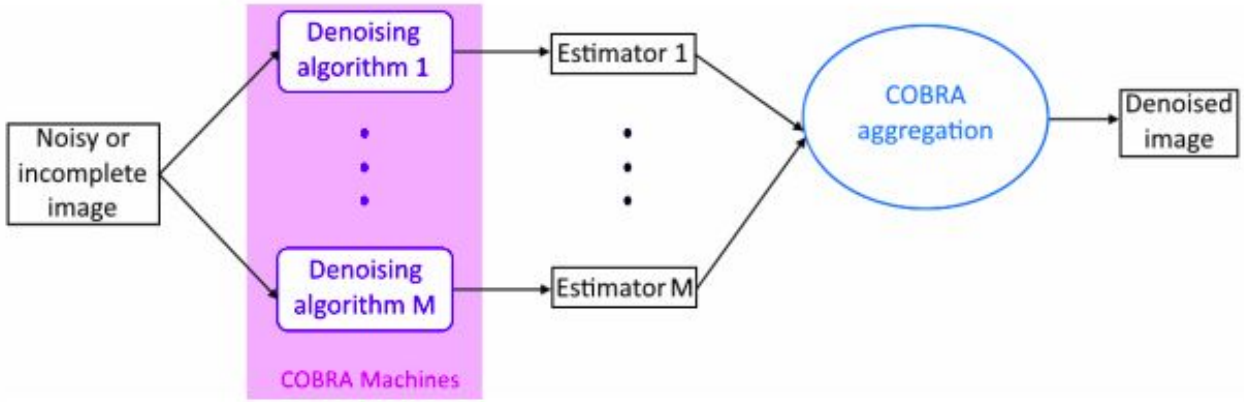
TV Chambolle



Richardson Lucy

Method: Non Linear Aggregation of filters - I

For each pixel p, call M different estimators
Aggregate these estimators by doing a weighted average



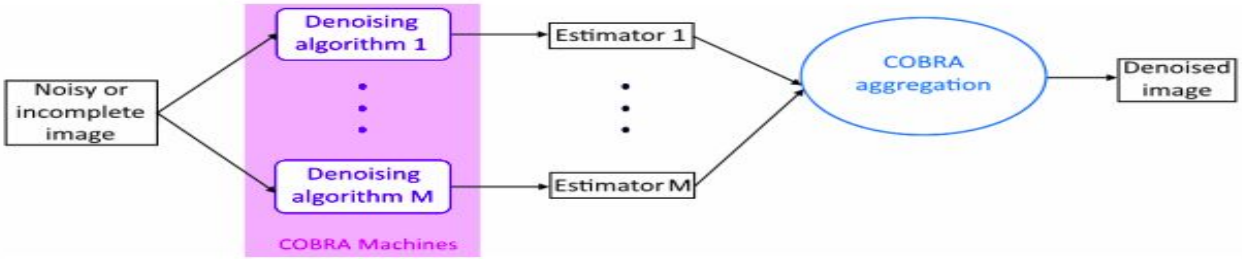
Method: Non Linear Aggregation of filters - II

Estimators

$$f(p) = \frac{\sum_{q \in x} \omega(p,q) x(q)}{\sum_{q \in x} \omega(p,q)}$$

Weights

$$\omega(p,q) = \mathbb{1}\left(\sum_{k=1}^{M} \mathbb{1}(|f_k(p) - f_k(q)| \leq \epsilon) \geq M\alpha \right)$$



