Detecting Doubly Compressed JPEG Images by Using Mode Based First Digit Features

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***Abstract*—In this paper, we utilize the probabilities of the first digits of quantized DCT (Discrete Cosine Transform) coefficients from individual AC (Alternate Current) modes to detect doubly compressed JPEG images. Our proposed features, named by *Mode Based First Digit Features* (MBFDF), have been shown to outperform all previous methods on discriminating doubly compressed JPEG images from singly compressed JPEG images. Furthermore, combining the MBFDF with a multi-class classification strategy can be exploited to identify the quality factor in the primary JPEG compression, thus successfully revealing the double JPEG compression history of a given JPEG image.**

I. Introduction

Discrete Cosine Transform (DCT) based JPEG lossy compression is the most popular scheme for image compression nowadays. In this scheme, source image samples are firstly grouped into non-overlapped and consecutive 8×8 blocks and each block is transformed by forward DCT into a set of 64 values referred to as DCT coefficients. The value located in the upper-left corner of the block is called DC (Direct Current) coefficient and the other 63 values are called AC (Alternate Current) coefficients. All the coefficients located in the same position within each of the 8×8 block form a ***mode*** (or called sub-band). In the next step, an 8×8 quantization table, consisting of 64 integer-valued ***quantization steps*** (QSs), is used to quantize the DCT coefficients. DCT coefficients from the same mode share the same QS. Although the quantization table can be arbitrarily defined, there is a standard quantization table recommended by JPEG standard [1]. Trade-off between visual quality and compression rate can be achieved by using a proper ***quality factor*** (QF), where QF=100 has the smallest quantization steps thus leading to the best quality and the least compression rate, and vice versa for QF=1. The standard quantization table corresponds to QF=50. Finally, the quantized DCT (QDCT) coefficients are further encoded into a bit-stream by applying entropy coding.

In practical scenarios, some images may not be compressed only once by JPEG lossy compression. For example, some forged images were originally stored in JPEG formats, then tempered in the decompression formats, and finally saved in JPEG formats again. The image has suffered JPEG compression twice. Identifying the double JPEG compression history may be an initial step to detect image forgeries. We have two main concerns with the issue of double JPEG compression detection. One is to differentiate the doubly compressed JPEG images, of which the quality factors in the primary compression and the secondary compression are different, from the singly compressed JPEG images. Another is to estimate the quality factor used in the primary compression of a doubly compressed JPEG image.

Three works [2]-[4] have been presented aiming to solve the problems. Lukas and Fridrich [2] studied how the shape of the histogram of QDCT coefficients is changed by the secondary JPEG compression. Then, three different approaches were proposed to estimate the QSs used in the primary compression. Two of them were claimed to be computationally expensive and not very reliable [2]. The most successful method in [2] is to use the histogram of the absolute values of the QDCT coefficients, whose values are in the range of 2 to 15, as features. These features are fed into a neural network for multi-class classification. Hence the QSs in the primary compression can be identified.

In another independent study, Popescu [3] also noticed that different quantization steps between the primary and the secondary compression introduce some abnormal statistical patterns in the histogram of QDCT coefficients. Hence he presented a detection method based on a periodicity measure, which evaluates whether the Fourier transform of the histogram has certain artifacts. If the answer is "yes" for at least one of the first 10 AC modes of a JPEG image, then the image is regarded as a doubly compressed one.

Based on the generalized Benford's law, Fu et al. [4] suggested utilizing the distribution of the first digits of QDCT coefficients from *all* AC modes to detect double JPEG compression. They found out that double compression would cause the distribution of the first digits violating the generalized Benford's law. However, the details of a double JPEG compression detection scheme and its performance were not reported in [4].

In this paper, we propose to use the probabilities of the first digits of QDCT coefficients from *individual* AC modes as features to detect doubly compressed JPEG images. With a two-class classification strategy, doubly compressed JPEG images and singly compressed JPEG images can be differentiated. When a multi-class classification is employed, the QF in the primary compression can be identified.

