BLUR DETERMINATION IN THE COMPRESSED DOMAIN USING DCT INFORMATION

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ABSTRACT

The paper presents a simple yet robust measure of image quality in terms of global (camera) blur. It is based on histogram computation of non-zero DCT coefficients. The technique is directly applicable to images and video frames in compressed (MPEG or JPEG) domain and to all types of MPEG frames (I-, P- or B-frames). The resulting quality measure is proved to be in concordance with subjective testing and is therefore suitable for quick qualitative characterization of images and video frames.

1. INTRODUCTION

Characterization of images in term of blur is required in many applications, such as image restorations and super-resolution image construction [3, 1, 6]. Another application that will benefit from qualitative analysis of the blur of images is key-frames extraction of videos in content-based video retrieval systems. Key-frames are images that best represent the content of video shots in an abstract manner and are used for indexing and browsing video sequences [8, 2]. Key-frames are usually extracted from the video shots according to a certain extraction criterion that characterizes content and its changes in a video sequence. A useful criterion for extracting key-frames is that key-frames should be of good visual quality (not blurred), thus suitable for visual browsing and printing.

The aim of blur analysis usually is to identify the image and blur model parameters of a degraded image in order to restore it. Accurate parameter estimation is therefore needed since the degradation process has to be somehow "reversed" based on the accurate estimation. For this purpose, two main classes of techniques exist: the first one relies on image modeling and maximum likelihood estimation [5], while the second initially detects image edges and then estimates blur in the perpendicular direction [4].

For the purpose of characterization (or qualitative analysis) of images, such as in key-frame selection, one only aims at extracting a measure, as reliable as possible, of the global camera blur. Although such a measure could be derived from the blur parameters estimated with classical techniques, the complicated process may be too expensive. Also, direct blur estimation from the DCT coefficients is desirable to take advantage from image analysis already performed in the compression process. One of such methods found in the literature is proposed in [7]. However, this method has two main drawbacks: first, its DCT has to be computed at once on the largest possible set of data, ideally on the whole image (i.e. a 256x256 image is transformed into a 256x256 DCT matrix). Second, it involves a lot of computation to manipulate DCT coefficients in polar coordinates and detect some absolute minima. The first constraint already makes the technique relatively unstable for MPEG data since the classical 8x8 DCT does not provide information enough for the algorithm to perform in a reliable way.

In this paper, we present a new solution proposed to aim at exploiting the available DCT information in MPEG or JPEG compressed video or images while involving a minimal computational load. As presented in the next section, the technique is based on histograms of non-zero DCT occurrences, computed directly from MPEG or JPEG compressed images. For MPEG compressed video, the proposed algorithm is suitable for all types of pictures: I-frames, P-frames or B-frames. Section 3 presents experimental evaluation of the proposed method, which shows that the method is effective

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in qualitatively characterizing blur of video frames.

2. THE PROPOSED BLUR MEASUREMENT METHOD

2.1. Formulation of the Problem

The objective of blur detection in our application is to provide a percentage indicating the global image quality in terms of blur: 0% would mean that the frame is totally blurred while 100% would mean that no blur at all is present in that particular frame. This blur indicator characterizes the global image blur caused by camera motion or out of focus. Since we focus analyzing MPEG compressed video data, it is desirable that the blur indicator can be directly derived from the DCT layer of an MPEG video bitstream. To achieve this objective, one should be aware that:

- The DCT coefficients used within MPEG are intended for compression and are deeply related to the image content. Basically, they reflect the frequency distribution of an image block.
- In a MPEG stream, DCT coefficients are directly applied on the pixels of I-frames. On the contrary, coefficients of P- and B-frames describe the residual image that remains after motion compensation.

It is therefore important to select a blur indicator which is as independent as possible from the particular content of an image as well as from the type of MPEG frames (I, P or B).