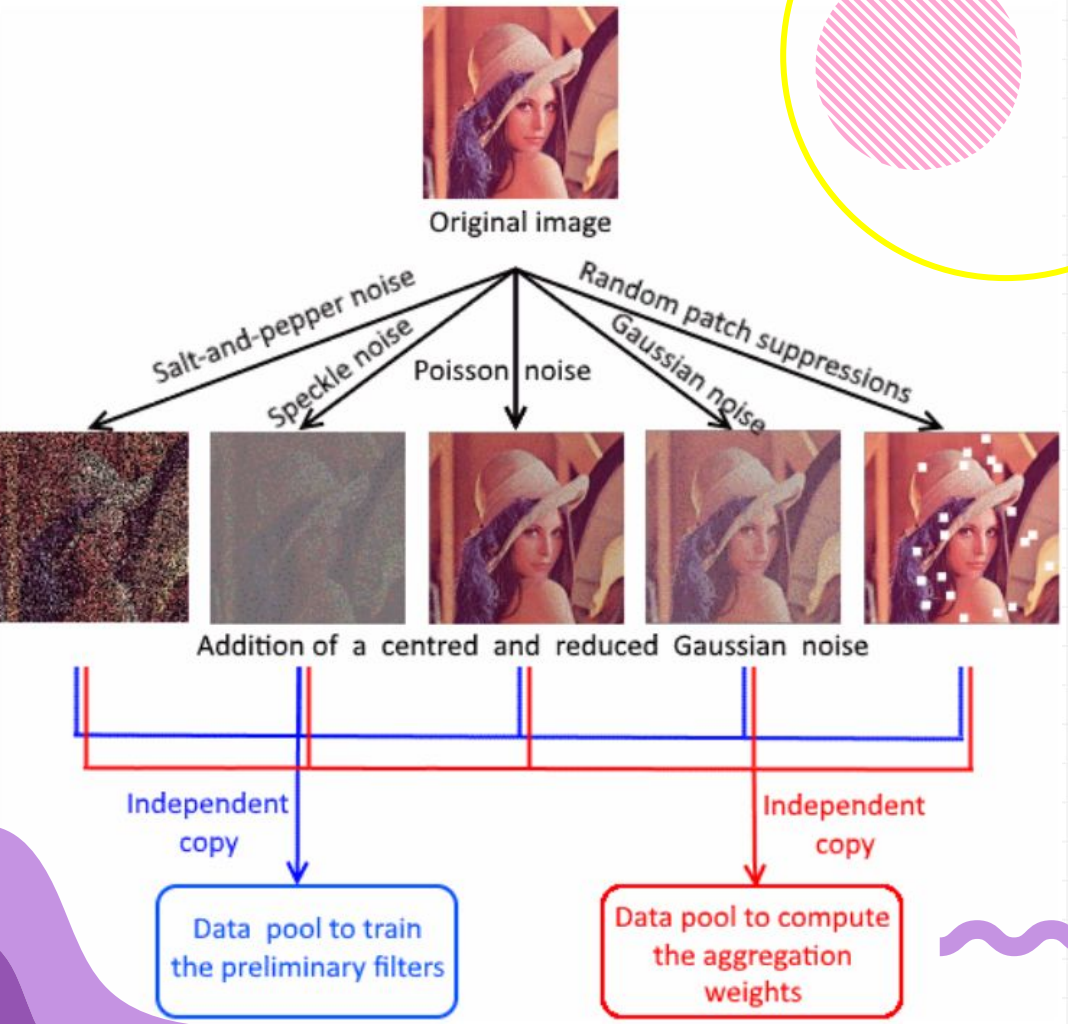
