CCITT SGXV
Working Party XV/1
Specialists Group on Coding for Visual Telephony

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TITLE : A PROPOSAL FOR CODING ALGORITHM

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1. Introduction

At the last meeting in Tokyo, transform-based algorithm with 8 x 8 blocksize was adopted as a basic algorithm. The importance of adaptavility in quantization of transformed coefficients and in variable length coding was also recognized as a key to improve coding efficiency and image quality. Annex 1/Document #103R summarizes the framework of adaptive quantization and coding strategy.

This document proposes a detailed coding algorithm as a continuation of Document #78 and #79, taking into account the summary of discussion in the last meeting, i.e. Document #103R, our experience in using the reference model and the recent study results on coding algorithm.

2. Guideline for Developing Coding Algorithm

There are many elements to be investigated in developing coding algorithms. Annex 1 and 2/Document #103R show typical examples of such elements. Since the reference model was specified in the last meeting, it seems to be a good way to compare proposed algorithms to the reference model item by item. However, the reference model itself does not give the sufficient quality and performance. Several improvements in the reference model have been introduced as described in Document #107 with keeping the framework of the original reference model, i.e. Document #104.

The reference model and the improved reference model are used to investigate coding algorithms. We also allow the use of frameworks which are not based on the reference model. Even in this case, care is paid to compare the effect of each technique without changing remaining parameters.

From the above study results, the desired combination of each element is chosen. However it is difficult to choose the best combination, because elements are related to each other and the combination of elements each of which gives the best result does not always give the best performance.

It is also important to examine coding algorithms from the viewpoint of hardware. The complexity of hardware should be considered in the selection of algorithms. For the purpose of specifying the basic structure of flexible hardware at first, it is important to clarify which elements are essential and which elements can be categorized in the range of flexibility.

3. Outline of Proposed Coding Algorithm

Blocks consisting of interframe prediction errors (with motion compensation) have a great variation depending on contents of images, movement of objects and so on. In order to code such blocks efficiently, an adaptive processing is essential.

In a proposed algorithm, the classification of each block is first carried out, then area of transmitted coefficients and code set for entropy coding are determined according to the class index. Outline of fundamental configuration of proposed coding algorithm is shown in Figure 1. It is almost the same as the configuration shown in Fig. 3/Annex 4/Document #103R. Functional blocks without description are the same as in Fig. 3/Annex 4/Document #103R. We use the DCT with blocksize 8 x 8 as the tranformer.

4. Proposed Coding Algorithm

A proposed coding algorithm is based on the algorithm discussed in Section 3.3/Document #78, taking into account the discussion in the last meeting in Tokyo and the recent study results on the coding algorithms including the reference model.

4.1. Classification

As for classification, it is required to specify the correspondence between class index and coding parameters, such as area of tranformed coefficients to be transmitted, variable length coding code sets and so on. Classification method itself is not relevant to compatibility.

The purpose of classification is to classify each block of prediction errors into a suitable class, where a class represents some characteristics of input block. Considering the performance and the simplicity in hardware implementation (refer to Document #79), classification is carried out as follows :

(1) Classification is carried out using the transformed coefficients before quantization.

(2) The minimum rectangle covering the all coefficients above a certain threshold (in absolute value) is detected. The number of possible rectangles is 64. Thus the variety of classes is 64. Of course, it may be possible to use less classes than 64. Optimization of the number of classes is left for further study.

Though the correspondence between each class index and coding parameters should be specified, the way to decide the actual relationship between them is left in the range of flexibility. There are the following two typical methods to define the actual relationship. Further study is required in order to compare their performance and select the better one.

(A) Using some kind of training technique

The statistical characteristics of blocks which belong to the same class is calculated as training prior to the design of codec. Typical example is the generation of variance tables for classes. The area of coefficients to be transmitted and suitable variable length coding code set are determined by using these variance tables.

(B) Without training technique

A rectangle zone detected in the classification process is directly used to determine the area of coefficients to be transmitted.

4.2. Transmitted coefficients

The determination of transmitted coefficients is important to represent the transformed result efficiently. Basically an area of transmitted coefficients is determined according to a class index. This area is then modified according to the assigned distortion, i.e. quantizer, to match the distribution of non-zero coefficients after quantization. Statistical characteristics of each class may be used to choose the proper area of transmitted coefficients.