The rest of the paper is organized as follows. In Section 2, we report the results obtained by employing the features suggested in [4], named ***Global First Digit Features*** (GFDF), for two-class classifications. The results show that the performance of GFDF is comparable to the results reported in [3], but it has some limitations. Hence, in Section 3, we develop ***Mode Based First Digit Features*** (MBFDF), which are derived from the probabilities of first digits from individual AC modes. Our experimental study indicates the distributions of first digits from some individual AC modes do not follow the generalized Benford's law well. However, the first digit features from individual AC modes can still be effectively used for a digital forensics purpose, i.e., detecting double JPEG compression. Experimental results show that MBFDF outperforms GFDF. We also report the two-class classification results on using the features introduced in [2], called ***Absolute Histogram Features*** (AHF) in this paper, for comparison. The performance of AHF is shown to be slightly superior to GFDF but inferior to MBFDF. In Section 4 we demonstrate that the primary QF in a doubly compressed JPEG image can be identified by using MBFDF with a multi-class classification strategy. Discussions and conclusions are given in Section 5.

If it is not specified, we refer to QDCT coefficients in the rest of the paper as the quantized AC DCT coefficients in the luminance channel, for either gray-scale images or color images.

II. Results on Detecting Doubly Compressed JPEG Images by Using GFDF

It is well known that the distribution of the QDCT coefficients of a singly compressed JPEG image follows a generalized Laplacian distribution [5] or Cauchy distribution [6]. In [4], Fu et al. observed that the distribution of the first digits of all QDCT coefficients of a singly compressed JPEG image follows a parametric logarithmic function, called generalized Benford's law, as follows:

$$p(d) = N\log_{10}(1+\frac{1}{s+d^{q}}),\ d \in \{1,\ 2,\ ...,\ 9\} \qquad (1)$$

where N is a normalization factor which makes $p(d)$ a probability distribution, and s and q are model parameters to precisely describe the distributions for different images with different quality factors. Assume x is a non-zero integer. The first digit of x can be computed as:

$$d = \left\lfloor \frac{x}{10^{\lfloor \log_{10} x \rfloor}} \right\rfloor \qquad (2)$$

where $\lfloor \cdot \rfloor$ is the operation of floor rounding.

Due to the different quality factors used in the primary and secondary JPEG compression, the QDCT coefficients of a doubly compressed JPEG image suffered from quantization twice with different quantization steps. Hence the distribution of QDCT coefficients may no longer follow a generalized Laplacian distribution or Cauchy distribution. Violation of the generalized Benford's law may also be visually observed in the distribution of the first digits of QDCT coefficients [4]. Figure 1 demonstrates the first digit distribution of all QDCT coefficients for a random selected doubly compressed JPEG image (primary-QF=75 and secondary-QF=85) and that for a singly compressed counterpart (QF=85). Obviously, the distribution for the doubly compressed image violates a logarithmic trend.

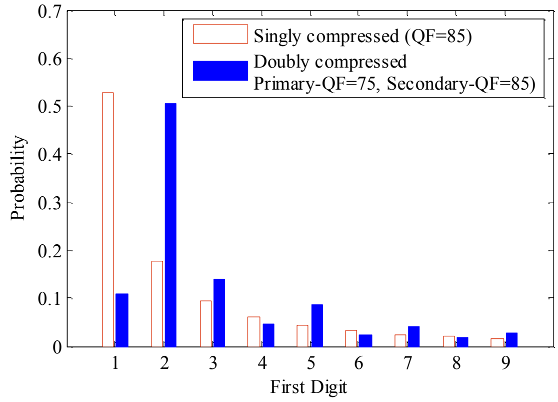

Fig.1. Distributions of first digits for a random selected doubly compressed JPEG image (primary-QF=75 and secondary-QF=85) and its singly compressed counterpart (QF=85). The distribution for the doubly compressed image violates a logarithmic trend.

Features extracted from the distribution of the first digits of all QDCT coefficients should be promising for classifying doubly compressed JPEG images from singly compressed JPEG images. However, the detail performance is not reported in [4]. Hence, we conduct experiments and give the results here by using the first digit distribution of all QDCT coefficients, as suggested in [4].

In our experiments, 1338 uncompressed images with the size of 384×512 (or 512×384) in UCID [7] are used for evaluation. Doubly compressed JPEG images are generated by consecutively compressing the images by a primary quality factor (QF1) and a secondary quality factor (QF2). Singly compressed JPEG images have the same quality factor as QF2. Several pairs of primary QF and secondary QF, ranging from 50 to 95 with a step size of 5, are used for demonstration as did in [3]. The probabilities of the first digits for all QDCT coefficients, denoted by $p(d)$ ($d\in\{1, 2, \dots, 9\}$) form a feature vector of 9 dimensions. We name the features as ***Global First Digit Features*** (GFDF). A simple and effective supervised learning algorithm, Fisher Linear Discriminant (FLD) analysis [8], is used for two-class classification. Of course, other supervised learning algorithms can also be employed. 1138 randomly selected doubly compressed images and their singly compressed counterparts are used for training an FLD classifier. The remaining 200 doubly compressed images and their counterparts are used for testing. We define the doubly compressed JPEG images as the positive class and the singly compressed JPEG images as the negative class. The classification accuracy, which is computed as (True Positive + True Negative)/2, is averaged over 20 times of experiments by randomly selecting the training and testing images. If not specified, the experiments in the rest of this paper have used the same setting. Table I gives the classification accuracies. We also show the results reported by [3] in Table II, where the results are the True Positive rates derived from 100 images