2.2. Proposed Method

Intuitively, blur is the opposite of edge sharpness. DCT coefficients render this sharpness via the high values of some AC coefficients. Our proposed blur measure therefore looks for the absence of such edges into the image, which is considered to prove a blurred image. Three steps lead to the final measure:

1. In order to characterize the global blur, it is proposed to establish a measure that takes into account the DCT information of the entire image as a whole. It is likely that any type of edge will cross some 8×8 blocks at least once in the image. Globalization among all DCT blocks would therefore enable to have an idea about the general edge sharpness, i.e. the global (camera or motion) blur.
2. In order to be as independent as possible of the content of the image, coefficients should not be considered directly since their values are closely related to the type of image they depict. One rather proposes to look at the distribution of null coefficients instead of the values themselves: blurred images are likely to have all of their high-frequency coefficients set to zero, whatever their content is.
3. In order to remove the dependency to the image size, the number of blocks in the image should divide the number of times a coefficient is not zero. This would limit histogram values to 1. However, coefficients are often zeros in P- and B-frames. In order to homogenize the look of the histogram for all types of pictures, the number of non-zero occurrences of a coefficient is divided by the number of non-zero occurrences of the DC coefficient.

With these three steps, a measure (histogram) is obtained which is independant of both the image content and the type of MPEG frames. Figure 1 depicts the resulting 8×8 histogram measured for typical I-, P- or B-frames: for every DCT coefficient, one counts how many blocks have this coefficient different from zero. Then, the value is divided by the the number of times that the DC coefficient is different from zero. The left-most value of the diagrams, which represents the histogram value for the DC coefficient, is therefore always set to 1. The right-most value indicates the same measure for the AC coefficient of highest frequency.

In the implementation, DCT coefficients whose value is inferior to a threshold *MinDCTValue* are considered null. This thresholding aims at neglecting small values which may result from noise. The threshold is typically set to 8, which is the DC value of a homogeneous luminance block with intensity 1.

In concordance with the intuition, it appears that high frequencies are more likely not to appear in many blocks than low frequencies. Some exceptions to this rule can occur for P- and B-frames where a precise frequency may have been wrongly estimated by the motion estimation procedure.

The idea of the blur estimation algorithm is then to examine the number of coefficients that are (almost) always zero in the image, i.e. to count the number of zeroes (or nearly zero values) in the histograms. In practice, all values inferior to a threshold *MaxHistValue* are considered as not relevant for the final computation. This threshold is generally set to 0.1, i.e. only coefficients that appear 10% as often as the DC coefficient are taken into account for the blur determination. The final quality measure is obtained via the weighting grid of figure 2: it gives more importance to the DCT

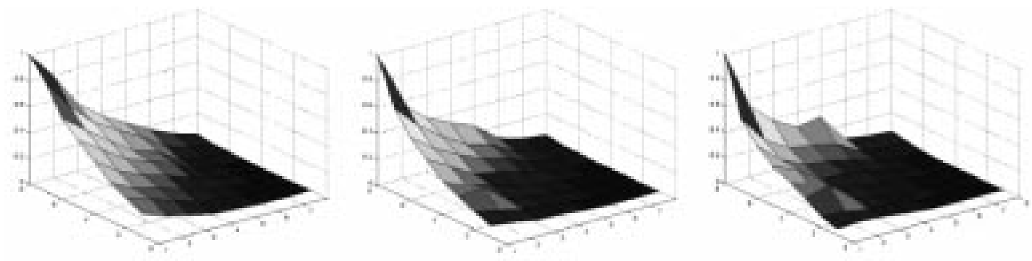

Figure 1: Normalized histogram appearance of a typical I-frame (left), P-frame (center), B-frame(right)

8	7	6	5	4	3	2	1
7	8	7	6	5	4	3	2
6	7	8	7	6	5	4	3
5	6	7	8	7	6	5	4
4	5	6	7	8	7	6	5
3	4	5	6	7	8	7	6
2	3	4	5	6	7	8	7
1	2	3	4	5	6	7	8

Figure 2: Weighting grid for the blur measure, to be applied on the DCT coefficient. The upper-left coefficient applies for the DC coefficient, while the bottom-right one applies to the highest AC coefficient.

coefficients on the central diagonal since they better represent global (circular, non-directional) blur. One should notice that this grid applies to DCT coefficients: its diagonal look aims at giving more importance to the chessboard-like structures of the DCT and has nothing to do with some kind of oriented spatial frequency as it would result from a Fourier analysis.