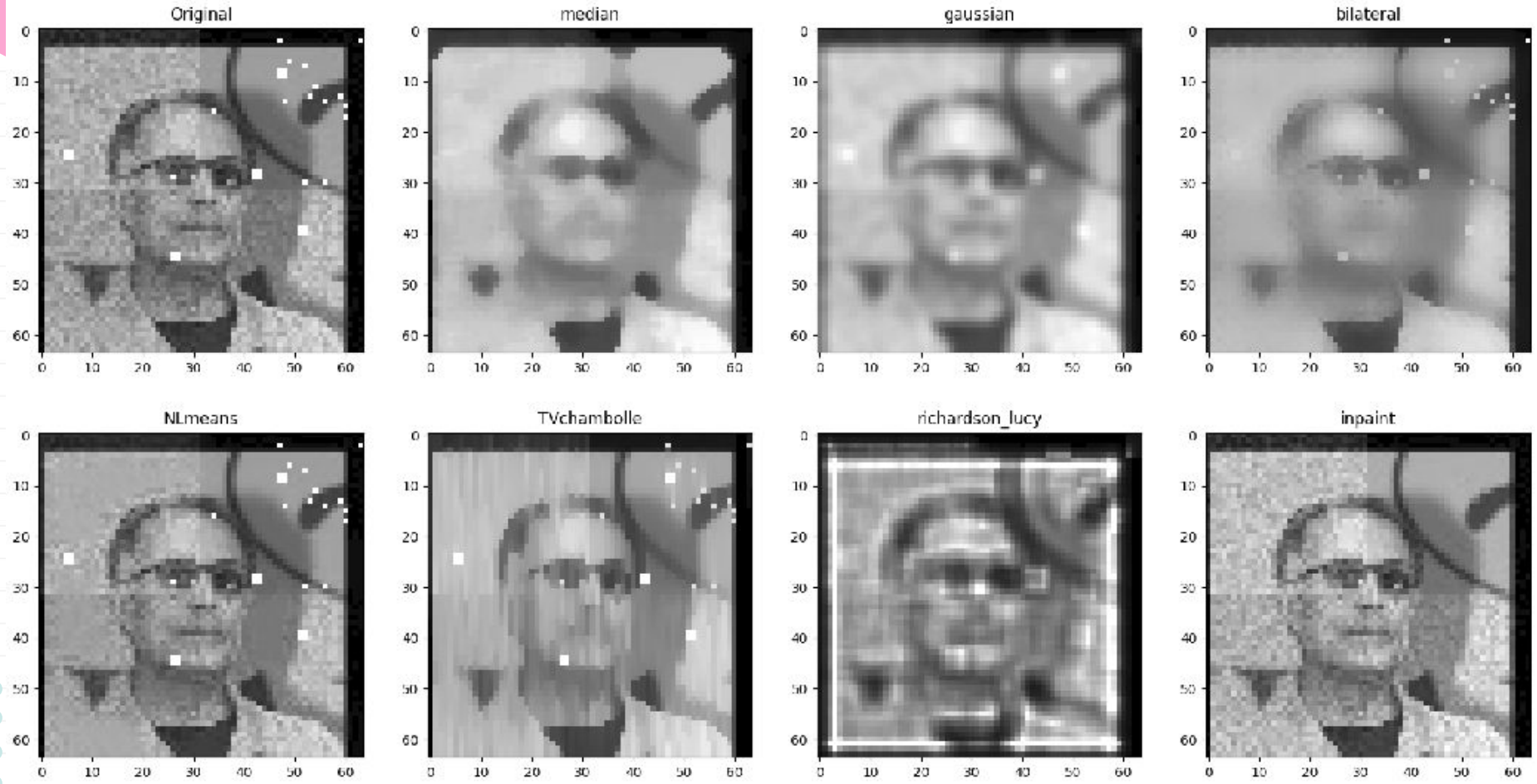