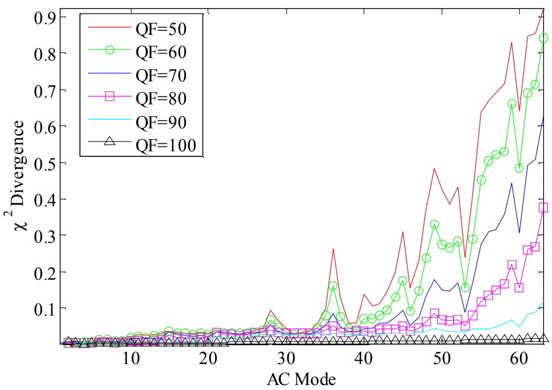

Fig. 2. The χ^2 divergence between the actual first digits distribution and the generalized Benford's Law for each AC mode (in zigzag order). The values of χ^2 divergence for each quality factor (QF) are averaged over 1338 UCID images.

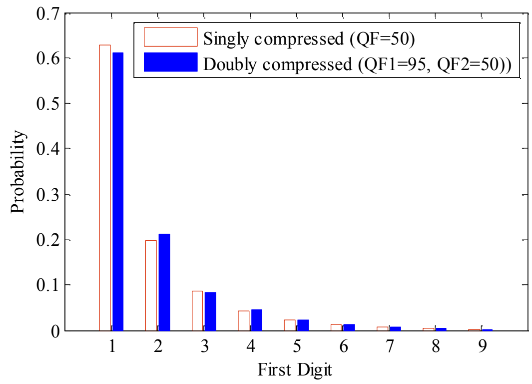

Fig. 3. Mean values of the probabilities of first digits in the 11th mode for 1338 doubly compressed JPEG image (QF1=95 and QF2=50) and their corresponding singly compressed JPEG image (QF=50).

different from UCID images, and the True Negative rates are all set to 100%. There are five cases (QF1=95 and QF2=50/50/70/75/80) that are undetectable by the method in [3]. As we can see, the results of GFDF are comparable to those in [3]. In four cases, i.e., QF1=95 and QF2=50, 55, 60 or 65, the performance of GFDF is close to or only slightly above a random guessing (50%). For the upper-right-triangle portion of Table I, where QF1<QF2, GFDF always gets a successful detection accuracy. The detection rates in the lower left portion of the table, where QF1>QF2, are not as high as those in the upper-right-triangle portion of the table. The reason will be explained in the next section.

III. Mode Based First Digit Features

The feasibility of double JPEG compression detection owes to the fact that the quantization steps in the primary compression are different from those in the secondary compression. The values of DCT coefficients before the secondary quantization are close to the multiples of the primary quantization step (QS1). If the secondary quantization step (QS2) is not an integer multiple of the QS1, double compression may introduce different QDCT coefficients from single compression. Otherwise, there are few differences in QDCT coefficients between the singly compressed and doubly compressed images [2][3]. We call an AC mode where QS2 is not an integer multiple of QS1 as ***distinguishable mode***. When QF1>QF2, especially when QS1 is close 1 or 2, the chance for QS2 being an integer multiple of QS1 is large. Even though we may have some distinguishable modes, unfortunately, GFDF only focuses on the statistics of *all* QDCT coefficients so that the influences of the *individual* distinguishable modes have been weaken. This explains why the performance of GFDF is not so good in the cases of large QF1 and small QF2, i.e., the lower left triangle portion of the Table I. Therefore, we propose to use the first digit features extracted from individual modes for classification. We name them ***Mode Based First Digit Features*** (MBFDF). In this way, the limitation in GFDF of being unable to capture the difference in distinguishable modes can be eliminated or at least reduced.

We denote the 63 AC modes in the zigzag order by i ($i \in \{1, 2, \ldots, 63\}$). A question may arise on whether the first digit distribution of each individual AC mode fits the generalized Benford's law well. To this end, we use the χ^2 divergence [9] as a metric to measure the quality of fitting. The χ^2 divergence is defined as

$$\chi^2 = \sum_{d=1}^{9} \frac{(p_i(d) - \hat{p}_i(d))^2}{\hat{p}_i(d)} \tag{3}$$

where $p_i(d)$ ($d \in \{1, 2, \ldots, 9\}$) denotes the observed first digit distribution of QDCT coefficients in the i-th mode and $\hat{p}_i(d)$ ($d \in \{1, 2, \ldots, 9\}$) denotes the corresponding theoretical distribution. We use the Matlab Curve Fitting Toolbox to compute the parameters of theoretical distribution in Eq. (1). The smaller the value of the χ^2 divergence is, the better the observed distribution fits the generalized Benford's law.

Figure 2 shows the averaged values of χ^2 divergence over 1338 UCID images for each AC mode and for QFs from 50 to 100. We observe that low frequency AC modes are more prone to have small χ^2 divergence values than high frequency AC modes. Additionally, it can be observed that given a specific mode, images with a small QF have larger χ^2 divergence values than that with a large QF.

The results of χ^2 divergence tell us that the first digit distribution of QDCT coefficients from individual AC modes does not always fit the generalized Benford's law well, especially for the high frequency AC modes with low QFs. However, even though the distributions of first digits of individual modes do not strictly follow the generalized Benford's law, the operation of double quantization still introduces a statistical pattern different from single quantization. The difference can be reflected by effective features for double compression detection. Figure 3 demonstrates the mean values of the probabilities of first

2	1	1	2	2	4	5	6
1	1	1	***2***	***3***	6	6	6
1	1	2	2	4	6	7	6
1	***2***	2	3	5	9	8	6
2	2	4	6	7	11	10	8
2	4	6	6	8	10	11	9
5	6	8	9	10	12	12	10
7	9	10	10	11	10	10	10

16	11	10	16	24	40	51	61
12	12	14	***19***	***26***	58	60	55
14	13	16	24	40	57	69	56
14	***17***	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Fig. 4. The quantization steps for QF=95 (left) and QF=50 (right). The QSs in the first 20 AC modes are highlighted. The non-integer multiple quantization step pairs are marked with underlined boldface font.

digits of QDCT coefficients in the 11th mode for 1338 doubly compressed images (QF1=95 and QF2=50) and their singly compressed images (QF=50). Although the differences are small, through pattern recognition techniques, the differences can be learned and used for classification.

Only the first 10 modes in the zigzag order are used in the detection scheme of [3]. The author claimed that for high frequency AC mode, the support of the histogram of QDCT coefficients is too narrow to work with. We propose to use the probabilities of the first digits of QDCT coefficients in the first K ($1 \leqslant K \leqslant 63$) AC modes in the zigzag order. In our experiments, we use K=20 in order to keep a low dimensionality and yet hoping that they can still cover some distinguishable modes. For example, in the case of QF1=95 and QF2=50, which is indistinguishable in [3] and GFDF, the quantization steps of the first 10 modes of QF=50 are all integer multiples of that of QF=95. But when we use the first 20 modes, it covers 3 non-integer-multiple QS pairs, as it is illustrated in Fig. 4.

In the MBFDF scheme, we use $p_i(d)$ ($i \in \{1, 2, \dots, 20\}$ and $d \in \{1, 2, \dots, 9\}$) to form a feature vector in 20×9=180 dimensions. The two-class classification strategy and the training-testing set splitting method are the same as the experiments for GFDF. The 20-time averaged classification results are shown in Table III. As we can see, great improvements have been achieved for the lower-left-triangle portion of the table. All of the undetectable cases in [3] and GFDF are detectable now.

We also employ the features proposed in [2] for comparison. The features are extracted from the normalized histogram of the absolute values of QDCT coefficients, whose values are in the range of 2 to 15. We name the features by ***Absolute Histogram Features*** (AFH). In [2], two AC modes (2nd and 3rd modes in the zigzag order) are used for illustrative purpose. Here for a fair comparison, we extract the AHF from the first 20 AC modes. As a result, there will be a feature vector in 20×14=280 dimensions. The same FLD classifier and training-testing set splitting method are used. As it is shown in Table IV, AHF performs better than GFDF but not as well as MBFDF in the lower-left-triangle portion.

IV. Identify the Primary QF by Multi-class Classification

In previous sections, we use the two-class classification strategy to distinguish the doubly compressed and singly compressed JPEG images. It has been demonstrated that our proposed features, MBFDF, outperforms all of the prior arts [2]-[4]. But the two-class classification cannot be applied immediately to practical scenarios for identifying the doubly compressed JPEG image. This is because the QF in the primary compression is assumed to be given in the two-class classification. In practice, however, we do not have any prior knowledge of the primary QF. Fortunately, we can achieve the goal of identifying the primary QF by using a "one-against-one" multi-class classification strategy [8]. In this strategy, we construct $C(C\text{-}1)/2$ binary classifiers for a total number of C classes. Each class represents a candidate primary QF and each classifier discriminates between two classes. A feature vector, extracted from the testing image, is assigned to a target class using each classifier in turn and a majority vote is taken. The maximum voted class is selected as the target class.

The FLD is still used as a binary classifier in the multi-class classification strategy. 1138 random selected singly compressed images and their various kinds of corresponding doubly compressed realizations with QF1=50 to 95 are used for training the FLD classifiers. The remaining 200 singly compressed images and their doubly compressed counterparts are used for testing. The multi-class classification results for QF2=50 and 70, which are averaged over 20 times for randomly selecting training and testing images, are shown in Table V and VI, respectively. As we can observe, except for the class of single compression by QF=50 versus the class of double compression by QF1=95 and QF2=50, other classes are seldom misclassified, which means the primary QF can be identified correctly in most of the cases.

V. Discussions and Conclusions

In this paper, we propose to extract features from the probabilities of the first digits of quantized DCT coefficients from individual AC modes, named by Mode Based First Digit Features (MBFDF), to handle the issue of double JPEG compression detection. Compared with the Absolute Histogram Features (AHF) originally proposed by [2] (but extended from using only 2 AC modes to using 20 AC modes reported in this paper), the results reported by [3], and the Global First Digit Features (GFDF) suggested by [4], our proposed features perform the best in classifying the doubly compressed and singly compressed JPEG images.

In a distinguishable mode, where the secondary quantization step is non-integer multiple of the primary quantization step, the QDCT coefficients are different for doubly compressed JPEG images and singly compressed JPEG images. The differences can be observed by extracting the statistics of the coefficients. The features used in [2] and

[3] are extracted from the histograms of the QDCT coefficients. And the effectiveness of GFDF and MBFDF are attributed to the first digit distribution. The relation between first digit features and histogram based features can be regarded as that a histogram feature space is *non-linearly* and *compactly* mapped into a 9-dimensional first digit feature space. Additionally, MBFDF compensates the limitation of GFDF by capturing the changes which introduced by double compression in individual AC modes.

Utilizing the multi-class classification strategy with MBFDF, the primary quality factors of doubly compressed JPEG images can also be effectively identified. The success of MBFDF shows a promising way for double JPEG compression detection and other digital forensics purposes.

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TABLE I

CLASSIFICATION RESULTS USING GFDF. THE RESULTS, COMPUTED AS (TRUE POSITIVE + TRUE NEGATIVE)/2, ARE AVERAGED OVER 20 TIMES. THE PRIMARY QUALITY FACTOR IS HELD CONSTANT ON THE ROWS AND THE SECONDARY QUALITY FACTOR IS HELD CONSTANT ON THE COLUMNS.

QF1 \ QF2	50	55	60	65	70	75	80	85	90	95
50	–	99%	100%	100%	100%	100%	100%	100%	100%	100%
55	96%	–	99%	100%	100%	100%	100%	100%	100%	100%
60	100%	98%	–	98%	100%	100%	100%	100%	100%	100%
65	100%	100%	94%	–	100%	100%	100%	100%	100%	100%
70	99%	100%	100%	99%	–	100%	100%	100%	100%	100%
75	93%	97%	100%	100%	100%	–	100%	100%	100%	100%
80	99%	94%	94%	100%	100%	100%	–	100%	100%	100%
85	88%	72%	97%	98%	98%	99%	100%	–	100%	100%
90	76%	87%	80%	91%	96%	98%	93%	100%	–	100%
95	52%	51%	56%	53%	61%	60%	74%	73%	94%	–

TABLE II

RESULTS REPORTED BY [3]. THE RESULTS ARE TRUE POSITIVE RATES DERIVED FROM 100 IMAGES. THE TRUE NEGATIVE RATES ARE ALL 100%. *N/D* STANDS FOR NOT DETECTABLE.