2.3. Pseudo-Code of Blur Characterization

The pseudo-code presented in the following illustrates the implementation of proposed blur detection method. The code is valid for any type of MPEG picture (I-, P- or B-frame), provided that DCT coefficients are first initialized to zero for all blocks (i.e. the implementation guarantees that blocks who do normally not have any DCT component actually have all of them equal to zero).

```
/* Extern parameters */
MinDCTValue; /* Minimum DCT value to take
                into account, typically 8 */
MaxHistValue;/* Histogram relative frequency
                to reach, typically 0.1 */

/* Constants for measure weighting */
Weight[64]={8,7,6,5,4,3,2,1,7,8,7,6,5,4,3,2,
6,7,8,7,6,5,4,3,5,6,7,8,7,6,5,4,4,5,6,7,8,7,
6,5,3,4,5,6,7,8,7,6,2,3,4,5,6,7,8,7,1,2,3,4,
5,6,7,8};
TotalWeight = 344;

/* Variables for computation */
DCTnonzeroHist[64]; /* histogram */
blur;  /* blur measure */

/* Initialization of histogram to zero */
for (k = 0; k < 64; k++)
   DCTnonzeroHist[k] = 0;

/* Compute Histogram */
for (all macroblocks)
   {
    for (every luminance block)
       {
        for (every DCT component k)
              /* 0 <= k < 64 */
           {
            /* Add to histogram if coeffi-
               cient is big enough */
            if (abs(blockDCT[k]) > MinDCTValue)
              DCTnonzeroHist[k]++;
           }
       }
   }

/* Estimate blur via weighting matrix */
blur = 0;
for (every DCT component k) /* 0 <= k < 64 */
/* add the corresponding weight for all
```

I-frame. Quality 78% P-frame. Quality 75% B-frame. Quality 85%

Figure 3: Typical frames with associated quality percentage

```
   coefficients with a sufficient number of
   occurences */
if (DCTnonzeroHist[k] <
      MaxHistValue*DCTnonzeroHist[0])
   blur += Weight[k];

/* divide by the sum of all weights */
blur /= WeightTotal;

/* 1-blur is the quality percentage of the
   frame in terms of blur */
```

3. APPLICATION TO MPEG VIDEO

In order to validate the proposed method for blur measurement, the method was tested on different sequences. Randomly selected pictures were analyzed and all images of a same type (I, P or B) were then rank ordered from the best one (less blurred) to the worst one. The automatic ranking was then presented to several users for manual evaluation The manual evaluation shown that the classification obtained by the proposed method generally agreed with that by human users.

From the evaluation results, it appears that the proposed blur estimation works properly for all three types of images, although it is often better for I-frames than for P or B ones. This is because if motion compensation provides a close to perfect prediction in a P- or B-frame, there may not be enough blocks with residual DCT coefficients in the frame needed in order to establish the quality index. Such cases will generate unstable and inaccurate result in blur detection using our proposed method. Figure 3 presents three consecutive frames of a MPEG stream along with the associated quality percentage. One can effectively notice that all image types actually have very similar visual quality, although blur measures produced by the method differ. However, the difference in blur measure between different types of frames are usually not significant as shown in Figure 3. In contrast, figure 4 shows another I-frame whose quality is obviously not as good and the associated quality percentage does indicate this fact.

The algorithm thus allows to associate a quality index to images with satisfactory performance. It is also particularly relevant for comparing the quality of different images of a same type.

However, the proposed blur detection method will nevertheless sometimes produce misclassifications for two types of images:

- Over-illuminated images or dark images, like the one of figure 5, are considered of bad quality although it is not directly imputable to blur. Nevertheless, this misclassification is not annoying since such images are effectively not suitable neither as for printing nor as good key-frames, which are our major applications of the proposed method.
- Images that only contain some text in front of a uniform background (cf. figure 6) are considered as almost totally blurred. This is due to the low impact of the only few blocks containing text on the final histogram.

4. CONCLUSION

In this paper, we have presented a simple yet robust method to qualify the global (camera) blur present in images. It is based on the occurrence histogram of non-zero DCT coefficients among all the 8×8 blocks of a frame. The technique is therefore directly applicable in the JPEG or MPEG compressed image without decompression. When applied to MPEG video, the

Figure 4: I-frame with quality 39%

Figure 5: B-frame with quality 18%

Figure 6: P-frame with quality 29%

method is effective for any type of images (I-, P- or B-frames). Experiments have shown that the image quality percentage produced by the proposed method is in concordance with subjective testing. Since it is able to effectively produce a qualitative blur measure, the method is suitable for video frame characterization and can serve as an add-on tool in video key-frames extraction process. It can also serve to determine which frames of a video sequences are most likely to be good stills (possibly at super-resolution).

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