Image Restoration with Neural Networks

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1. Introduction

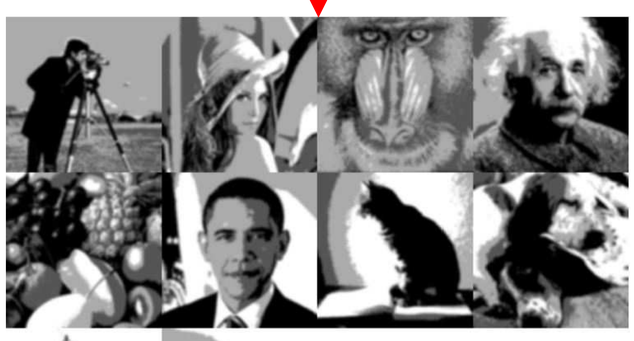
This work presents the results obtained in the **restoration of images using two neural networks**: multilayer perceptron - **MLP** and convolutional neural network - **CNN**.

Original Images

Point Spread Function (PSF)

gaussian PSF

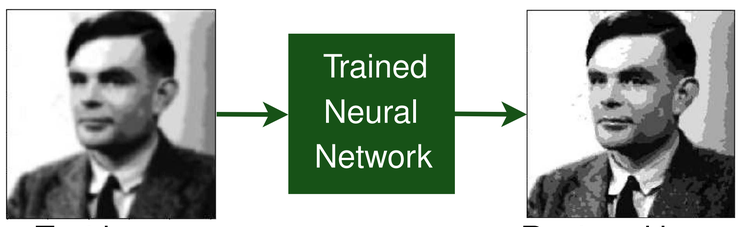
$$\mathbf{H}(n_1, n_2) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{n_1^2 + n_2^2}{2\sigma^2}\right)$$



Blurred Images ($\sigma = 2$)

Neural Network Training

Neural Network Training



Test image (gaussian, $\sigma = 2$)

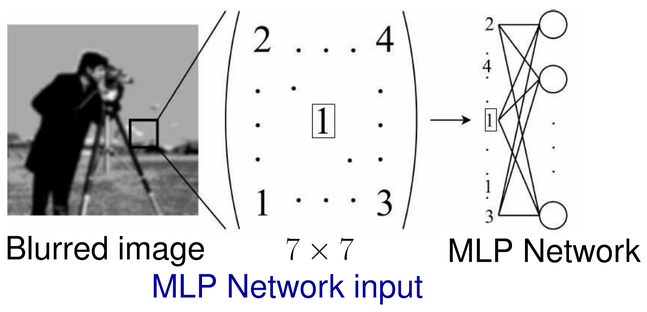
Restored image

Neural Network Test

The mean structural similarity (MSSIM) index was used to measure the similarity between the blurred and/or restored image with the original one (with no blur). This measure takes value in the interval $[0,\ 1]$, being equal to one when the two images are equal.

2. Results with 4 levels

Firstly, two MLP networks (MLP-A e MLP-B) were trained with images containing 4 levels of gray. The configurations of these networks are described in the sequel.



Blurred image 7×7 MLP Network

MLP Network input

MLP Network configurations
- Input: 7×7 matrix $\rightarrow$ vector with 49 pixels of 20 blurred 256×256 images
- Output: 4 neurons (one for each gray level); the network decided by the grayscale level related to the output neuron that presented the highest value
- Hidden layers: 2 with 40 neurons each
- Algorithm: *Backpropagation*
- Optmizer: Stochastic gradient descent (SGD), $\eta = 0.1$ to 0.001; $\alpha = 0.001$; mini-batch $k = 32$
- Activation function MLP-A – Sigmoid; MLP-B – Hyperbolic tangent for hidden layers and Softmax for output layer
- Cost function: MLP-A – Mean squared; MLP-B – Cross-entropy

The MLP-A has a classic configuration while the MLP-B uses the recent advances in *deep learning*.

Original

Blurred MSSIM= 0.77

Restored – MLP-A MSSIM= 0.83

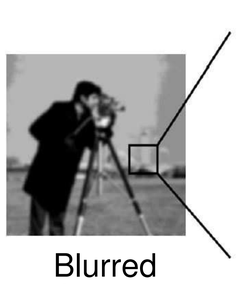
Restored – MLP-B MSSIM= 0.89

Restoration with MLP after 100 epochs

The image restored by MLP-B is better than that restored by MLP-A. The MSSIM values corroborate with this observation.

3. Results with 8 levels

Secondly, two MLP networks (MLP-SGD and MLP-Adam) and two CNNs (CNN-Small and CNN-Large), were trained with images containing eight grayscale levels. The network configutarions are described in the sequel.

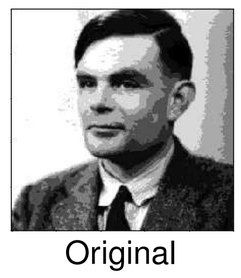


Blurred Image

CNN Input

MLP Network configurations
- Input: 7×7 matrix $\rightarrow$ vector with 49 pixels of 19 blurred images 256×256
- Output: 8 neurons (one for each gray level); the network decided by the grayscale level related to the output neuron that presented the highest value
- Hidden layers: 2 with 40 neurons each
- Algorithm: *Backpropagation*
- Activation function: ReLU for hidden layers and Softmax for the output layer
- Cost function: Cross-entropy
- Optimizer: MLP-SGD ($\eta = \alpha = 0.001$; $k = 32$); MLP-Adam ($\eta = 0.001$; $k = 32$)

CNN configurations
- Input: 7×7 matrix of 19 blurred images 256×256
- Output: 8 neurons
- Hidden layers: CNN-Small – 3 layers with 8 filters 3×3 each; CNN-Large – 3 layers with 8, 16 and 32 filters 3×3, respectively
- Algorithm: *Backpropagation*
- Activation function: ReLU for hidden layers and Softmax for the output layer
- Cost function: Cross-entropy
- Optimizer: Adam ($\eta = 0.001$; $k = 32$)

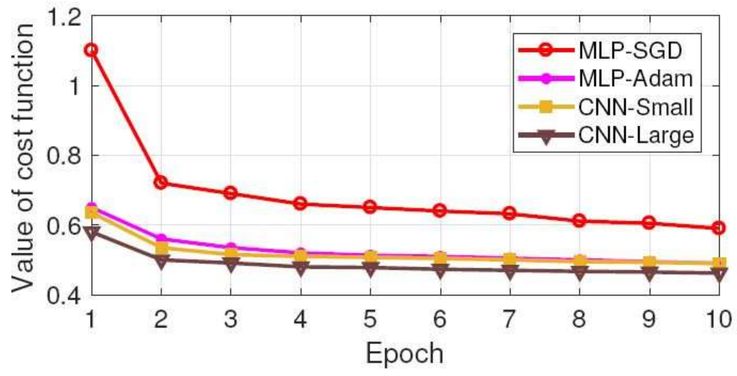


Original

Blurred MSSIM= 0.77

Restored MSSIM= 0.87

Restoration with CNN-Large after 10 epochs



Cost function value along the epochs

- CNN-Large reached the lowest value of the cost function in the second epoch
- MLP-SGD is also able to achieve the same performance, but it takes about 100 epochs
- The MLP-Adam and CNN-Small networks show the worse performance in terms of MSSIM, even after 100 epochs, although they reach approximately the same value of the cost function of that of CNN-Large
- The processing time of an MLP-SGD epoch is 1.43 times smaller than that of CNN-Large. To achieve the same MSSIM, the total training time of CNN-Large is about 35 times smaller than that of MLP-SGD

4. Conclusions

- Results obtained with neural networks that take into account recent advances in deep learning are better compared to those of the classic networks
- CNN has advantages in terms of computational cost when compared to MLP
- In a future work, we intend to consider other types of PSF for image degradation, which can lead to a mixture of specialists and enable a blind restoration