IQA: The Role of DCT Algorithms in Automatic, Image Processing

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Abstract

The DCT-based image processing platform enables the implementation of various image processing algorithms such as pyramid noise reduction, linear filtering and image resizing in a common architecture. The DCT is a widely used transform in many of the current image coding standards such as JPEG and MPEG. Because these standards are supported and used in the World Wide Web, multimedia CD, and various imaging devices, efficient hardware and software implementations for the DCT are available. The ability to perform image processing functions beside compression will allow us to leverage the existing fast software implementations and cheap and powerful hardware for the DCT. The DCT-based platform is flexible, extendible and can be used to perform additional image processing algorithms.

Introduction

The DCT plays an important role in the image processing algorithms of IQA (Image Quality Assured). IQA is a unified image processing platform that automatically enhances images from various sources/destinations. A detailed description of IQA, from a system point of view, can be found in [1]. In this paper we will discuss in detail three DCT based image processing algorithms that are implemented in the IQA platform: Pyramid Noise Reduction, Linear Filtering and Image Resize.

Pyramid Noise Reduction

The Laplacian pyramid which was introduced by Burt and Adelson [2] is an example of a representation where the image is decomposed into different resolutions to perform compact image coding. Multiresolutions representation is also useful for image noise reduction because it allows us to tune our method to the different types and amount of noise that exist at different resolutions.

Figure 1 shows the three major steps involved in performing the proposed pyramid noise reduction method:

- Pyramid decomposition (DCT with overlap)
- Adaptive Wiener Filtering
- Pyramid reconstruction (IDCT with save)

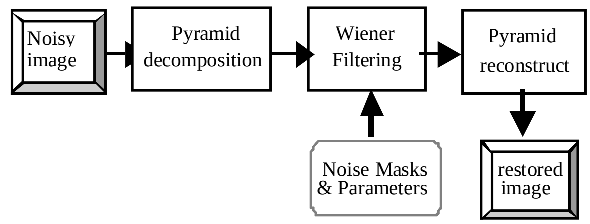

Figure 1: Block diagram of pyramid noise reduction.

We form pyramid decomposition by using the DCT on overlapped blocks of the image and perform downsampling by grouping the DC coefficients from each of the DCT block to form the lower resolution image. The process of applying overlapped DCT and grouping the DC coefficients is repeated to obtain lower resolution levels of the pyramid.

After the pyramid decomposition stage, the noisy image in the spatial domain is transformed into a pyramid representation in the DCT domain. Then, we perform adaptive wiener filtering in the overlapped DCT domain. The parameters for the appropriate amount of noise reduction are obtained using IQA logic and profiles. IQA logic is an intelligent control system that tries to optimize image quality by looking at the entire signal processing chain, [4] addresses the methodology for designing and solving the logic functions to obtain optimum image quality. Finally, image reconstruction is obtained by performing IDCT on each of the filtered DCT block. Because of the overlap, we perform save operation by discarding the pixels at the boundaries and just save the region in the center. A detailed description of pyramid noise reduction method can be found in [3].

Linear Filtering

Linear filtering or convolution of an image with a particular filter is desirable in many image processing applications. Typically, the length of the filter is much smaller than the image. The filtering operation can be done directly in the spatial domain using the simple convolution sum formula. An alternative method for performing convolution is based on the well-known dual property of the DFT where multiplication in the frequency domain is equivalent to circular convolution in the spatial domain. Using this property and the fast and efficient algorithms to compute the DFT, we could obtain the resulting filtered image faster than the direct spatial domain method. Because circular convolution is an aliased version of the linear convolution and the aliasing occur at the boundaries, we discard the boundary region to obtain the linear part. This method is known in the literature as Overlap-Save method for implementing linear filtering in the frequency domain.

Similar to the Overlap-Save method of the DFT, we propose a method to implement linear filtering using the DCT. The method is not a simple extension because the DCT dos not have the simple convolution-multiplication property of the DFT [6]. Figure 2 shows a block diagram for our proposed method, where [x] and [h] represent the input block and the desired filter in the spatial domain. [X] represents the DCT of the input block [x], and [H] represents the Discrete Odd Cosine Transform (DOCT) of the desired filter. The resulting block [Y] is obtained by performing point-wise multiplication of each elements in block [X] and [H]. The final block, y, is obtained by performing Inverse DCT (IDCT) on block [Y]. After discarding the boundary points of the resulting block, y, we obtain the points that correspond to linear filtering.

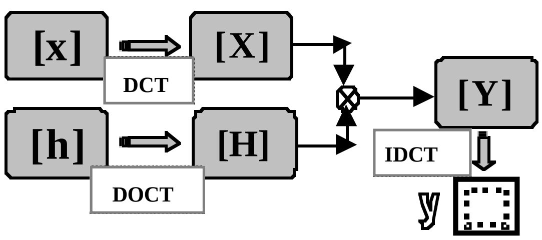

Figure 2: Linear filtering or convolution in the DCT domain.

Image Resize

Image resizing which includes both upsampling and downsampling is needed to change the image sampling rate. Common approaches for image resize includes zero-order-hold, linear and cubic interpolation. In the case of downsampling, anti-aliasing filtering is needed in order to avoid aliasing. The image resizing approach that we describe in this paper is based on the DCT and works for both upsampling and downsampling. In addition, the anti-aliasing filter required for downsampling can be included in the resampling step.

The DCT-based interpolation method works by dividing the input signal into fixed-size blocks. Then, it uses the DCT basis functions to fit the pixels, inside each block, with cosines at different frequencies. Thus, the cosines are used as our interpolation functions. By using the linear combination of cosines, we can now obtain the values of the function at any point in the real axis. The desired values at any location between the beginning and the end of a block are obtained by calculating the corresponding inverse basis functions at the desired locations over the real axis.

We give a simple example in order to illustrate mathematically the two main steps that are required to use the DCT in performing resampling: The first step is to fit the signal with cosines then obtain the signal values at the desired locations. Let us assume that we have a discrete N-point signal, x[n]. By performing the N-point DCT, as shown in the following Equation, we are effectively fitting a linear combination of cosines to the N input points:

$$X[k] = \sqrt{\frac{2}{N}} \sum_{n=0}^{N-1} c_k \times x[n] \cos \frac{\Pi k}{2N}(2n+1)$$

Where K = 0,…., N-1 and Ck is a scaling factor. The cosine functions can now be evaluated at the continuous real axis, not just at the discrete locations, to perform resampling. Evaluating the signal at any desired locations within the input boundaries is obtained by performing the following inverse DCT Equation:

$$d[t] = \sqrt{\frac{2}{N}} \sum_{k=0}^{N-1} c_k \times X[n] \cos \frac{\pi k}{2N}(2n+1)$$

Where d[t] is the continuous desired signal and t could be evaluated at the continuous interval [0,N-1].

Concluding Remarks

We have shown three different image processing functions that can be performed using the DCT. Other functions that we did not discuss include image differentiation in which all even derivatives may be implemented in a form identical to convolution (i.e. DCT mask multiply and IDCT). This may be used in image segmentation and recognition. Large symmetric kernels of size greater than the DCT block may be handled within this framework. Additional image processing functions that we have implemented in the IQA but did not discuss here, include image rotation, coding, edge detection, exposure correction [1] and burning and dodging.

References

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