Image deblocking using convex optimization

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Abstract

Images encoded at low-bit rate may suffer from blocking artifacts, which can dramatically degrade the visual quality. In this paper, a novel approach to image deblocking is presented. Based on the analysis of image coding process and the property of natural images, an objective function and a set of constraint functions are proposed, and image deblocking is formulated as a convex optimization problem which can be easily solved using numerical methods. The feasibility of the convex optimization problem is utilized to detect the true object edges and avoid blurring. Experimental results demonstrates the effectiveness of the proposed approach.

Introduction

Block-based transform followed by scalar quantization is the most popular scheme of image compression. While significantly reducing the number of bits for content representation, this scheme can introduce serious blocking artifacts into the decoded image and degrade the visual quality. It is thus highly desirable to develop post-processing techniques to alleviate the blocking artifacts in the decoded image. Until now, many different methods have been developed for image deblocking. Among them, one popular class of post-processing algorithms is based on the theory of projections onto convex sets (POCS). In these methods, a number of convex constraint sets (described by the corresponding convex functions) have been defined to describe the blocking-free image, and the original image is assumed to be in the intersection of these sets. To achieve de-blocking, the decoded image is treated as an initial guess of the original image and is then iteratively projected onto every set. It is expected that the image will converge to a blocking-free one with all the constraints satisfied.

problems

While exhibiting deblocking capability, POCS-based approach has two limitations. First, there is no optimization criterion in the deblocking. The projection iteration will stop when all the constraints are satisfied and thus POCS-based approach only solves a feasibility problem. Second, the users have to define the projection operation for every constraint set. For some sets, the corresponding projection operations may not be easy to recognize. With improper projection operations, the iteration process may diverge and give even worse image than before deblocking.

In this paper

In this paper, a novel approach to image deblocking is proposed. In the proposed approach, based on the analysis of image compression process and the properties of natural images, a set of convex constraint functions are proposed. Furthermore, an objective function based on maximum-likelihood estimation is also proposed. With these constraint functions and the objective function, image deblocking is formulated as a convex optimization problem which is easy to solve using numerical methods, and the final image will be the optimal one that minimizes the given objective function while satisfying all the constraints. Experimental results show that the proposed approach can effectively suppress the blocking artifacts while preserving image edges.

proposed approach

The proposed approach formulates image deblocking as a convex optimization problem. A convex optimization problem consists of optimization variables, an objective function to be minimized and a number of constraint functions. The objective function and constraint functions have to be convex (equality constraint functions are further restricted to be linear). The optimization process targets at finding the optimal values of optimization variables such that the objective function is minimum while all the constraints are satisfied.

In the proposed approach, convex optimization is performed for every 8X8 image block, and thus the optimization variable is the current 8X8 block, which we denote as X. Based on the analysis of the image coding process and the property of natural images, the following constraint functions and objective function are defined.

Quantization constraints

To establish the quantization constraints, image coding is briefly reviewed. Let Xo be the input block. First, DCT transform is applied to Xo, giving rise to DCT block Yo,

$\mathbf{Y}_o = \mathbf{H}^T \mathbf{X}_o \mathbf{H}(1)$

where H and HT are the DCT transform matrix and its transpose respectively. Afterwards, the DCT matrix Yo is quantized. The quantization process is not part of the coding standard, and thus c an be user-defined. In this paper, a widely-used quantization process is assumed. Let Yo(i,j) be the (i,j)th coefficient of Yo. The quantization process of Yo(i,j) can be described using the following equation:

$\mathrm{Y}_q(i,j) = \mathrm{sign}(Y_o(i,j)) \cdot \left\lfloor \frac{|Y_o(i,j)|}{\alpha \cdot Q(i,j)} + 0.5 \right\rfloor (2)$

Quantization constraints

where Yq(i,j) is the quantized value of Yo(i,j),$\alpha isquantizationparameter(qp), Q(i,j)isthe(i,j)thcoefficientofquantizat$
0; 0 when y=0; and-1 when y= ≤ 0.
At the decoder side, Yq(i,j), and Q(i,j) can be obtained from the bitstream (for the case that the decoding process is not accessible, these parameters can be estimated from the decoded image;. Given Yq(i,j), and Q(i,j), we can determine the maximum and minimum possible values of Yo(i,j). We define matrices U and L, whose elements U(i,j) and L(i,j) are the the maximum and minimum possible values of Yo(i,j) respectively. The expressions of U(i,j) and L(i,j) are as follows,
U(i,j)=$\alpha \cdot Q(i,j) \cdot (Y_q(i,j)+0.5), (3) \ \ L(i,j) = \alpha \cdot Q(i,j) \cdot (Y_q(i,j) - 0.5).(4)$

