



A multi-objective evolutionary approach to image quality/compression trade-off in JPEG baseline algorithm

Beatrice Lazzerini^a, Francesco Marcelloni^a, Massimo Vecchio^{b,*}

^a Dipartimento di Ingegneria dell'Informazione, University of Pisa, Via Diotisalvi 2, 56122 Pisa, Italy

^b ASAP Research Team, INRIA, Saclay, 4 Rue Jacques Monod, 91893 Orsay Cedex, France

ARTICLE INFO

Article history:

Received 11 February 2008
Received in revised form 24 March 2009
Accepted 23 August 2009
Available online 28 August 2009

Keywords:

Multi-objective evolutionary algorithms
Image compression
JPEG algorithm

ABSTRACT

The JPEG algorithm is one of the most used tools for compressing images. The main factor affecting the performance of the JPEG compression is the quantization process, which exploits the values contained in two tables, called quantization tables. The compression ratio and the quality of the decoded images are determined by these values. Thus, the correct choice of the quantization tables is crucial to the performance of the JPEG algorithm. In this paper, a two-objective evolutionary algorithm is applied to generate a family of optimal quantization tables which produce different trade-offs between image compression and quality. Compression is measured in terms of difference in percentage between the sizes of the original and compressed images, whereas quality is computed as mean squared error between the reconstructed and the original images. We discuss the application of the proposed approach to well-known benchmark images and show how the quantization tables determined by our method improve the performance of the JPEG algorithm with respect to the default tables suggested in Annex K of the JPEG standard.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

JPEG is an acronym for “Joint Photographic Experts Group” [1]. This group has been working under the auspices of three major international standards organizations (ISO, CCITT and IEC) for the purpose of developing a standard for colour image compression. As the standard evolved and implementers started deploying it, the name quite naturally became attached in an informal way to the standard itself.

JPEG uses the Discrete Cosine Transform (DCT) for its baseline coding technique. The DCT was first applied to image compression in [3]: in this pioneering work the authors showed that DCT is very similar to the KLH (Karhunen–Loeve–Hotelling) transform that performs a decorrelation process so as to produce uncorrelated coefficients. Decorrelation is very important for compression, because each coefficient can be treated independently without losing compression efficiency. Essentially, the $n \times n$ 2-D version of DCT decomposes an $n \times n$ block of an image into a set of waveforms, each with a particular spatial frequency; thanks to this decomposition, we can separate the image structure the eye can see from the structure that is imperceptible.

The JPEG baseline coding algorithm can be summarised as follows: the original uncompressed image is represented in the $YCbCr$ colour space, where Y , Cb and Cr denote luminance, and blue and red chrominance components, respectively; each component is treated separately. For the sake of simplicity we will refer only to the luminance component Y . Anyway, a lot of considerations discussed in this paper can be generalised to manage the other two components. The component Y of the image is segmented into 8×8 blocks; each block is transformed independently. The 8×8 blocks are zero-shifted by subtracting 128 from the data before applying DCT. Each transformed block is therefore quantized. Quantization introduces an accuracy loss due to the coarse-grained representation of the DCT coefficients. In JPEG coding the accuracy loss occurs entirely in quantization, and much of the compression is gained by run-length coding of coefficients which quantize to zero. After quantization, each block can be efficiently entropy encoded: in this step no information loss occurs. We provide a detailed description of the entire encoding/decoding process in Section 2.

As briefly mentioned above, the quantization process is central to the compression/accuracy performance of the JPEG algorithm. The JPEG standard does not specify a quantization table, although two possible tables, namely the Default Luminance Quantization Table (DLQT) and the Default Chrominance Quantization Table (DCQT), are suggested as examples in Annex K. These tables are used for quantizing all the DCT coefficient blocks of luminance and chrominance components, respectively. Unfortunately, it is very

* Corresponding author.

E-mail addresses: b.lazzerini@iet.unipi.it (B. Lazzerini), f.marcelloni@iet.unipi.it (F. Marcelloni), massimo.vecchio@inria.fr (M. Vecchio).

difficult to find a quantization table suitable for all images because the coefficient statistics are different from an image to another.

In the last recent years, a lot of work has been done in the attempt of determining optimal quantization tables which guarantee the best trade-off between image quality and compression ratio for specific classes of images (natural images, medical images, etc.). To this aim, several optimization methods have been applied. We can coarsely classify them into the following classes:

1. Statistics methods: these methods are based on statistical analysis of the distributions of DCT coefficients for sets of images [5,8,9,13,14,17,20,22,28].
2. Adaptive methods: these methods start from criticizing the use of a unique quantization table for not only all images, but also for all blocks of a particular image. Thus, they propose an image-dependent approach that makes the JPEG algorithm locally adaptive. These approaches exploit the local frequency content of the image to provide finer control of the DCT coefficients quantization process [4,24,25].
3. Standard optimization methods: these methods adopt standard optimization techniques, such as gradient method [11] and simulated annealing [16,21].
4. Direct search based methods: these methods exploit single-objective evolutionary algorithms (SOEAs) to search for a quantization table which allows obtaining an optimal compression/accuracy trade-off for specific types of images [6,27].