Image Dataset Creation

Add 5 noise models to 25 ground-truth images
Create copies of 125 noisy images obtained
Add normal noise to the copy set of 125 images
Desired dataset is the two pools of 125 images

Noise functions

Classical Denoising Algorithms

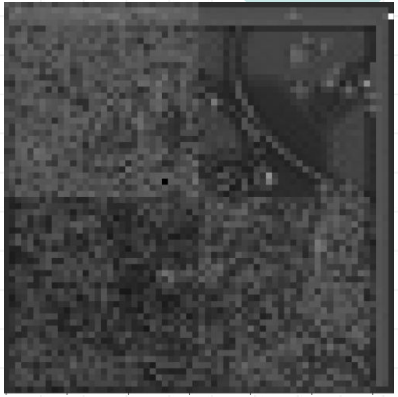


COBRA Results

Original Image

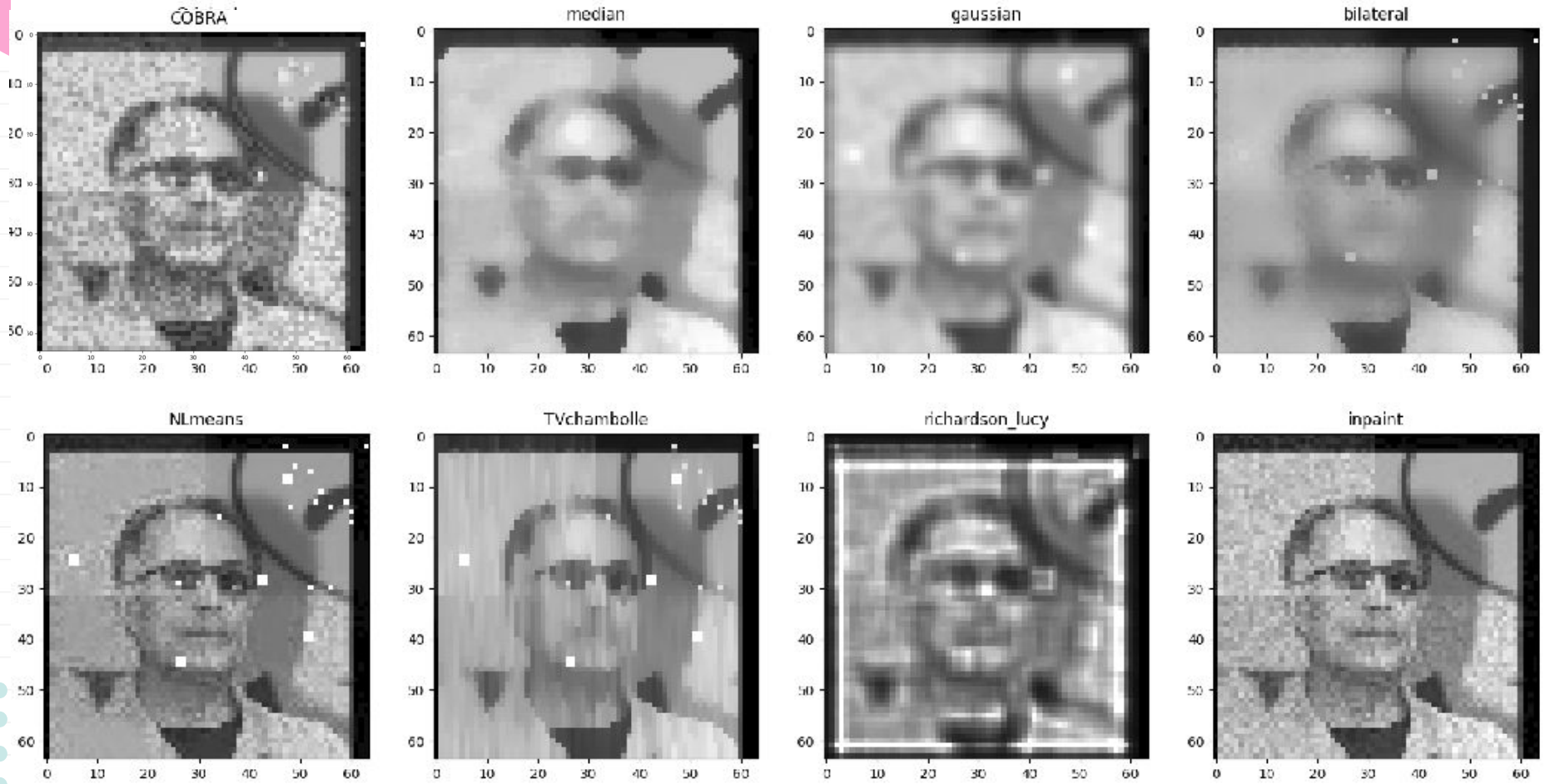
MultiNoise Image

Cobra Denoised Image



Difference Image

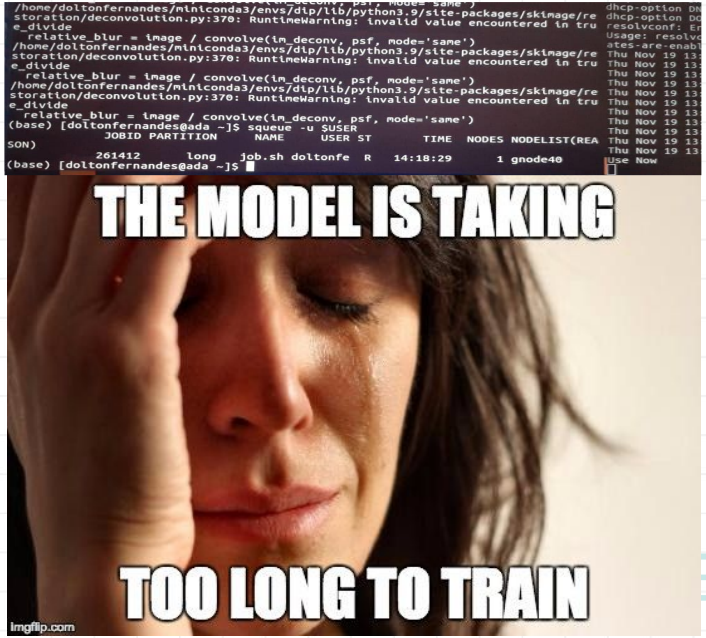
COBRA RESULTS: Comparision



COBRA Results: Relative Comparison

Error Metric/ Denoising Method	Euclidian	PSNR	RSME	SSIM
Noisy Image	7979.8508131418	30.623494188000	7.5052553202322	0.7905336129152
COBRA Image	9.2790135936459	64.904366869164	0.1449845874007	0.6711313990481

Challenges Encountered



15 hours!! Without parameter optimization

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Reason:
Blackbox we were using to train (pycobra) uses sklearn. It doesn't use GPU and CPU parallelization isn't out yet. :(

Our Unique Contribution: New Facets Explored

01. **New Dataset:** Evaluated on a new dataset (Labelled Faces in the Wild)

02. **New Metric**: The SSIM Index for Image Quality Assessment

    Observation: SSIM gives worse results after denoising.

Features Implemented and Work Distribution

No	Task	Done By
1	Theory: Understand the given paper	Amogh, Dolton, George, Naren
2	Find a new dataset to try	Amogh
3	Implement functions to add noise	Dolton, George
4	Implement classical denoising algorithms	Dolton, George, Naren
5	Implement COBRA for aggregated image denoising	Amogh, Dolton, George, Naren
6	Implement error functions (New: SSIM)	Amogh, Naren
7	Documentation: README, Presentation	Amogh, Dolton, George, Naren

Thank you!

Supplementary Material

Noise Algorithms we used

1) **Gaussian -** Gaussian Noise is a statistical noise having a probability density function equal to normal distribution, also known as Gaussian Distribution. Random Gaussian function is added to Image function to generate this noise. It is also called as electronic noise because it arises in amplifiers or detectors.