From the above explanation, it is possible to define an area of transmitted coefficients as a function of class index and assigned distortion. Fugure 2 shows an example of this relationship.

Since the average zero run length in a transmitted area is rather short, the usage of zero run length is not attractive. We code both zero coefficients and non-zero coefficients in the same manner by using the variable length codes.

4.3. Quantization

DC component in intra mode block is linearly quantized with step size $g = 4$ and dead zone $d = 0.5\ g$ as shown in Figure 3 (a). This will be a great help to reduce block noises in background area and to improve the quality of decoded images.

Quantizer for DC component in inter mode block may be either independent of or identical to that for DC component in intra mode block or that for AC components. This requires the further study.

For AC components, the same type of quantizer is used in both intra and inter mode blocks. AC components are linearly quantized with dead zone d and step size g as shown in Figure 3 (b). The value of d is between 0.5 g and 1.0 g, and is determined depending on the value of g, that is, d is a function of g.

The same or different quantizers for luminance and chrominance signals are left for further study. However, we have not felt the necessity of different quantizers for each signal until now.

4.4. VLC for quantization index

Since the distribution of quantized levels have variations depending on sequencies, it is useful to prepare several variable length coding code sets (VLCs), each of which is designed according to typical distribution of quantized levels.

In summary, the following number of code sets are used,
- Intra DC component : 9 bit FLC,
- Inter DC component : one kind of VLC,
- AC components : n kinds of VLCs,
n = 4 may be sufficient. Whether it is possible to reduce this number or not is left for further study.

Above code sets are assigned to each coefficient according to a class index, distortion (applied quantizer) and coding mode (intra/inter). In this case, assignment of each code set is indicated by such table as shown in Figure 4. Each component in a table holds the index of VLC code set.

Determination of area of transmitted coefficients and assignment of VLC code sets to them play important roles in the coding process. Thus, we propose the implementation of above methods in the flexible prototype hardware so that we can evaluate their effects in the hardware and decide the desirable selection of algorithm and parameters.

4.5. Control

4.5.1. Coding control

From the simulation experience using the reference model, coding control based on a block or a group of blocks (GOB) does not work well. That is, the quality of decoded images is quite different in the upper and middle parts of image (rather good) and the bottom part of image (bad). Thus coding control should be carried out in such large unit as a frame. Detailed discussion on coding control is given in Document # 111.

4.5.2. Frame dropping control

Both a source buffer and a display buffer is required to carry out frame dropping control, where the number of dropping frames is variable (2:1 or 3:1). A source buffer and a display buffer stores an input frame and a decoded frame, respectively, during the period of two or three frames. Detailed discussion will be given in Document # 116.

5. Related Topics

5.1. Motion compensation

5.1.1. General

For motion compensation, integer displacement is preferred. As for coding method of motion vectors, block difference transmission is favored with run length coding of zero vectors.

Detailed discussion is described in Document # 114.

5.1.2. Motion compensation for chrominance signals

There are three methods to treat chrominance signals as described in Section 9/Document # 103R,

(a) derived from luminance
(b) none
(c) independent.

Performance of these three methods are varied depending on the contents of images, motion of colored objects and so on. (b) may be recommended, because it requires no extra hardware and no overhead information of motion vectors. Detailed discussion is given in Document # 112.

5.2. Significant/insignificant block identification

No comments at the moment.

5.3. Intra/inter mode selection

Intra/inter mode is determined according to the MC prediction error before transformation. Selection of intra/inter mode is not relevant to compatibility, but care should be paid to the following :

- intra mode should not be selected when the prediction errors are small enough,
- inter mode should not be selected when the prediction errors are large enough.

5.4. Scene cut detection

No comments at the moment.

5.5. Discarding of Significant Coefficients

As shown in the previous document # 79, the discarding of some of significant tranformed coefficients based on the characteristics of human visual perception is useful to improve the coding performance. Since the effect of this method has not been confirmed in the reference model yet, the further study is required to decide the adoption of this method. Detailed discussion is given in Document # 109.

5.6. Filter inside the coding loop

Adaptive application of some kinds of smoothing filter inside the coding loop may improve the image quality and coding efficiency. The type of filter and the condition of adaptivity are for further study. Some simulation experiments have been carried out and results are shown in Document # 110.

6. Conclusion

A proposed algorithm for the efficient coding of interframe prediction errors based on transform technique has been described. Several items which are not relevant to compatibility are left for further study.

Examples of decoded images obtained by the proposed coding algorithm will be demonstrated on VTR at the meeting. Annex of this document shows actual values of parameters used in the simulation.

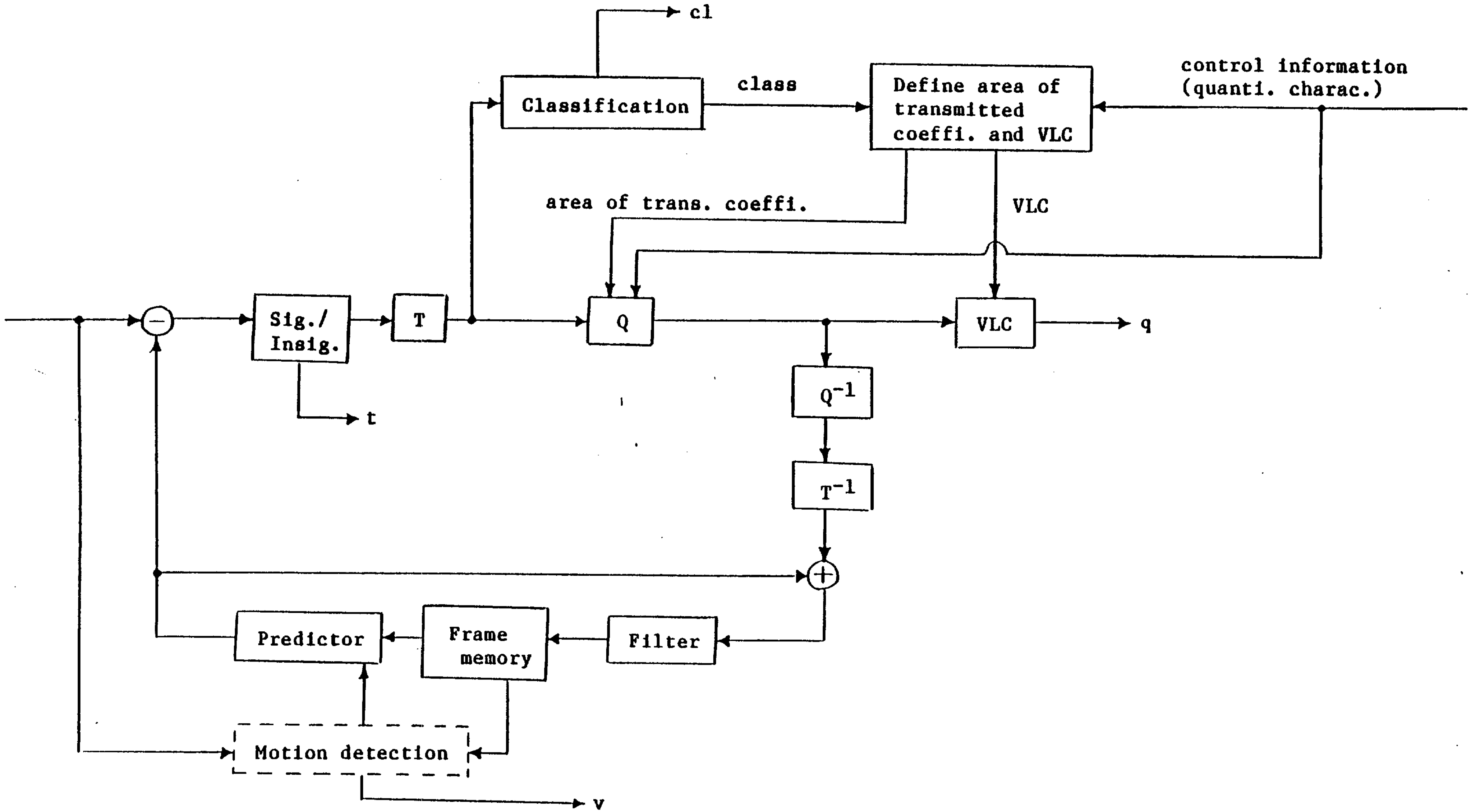


Figure 1. Outline of coding algorithm.

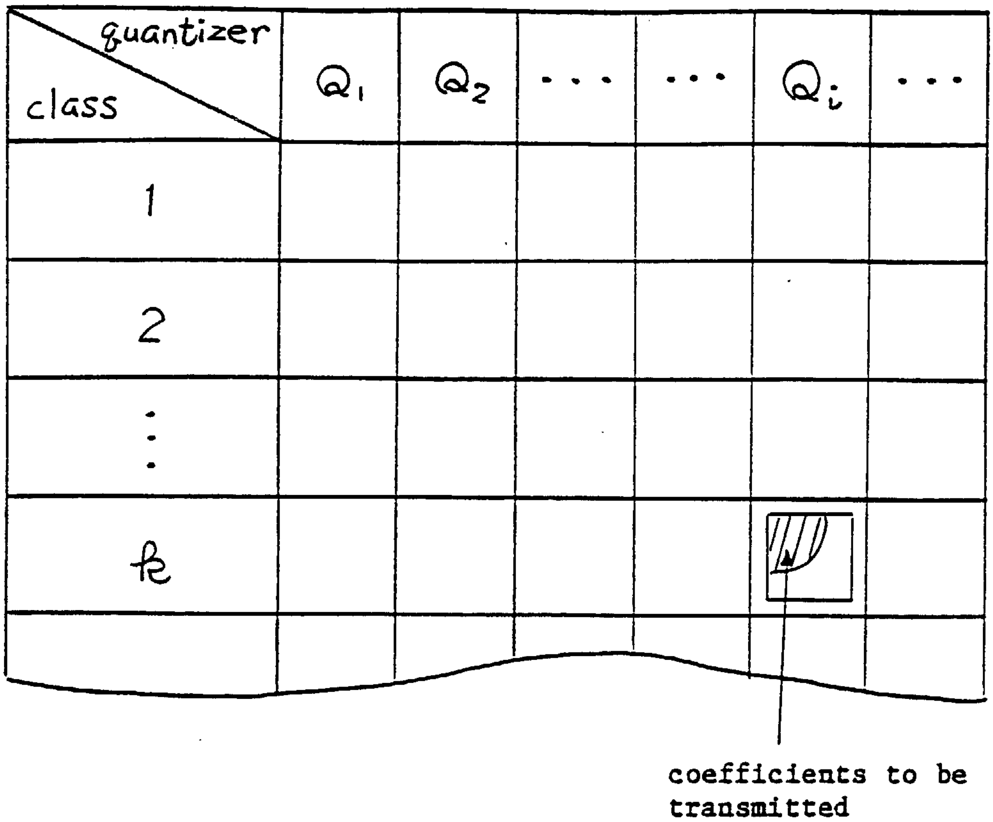
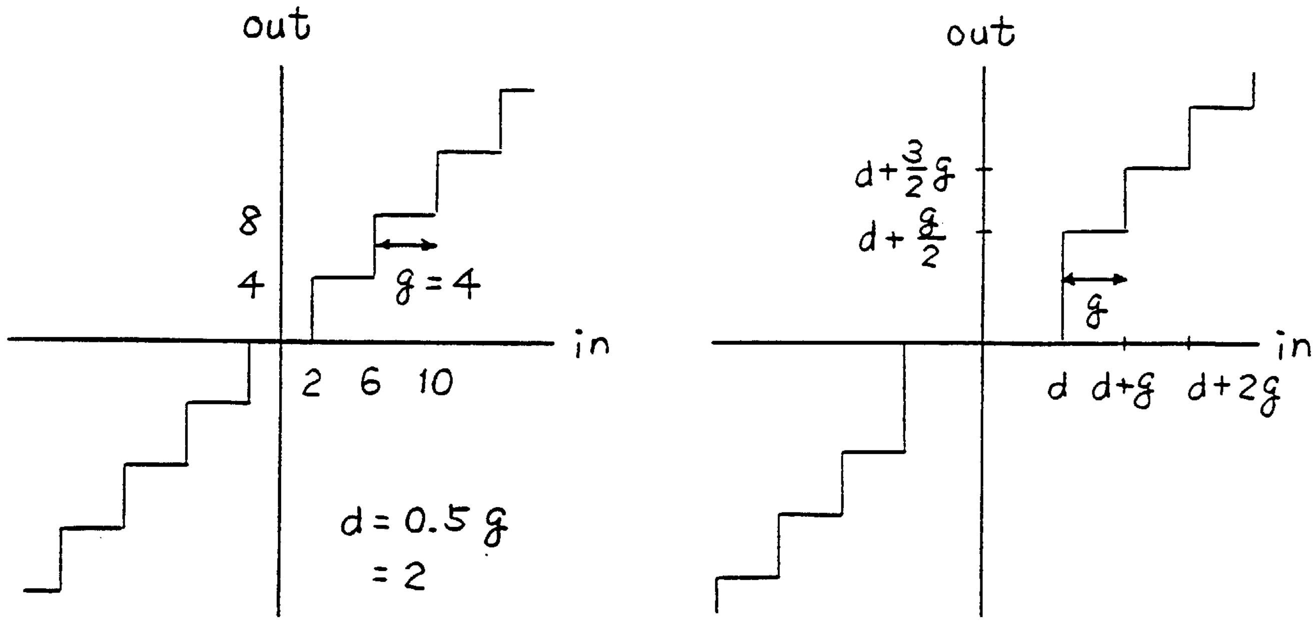


Figure 2. How to define area of transmitted coefficients.

v \ u	0	1	2	3	4	5	
0	A	B	C	D	E	Ø	
1	B	C	D	E	Ø		
2	C	D	E	Ø			
3	Ø	Ø	Ø				

A ~ E : VLC code sets
Ø : coefficients not to be transmitted

Figure 4. Examples of assignment of VLC code sets to each transformed coefficients. u and v represent horizontal and vertical sequencies, respectively.



(a) Quantizer for DC component - in intra mode block.

(b) Quantizer for AC components.

Figure 3. Quantizer for transformed coefficients. Linear quantizer with step size g and dead zone d (a function of g) is employed.

ANNEX to Doc. #108

SIMULATION RESULTS OF PROPOSED ADAPTIVE CONDING

This annex describes the simulation results of an adaptive zonal coding in which input signals are classified into several categories according to their power distribution in the coefficient domain. The simulated pictures are demonstrated at the meeting. The algorithm and parameters are varied step by step so that strict comparison can be achieved.

1. Methods of classification

The configuration of the simulated coding algorithms are shown in Figure 1/Document #108. For classification, minimum sized rectalgle are used as described in Sec. 4. 1/Document #108. Each rectangle corresponds to classification index.

VWL code set assignment table is designed using a long run test sequence, in which classification index and distortion (quantizer) give coded area and VWL code set.

2. Method of adaptive entropy coding

The input coefficients are scalar quantized, then quantized values are variable word length coded. The vwl code set assignment table which corresponds to each class index and distortion (quantizer) give coding area and a Huffman code set to each coefficient in the coding area.

Quantizers are changed to keep the fixed data rate. Quantizer characteristics are derived from buffer memory occupancy and classification result. Quantizer holds its characteristics during a frame period.

3. Simulation parameters and simulation results

Simulation parameters are shown in Table 1. 'Reference MOD 10' (Doc #104) and improved Ref MOD 14 (Doc #107) also appear in the table for comparison.

Simulation results are shown in Table 2 to Table 5.

Table 1 Simulation parameters

<table>
<tr><th colspan="2">Item</th><th>Ref MOD 10 (Doc #104)</th><th>Ref MOD 14</th><th>Proposed method</th></tr>
<tr><td colspan="2">Sig/insig bloc detection</td><td colspan="2">After quantization</td><td>Before quantization</td></tr>
<tr><td colspan="2">inter/intra detection</td><td colspan="2">After quantization</td><td>Before quantization</td></tr>
<tr><td rowspan="3">Quant-izer</td><td>intra DC</td><td colspan="3">9 bit linear</td></tr>
<tr><td>inter DC, AC</td><td colspan="2">Linear with 1.5g dead zone</td><td>Linear with 0.5g dead zone</td></tr>
<tr><td>Y/C</td><td colspan="3">Same</td></tr>
<tr><td colspan="2">Quantizer control</td><td>Block basis</td><td colspan="2">Frame basis</td></tr>
<tr><td colspan="2">Determination of transmitted coefficients</td><td colspan="2">Threshold coding with zig-zag scan</td><td>Zonal coding based on class and distortion</td></tr>
<tr><td colspan="2">Classification</td><td colspan="2">None (but EOB)</td><td>Min. rectangle (includes all sig. coeffs)</td></tr>
<tr><td colspan="2">VWL</td><td>One for coef
One for EOB</td><td>Modified for large levels</td><td>Four for a.c. coefficients</td></tr>
<tr><td colspan="2">Table for coding</td><td colspan="2">None</td><td>VLC and zone table</td></tr>
<tr><td rowspan="2">MC</td><td>Detection</td><td>Off with |FD|</td><td colspan="2">Off with |FD| and |DFD|</td></tr>
<tr><td>Other param.</td><td colspan="3">Same (See Doc. #107)</td></tr>
<tr><td colspan="2">Filter inside the coding loop</td><td>None</td><td colspan="2">Adaptive median filter</td></tr>
<tr><td colspan="2">Prefilter</td><td>None</td><td colspan="2">Temporal filter</td></tr>
<tr><td rowspan="3">Block attri-bute</td><td>Block type</td><td>2 bit/block</td><td colspan="2">Y/C for GOB
Scene cut for PSC</td></tr>
<tr><td>Q. step</td><td>3 bit/block</td><td colspan="2">GOB</td></tr>
<tr><td>MC</td><td colspan="3">8 bit/block</td></tr>
</table>

Table 2 Simulation results (1) MISS AMERICA

* ITEM	REF MOD 10 (DOC #104)	REF MOD 14	PROPOSED METHOD
STEP VALUE		6. 8	10. 2
THRESHOLD VALUE		10. 2	10. 2
SIGNIFICANT COEFFICIENTS		3. 0	5. 3
SENT COEFFICIENTS		12. 2	9. 5
ATTRIBUTE	See	3469	3423
MC VECTOR	Doc # 107	1932	1947
BIT EOB/CLASS		1965	2567
SQ		13214	12525
LUMINANCE		74. 7	73. 2
CHROMINANCE		25. 3	26. 8
SIGNIFICANT BLOCK		664	590
INTRA BLOCK		0	0
S/N (dB)	38. 79	42. 00	42. 13

* Key words are represented in Annex to Document #107.

Table 3 Simulation results (2) CHECKED JACKET

* ITEM	REF MOD 10 (DOC-#104)	REF MOD 14	PROPOSED METHOD
STEP VALUE		8. 2	11. 6
THRESHOLD VALUE		12. 3	11. 6
SIGNIFICANT COEFFICIENTS		3. 7	8. 4
SENT COEFFICIENTS		21. 3	16. 4
ATTRIBUTE	See	3137	2997
MC VECTOR	Doc # 107	1046	1002
BIT EOB/CLASS		1915	2257
SQ		15281	14741
LUMINANCE		92. 6	90. 7
CHROMINANCE		7. 4	9. 3
SIGNIFICANT BLOCK		546	459
INTRA BLOCK		0	0
S/N (dB)	37. 45	39. 48	40. 29

* Key words are represented in Annex to Document #107.

Table 4 Simulation results (3) SPLIT-TREVOR

* ITEM	REF MOD 10 (DOC #104)	REF MOD 14	PROPOSED METHOD
STEP VALUE	See Doc #107	10.7	18.2
THRESHOLD VALUE		16.1	17.2
SIGNIFICANT COEFFICIENTS		4.1	6.9
SENT COEFFICIENTS		14.0	12.9
ATTRIBUTE		3482	3455
MC VECTOR		4017	4039
BIT EOB/CLASS		3190	4033
SQ		21010	20082
LUMINANCE		91.2	90.0
CHROMINANCE		8.8	10.0
SIGNIFICANT BLOCK		791	696
INTRA BLOCK		15	15
S/N (dB)	35.62	38.20	38.33

* Key words are represented in Annex to Document #107.

Table 5 Simulation results (4) GRAPHIC

* ITEM	REF MOD 10 (DOC #104)	REF MOD 14	PROPOSED METHOD
STEP VALUE	See Doc #107	21.4	24.2
THRESHOLD VALUE		32.1	18.0
SIGNIFICANT COEFFICIENTS		2.2	7.0
SENT COEFFICIENTS		28.4	22.7
ATTRIBUTE		3287	2853
MC VECTOR		147	90
BIT EOB/CLASS		2348	2569
SQ		27956	28270
LUMINANCE		90.8	83.1
CHROMINANCE		9.2	16.9
SIGNIFICANT BLOCK		791	615
INTRA BLOCK		0	0
S/N (dB)	No data	30.68	32.00

* Key words are represented in Annex to Document #107.