These classes of methods provide a unique solution independently of the particular context in which the compression is required: in some contexts compression could be more relevant than image quality and vice versa. Unfortunately, these methods fix the context before performing optimization: typically, they adopt fitness functions which weight differently the objectives. Once fixed the weights, the methods search the best solution for these weights. Often, it would be preferable to have a family of solutions with different optimal trade-offs between image quality and compression and select the most suitable trade-off for the specific context when necessary.

To this aim, we adopt a multi-objective evolutionary algorithm (MOEA) based approach. MOEAs generate a family of equally valid solutions, where each solution tends to satisfy an objective to a higher extent than another. In our case, each solution represents a different quantization table and the two objectives are, respectively, the difference in percentage between the sizes of the original and compressed images, and the mean squared error

between the reconstructed and the original images. Thus, the choice of the best solution for the specific context can be delayed to the time in which the compression has to be performed. The use of an MOEA rather than an SOEA is generally preferred when the objectives to be satisfied are in competition and therefore cannot be optimised concurrently. Though the problem of determining optimal quantization tables for classes of images is inherently multi-objective, to the best of our knowledge this problem has been never tackled by using MOEAs. In this paper, we adopt one of most popular MOEAs, the NSGA-II algorithm proposed in [7].

We first apply NSGA-II to three well-known image processing benchmarks, namely, Barbara, Lena and Boat images and discuss how the quantization tables determined by NSGA-II allow achieving remarkable trade-offs between image quality and compression. Then, we show how some of these quantization tables achieve both a higher compression ratio and a better quality than the DLQT. Finally, we replace the DLQT with three of these tables in the free library for JPEG image compression proposed by the Independent JPEG Group (IJG) [2]. We show that the three quantization tables allow producing better trade-offs between image quality and compression than the DLQT with respect to variations of the quality switch, provided in the library to change the quality/compression trade-off.

The paper is organized as follows. We first briefly review JPEG image compression baseline algorithm in Section 2. Then, in Section 3 we discuss the quality/compression trade-off issue. In Section 4, we introduce our approach. Finally, in Section 5 we discuss the experimental results.

2. The JPEG image compression

Fig. 1 shows the modules of the JPEG image compression standard baseline algorithm. The source image is an 8×8 block of a component represented in the $YCbCr$ colour space. The Encoder transforms the source image into a bitstream, which represents the JPEG compression version of the original image. The decoder performs the inverse task, that is, it reconstructs the original image from the corresponding bitstream. In the following, we introduce and discuss the single modules in detail. For the sake of simplicity, we refer only to the luminance component Y .

2.1. The DCT and IDCT modules

The values of the 8×8 blocks are shifted from unsigned integers in $[0, 2^p - 1]$ to signed integers in $[-2^{p-1}, 2^{p-1} - 1]$, where

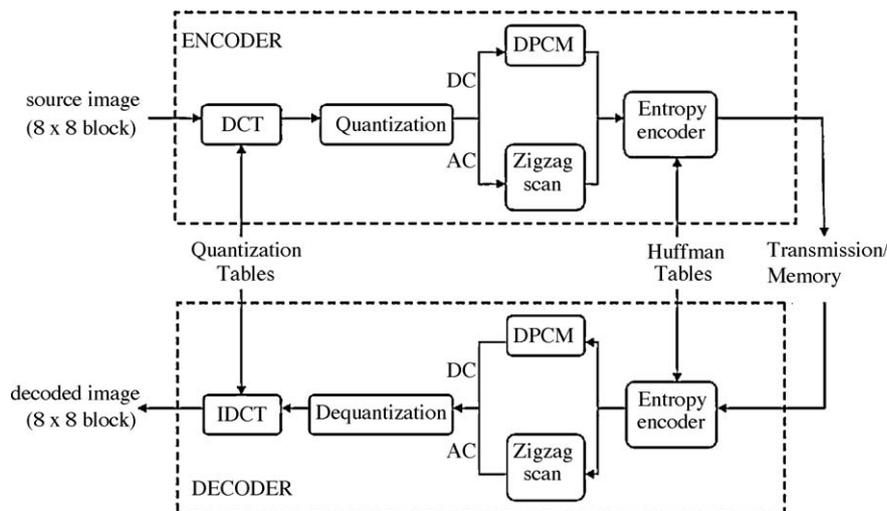


Fig. 1. Modules of the JPEG algorithm.

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات