

Comparison of Image Compressions: Analog Transformations [†]

Jose Balsa

CITIC Research Center, Universidade da Coruña (University of A Coruña), 15071 A Coruña, Spain; j.balsa@udc.es

[†] Presented at the 3rd XoveTIC Conference, A Coruña, Spain, 8–9 October 2020.

Published: 21 August 2020

Abstract: A comparison between the four most used transforms, the discrete Fourier transform (DFT), discrete cosine transform (DCT), the Walsh–Hadamard transform (WHT) and the Haar-wavelet transform (DWT), for the transmission of analog images, varying their compression and comparing their quality, is presented. Additionally, performance tests are done for different levels of white Gaussian additive noise.

Keywords: analog image transformation; analog image compression; analog image quality

1. Introduction

Digitized image coding systems employ reversible mathematical transformations. These transformations change values and function domains in order to rearrange information in a way that condenses information important to human vision [1]. In the new domain, it is possible to filter out relevant information and discard information that is irrelevant or of lesser importance for image quality [2]. Both digital and analog systems use the same transformations in source coding. Some examples of digital systems that employ these transformations are JPEG, M-JPEG, JPEG2000, MPEG-1, 2, 3 and 4, DV and HDV, among others. Although digital systems after transformation and filtering make use of digital lossless compression techniques, such as Huffman.

In this work, we aim to make a comparison of the most commonly used transformations in state-of-the-art image compression systems. Typically, the transformations used to compress analog images work either on the entire image or on regions of the image. The transforms whose performance will be analyzed with compression and analog noise are the discrete Fourier transform (DFT), discrete cosine transform (DCT), the Walsh–Hadamard transform (WHT) and the Haar-wavelet transform (DWT) [3,4].

These transformations can be applied to the whole image or to parts of the image. The decision will depend on the performance of the transformation, the computational load, the desired compression level and the impact of the noise on the coefficients of the transformed domain. In this work, we intend to make an analysis of the performance of the above-mentioned transformations by varying the characteristics listed.

2. System Description

The system proposed and implemented in MATLAB performs the four transformations, DFT, DCT, WHT and the Haar-based wavelet (DWT), simultaneously, with the same images, the same compression ratio and additive white Gaussian noise (AWGN) with the same intensity. The purpose of the system is to test and compare the performance of the four transformations applied to images as a function of the compression ratio and noise.

The operation of the DFT, DCT and WHT transforms are similar. These transforms change the domain of the image symbols to concentrate the relevant information into certain coefficients, allowing for compression by setting a transmission threshold. These transforms are applied to the entire image or to smaller divisions of the image, usually in squares. The selection of the size of the block where it will be applied is also relevant to the quality of the image [1], and we will take it into account in the results.

The Haar-based wavelet [4] is a transformation that condenses the important information of an image onto certain symbols. The reverse transformation allows the recovery of the exact image. For the compression, a threshold is set from which the symbols are approximated by zero and it is these zeros over the total symbols that allow the calculation of the compression ratio.

Therefore, the system created allows a comparison of the four transformations as a function of image quality, using the structural similarity index measure (SSIM) [5], and varying the compression ratio and noise intensity. A bank of 14 images with different characteristics is used.

3. Results and Conclusions

The results shown are for a block size of 16×16 for the DFT, DCT and WHT transformations. In the case of the Haar-based wavelet transformation, it is performed on the whole image. In addition, a filling with zeros is performed if the multiplicity is not met, as in the case of WHT and the DWT. For this purpose, it is necessary to do the reverse transform at the reception and then remove the image positions that were filled with zeros.

Figure 1a shows the result for when there is practically no noise; in this case, we can see how the DWT has the best behavior, followed by the DCT. It should be noted that the DFT is sluggish and does not achieve the maximum quality of 1 of SSIM. This is due to the fact that when we do the DFT transform we get twice as many symbols as the rest of the transforms because they are in the real and imaginary domain, so this coding is considerably penalized when comparing the number of symbols transmitted.

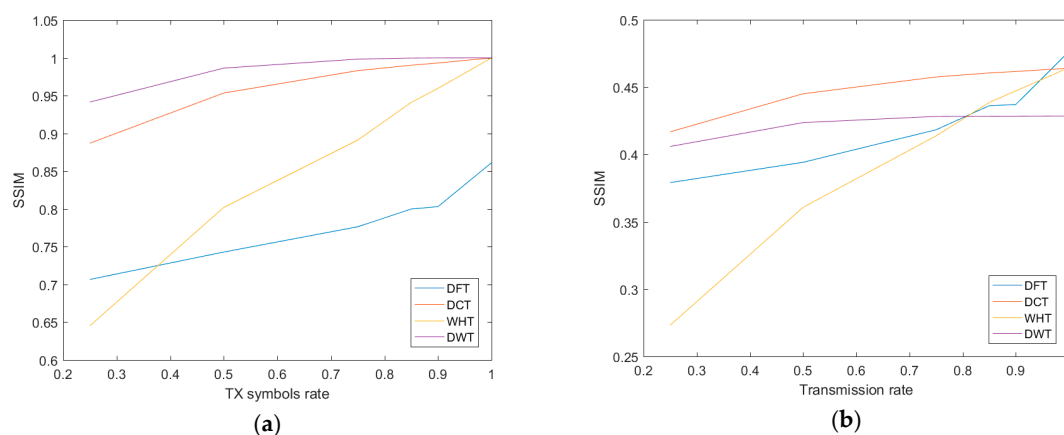


Figure 1. The relationship between compression rate and image quality (SSIM) is shown for two levels of signal-noise rate (SNR): (a) 100 dB additive white Gaussian noise (AWGN); (b) 15 dB AWGN.

Figure 1b shows the result for the above situation, but with an AWGN noise level of 15 dB. This time, a better performance of the DCT is shown in general. It can be noticed that the DFT, when there is no compression, obtains better results than the rest of the transformations, but we must emphasize that we are in a very small range of SSIM values, so its relevance is small.

As a conclusion, we can say that, among the most known transformations for images, those that present a greater performance are the DCT and the wavelet. In view of the results obtained, the DCT presents a higher quality of SSIM for noise levels below 20 dB AWGN and the wavelet for higher levels of 20 dB. With this, we can say that it is interesting to use the wavelets for digital systems because the noise does not affect the transformed values. However, for analog systems, where noise

is introduced into the transformed symbols, the DCT is the best choice because, in view of the results, it offers a better balance between noise-free and noisy transmissions. Finally, we can say that the WHT and the DFT offer the worst results for transmissions with and without noise.

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