2) **Salt -** Salt noise is added to an image by addition of random bright (with 255 pixel value) all over the image.
3) **Pepper -** Salt noise is added to an image by addition of random dark (with 0 pixel value) all over the image.
4) **Poisson -** The appearance of this noise is seen due to the statistical nature of electromagnetic waves such as x-rays, visible lights and gamma rays. The x-ray and gamma ray sources emitted number of photons per unit time.
5) **Speckle -** Speckle is a granular noise that inherently exists in an image and degrades its quality. Speckle noise can be generated by multiplying random pixel values with different pixels of an image.
6) **Random Patch Suppression -** Random patches in image are deleted (Made bright).

Denoising Algorithms we used

1) **Bilateral -** A bilateral filter is a non-linear, edge-preserving, and noise-reducing smoothing filter for images. It replaces the intensity of each pixel with a weighted average of intensity values from nearby pixels.
2) **Non-local means -** Unlike "local mean" filters, which take the mean value of a group of pixels surrounding a target pixel to smooth the image, non-local means filtering takes a mean of all pixels in the image, weighted by how similar these pixels are to the target pixel. This results in much greater post-filtering clarity, and less loss of detail in the image compared with local mean algorithms.
3) **Gaussian -** Blurs the image according to the gaussian function.
4) **Inpainting -** Image inpainting is the task of reconstructing missing image parts from available known data.
5) **Median -** The median filter is a non-linear digital filtering technique, often used to remove salt-pepper noise from image.
6) **TV Chambolle -** It is based on the principle that signals with excessive and possibly spurious detail have high total variation, that is, the integral of the absolute gradient of the signal is high.
7) **Richardson Lucy -** The Richardson–Lucy algorithm, also known as Lucy–Richardson deconvolution, is an iterative procedure for recovering an underlying image that has been blurred by a known point spread function.