QF1 \ QF2	50	55	60	65	70	75	80	85	90	95
50	–	100%	100%	100%	100%	100%	100%	100%	100%	100%
55	70%	–	99%	100%	100%	100%	100%	100%	100%	100%
60	98%	85%	–	100%	100%	100%	100%	100%	100%	100%
65	100%	100%	100%	–	100%	100%	100%	100%	100%	100%
70	100%	100%	100%	97%	–	100%	100%	100%	100%	100%
75	93%	100%	100%	100%	100%	–	100%	100%	100%	100%
80	96%	100%	98%	100%	100%	100%	–	100%	100%	100%
85	74%	65%	100%	98%	100%	100%	100%	–	100%	100%
90	48%	63%	78%	89%	99%	100%	100%	100%	–	100%
95	*N/D*	*N/D*	73%	98%	*N/D*	*N/D*	*N/D*	100%	100%	–

TABLE III

Classification Results using MBFDF. The results, computed as (True Positive + True Negative)/2, are averaged over 20 times.
The primary quality factor is held constant on the rows and the secondary quality factor is held constant on the columns.

QF1 \ QF2	50	55	60	65	70	75	80	85	90	95
50	–	100%	100%	100%	100%	100%	100%	100%	100%	100%
55	99%	–	100%	100%	100%	100%	100%	100%	100%	100%
60	100%	100%	–	100%	100%	100%	100%	100%	100%	100%
65	100%	100%	100%	–	100%	100%	100%	100%	100%	100%
70	100%	100%	100%	100%	–	100%	100%	100%	100%	100%
75	97%	100%	100%	100%	100%	–	100%	100%	100%	100%
80	100%	100%	100%	100%	100%	100%	–	100%	100%	100%
85	100%	100%	100%	100%	100%	100%	100%	–	100%	100%
90	98%	99%	100%	100%	100%	100%	100%	100%	–	100%
95	78%	83%	93%	98%	95%	98%	99%	100%	100%	–

TABLE IV

Classification Results using AHF, which originally proposed by [2] but extended from using 2 AC modes to using 20 AC modes.
The results, computed as (True Positive + True Negative)/2, are averaged over 20 times.
The primary quality factor is held constant on the rows and the secondary quality factor is held constant on the columns.

QF1 \ QF2	50	55	60	65	70	75	80	85	90	95
50	–	100%	100%	100%	100%	100%	100%	100%	100%	100%
55	99%	–	100%	100%	100%	100%	100%	100%	100%	100%
60	100%	100%	–	100%	100%	100%	100%	100%	100%	100%
65	100%	100%	100%	–	100%	100%	100%	100%	100%	100%
70	100%	100%	100%	100%	–	100%	100%	100%	100%	100%
75	93%	100%	100%	100%	100%	–	100%	100%	100%	100%
80	100%	100%	99%	100%	100%	100%	–	100%	100%	100%
85	99%	99%	100%	100%	100%	100%	100%	–	100%	100%
90	92%	96%	98%	98%	99%	100%	100%	100%	–	100%
95	62%	66%	76%	83%	80%	87%	95%	100%	100%	–

TABLE V

Multi-class classification results for QF2=50.
The actual compression quality factors are held on the rows and the estimated quality factors are held constant on the columns.

Actual	Estimated QF1-QF2									
QF1-QF2	**single(50)**	**55-50**	**60-50**	**65-50**	**70-50**	**75-50**	**80-50**	**85-50**	**90-50**	**95-50**
single(50)	75%	0%	0%	0%	0%	2%	0%	0%	1%	22%
55-50	1%	99%	0%	0%	0%	0%	0%	0%	0%	0%
60-50	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
65-50	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
70-50	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
75-50	2%	0%	0%	0%	0%	97%	0%	0%	0%	1%
80-50	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
85-50	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
90-50	2%	0%	0%	0%	0%	0%	0%	0%	98%	0%
95-50	20%	0%	0%	0%	0%	2%	0%	0%	1%	77%

TABLE VI

Multi-class classification results for QF2=70.
The actual compression quality factors are held on the rows and the estimated quality factors are held constant on the columns.

Actual	Estimated QF1-QF2									
QF1-QF2	**single(70)**	**50-70**	**55-70**	**60-70**	**65-70**	**75-70**	**80-70**	**85-70**	**90-70**	**95-70**
single(70)	93%	0%	0%	0%	0%	0%	0%	0%	0%	7%
50-70	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
55-70	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
60-70	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
65-70	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
75-70	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
80-70	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
85-70	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
90-70	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
95-70	4%	0%	0%	0%	0%	0%	0%	0%	0%	96%