all equations

$\mathbf{L} \preceq \mathbf{H}^T\mathbf{X}\mathbf{H} \preceq \mathbf{U}(5)$
$\mathrm{G}_h(i,j) = |X(i,j) - X(i+1,j)|, i\text{=}0\ldots6; |X(7,j) - X_r(0,j)|,\text{otherwise}.(6)$
$\mathrm{G}_v(i,j) = |X(i,j) - X(i,j+1)|,\text{j=}0\ldots6; |X_b(i,0) - X(i,j)|,\text{otherwise}.(7)$
$\mathrm{G}_h(7,j) \leq \zeta_h, \qquad j = 0,\ldots,7(8)$
$\mathrm{G}_v(i,7) \leq \zeta_v, \qquad i = 0,\ldots,7(9)$
$\zeta_h = \tau_h + c_h, (10)$
$\zeta_v = \tau_v + c_v.(11)$

Based on the previous three subsections, the convex optimization problem for image blocking can be formulated as

$$\min \quad -\log p(\mathbf{X}|\mathbf{X}_q) + \lambda \sum_{i,j=0}^{7} (G_h^2(i,j) + G_v^2(i,j))$$
$$\text{s.t.} \quad \mathrm{G}_h(7,j) \leq \zeta_h$$
$$\mathrm{G}_v(i,7) \leq \zeta_v$$

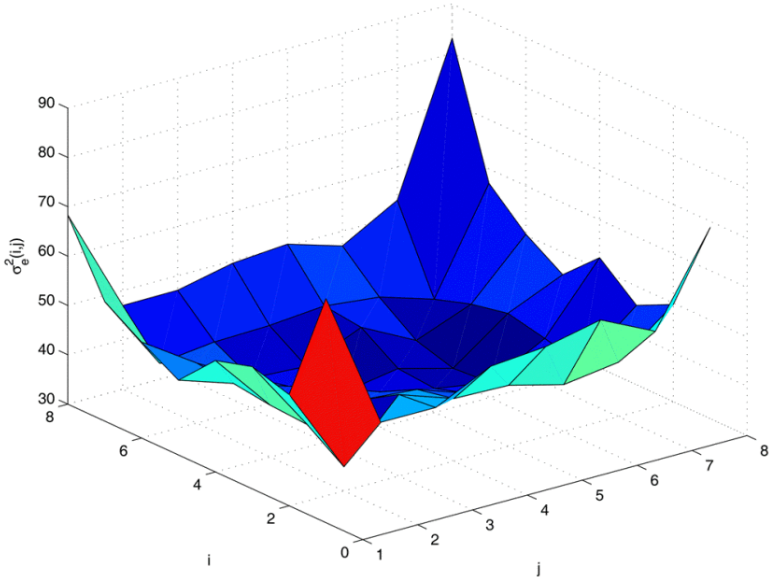
$\mathbf{L} \preceq \mathbf{H}^T \mathbf{X} \mathbf{H} \preceq \mathbf{U}$(18)

Extensive experiments have been conducted to evaluate the performance of the proposed deblocking approach. Five 256256 test images including Lena, House, Woman, Baboon and Sam are used. The test images are compressed by a JPEG encoder first and then the decoded images are processed by the proposed approach. For comparison, a POCS-based approach is also used in the experiment. A parameter is utilized in the approach presented in but the authors did not specify its value. In the experiments, we set $\eta = 1$, for good deblocking performance.

The deblocking images of Lena are shown in for subjective quality evaluation. It can be seen that the proposed approach can significantly suppress most blocking artifacts in the decoded images, while preserving important edges. On the contrary, the POCS-based approach is not as effective as the proposed method, and the processed image seems still blocking. Similar results can be observed on other test images (they are not presented due to limit of space).

conclusion

In this paper, a novel approach to image deblocking is proposed. In the proposed approach, by defining a number of convex constraint function and a convex object function, image deblocking is reformulated as a convex optimization problem. The convex constraint functions are used to reflect the characteristics of natural image, and the objective function is used to find the image most similar to the original one under the constraints. Experimental results show the proposed approach can suppress blocking artifacts while preserving edges.



90
80
70
60
50
40
30
$\sigma_e^2(i,j)$
8
6
4
2
0
i
1
2
3
4
5
6
7
8
j

(a)

(b)

(c)

(d)

And last

Thank You