

Software methodologies: Image processing: A report on Non-Local Means Denoising

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1 The non-local means denoising algorithm.

Non-local means is an algorithm for denoising images, based on the principle of replacing a pixel of an mean of all the pixels in the image weighted by how similar their surroundings are to the surroundings of the original pixel.

As the introduction of [1] states, the goal of image denoising methods is to recover the original image from a noisy measurement.

As described in [4], the value of a pixel can be thought of as the sum of the original value plus a random noise element e.g.

$$P = P_0 + N$$

because of this, we can take multiple similar areas in the image we are trying to denoise, each with a different noise added to it but the same original value e.g.

$$P_1 = P_0 + N_1$$

$$P_2 = P_0 + N_2$$

$$\vdots$$

$$P_n = P_0 + N_n$$

finding the mean of P_n results in the sum of P_0 and the average of N . Since N can be modeled with a mean of 0, for large values of n the mean of P_n tends towards P_0

1.1 The Algorithm

the algorithm is defined by [2] to be:

$$NL(v)(i) = \sum_{j \in I} w(i, j) v(j)$$

with $w(i, j)$ being the similarity function, which is the square of the euclidian distance between the two areas surrounding the pixels i and j , calculated by:

$$\|v(\mathcal{N}_i) - v(\mathcal{N}_j)\|_{2,a}^2$$

with \mathcal{N}_i referring to the pixels surrounding i

A useful property of this similarity function is that, as explained in [2] is that the Euckudean distance preserves the order of similarity between pixels, which is to say, that the similarity of a to b is the same as the similarity of b to a .

2 Implementations of the algorithm and their efficiency.

There are two main implementations of the algorithm, pixelwise and patchwise:

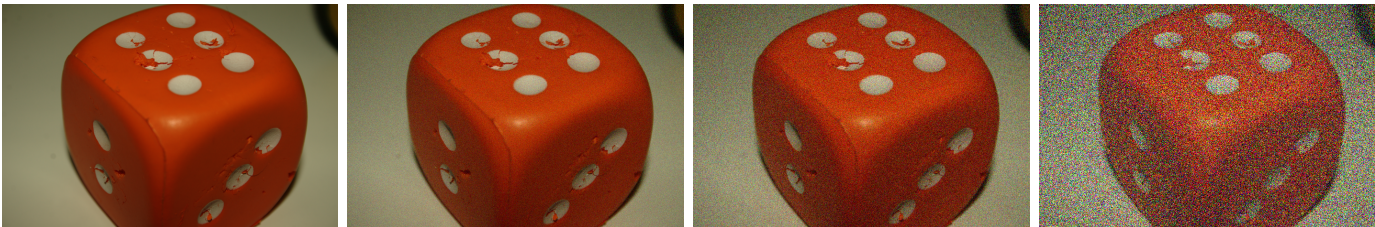


Figure 1: An image of a die, with gradually more noise

2.1 Pixelwise

The pixelwise implementation is as described in section 1.1, however due to computational limitations, in [3], the search windows, instead of being the entire image, is limited to a 21×21 square around the pixel in question for small values of σ and to a 35×35 square for large values.

2.2 Patchwise

The patchwise implementation of the algorithm is similar to the pixelwise, except that it is applied to a patch instead of a pixel, and the final value of each pixel is the mean value of all the patches it is part of.

The Patchwise implementation has an algorithmic complexity of $N^2(2f + 1)^2$ where f is the patch size.

3 The influence of the algorithmic parameters on the output.

Figure 1 shows the image we are going to use to demonstrate the effects of the algorithms parameters.

4 The strengths and limitations of non-local means compared to other denoising algorithms.

5 Modifications and extensions of the algorithm that have been proposed in the literature.

An extension of the algorithm that has been proposed in [5] is to use principle component analysis (PCA) to significantly reduce the dimensionality of the similarity calculation.

The idea is to model the image neighbourhood as a vector (e.g. for a 7×7 neighbourhood, 49 dimensions would be used) and find a number of principle components e.g. 6. Then, when comparing the similarities between neighbourhoods, find the Euclidian distance between the values in the 6 principle components for the areas.

Because the Euclidian distance is calculated between two only 6 dimensional vectors rather than two 49 dimensional vectors, [5] finds that the computational cost of the non-local means algorithm is improved upon, and because the dimensions chosen are principle components, this can be achieved without a large loss in quality.

6 Applications of the original algorithm and its extensions.

application to video

References

- [1] A. Buades, B. Coll, and J.-M. Morel. A non-local algorithm for image denoising. In *2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR05)*. IEEE.
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- [3] Antoni Buades, Bartomeu Coll, and Jean-Michel Morel. Non-local means denoising. *Image Processing On Line*, 1, sep 2011.
- [4] Alan Saberi. Digital image processing: p020 - non-local means. <https://www.youtube.com/watch?v=9tUns4HYtcw>, 2013.
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