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TITLE : ADAPTIVE QUANTIZATION AND CODING

1. Introduction

Adaptive control of quantization and entropy coding parameters in transform-based algorithm is one of the most important subjects to attain high coding efficiency, and some adaptive coding methods have been proposed in the past meetings. It is necessary to clarify their merit and demerit in standardizing a unique coding algorithm for n x 384 kbit/s codec.

This contribution compares three classification methods for adaptive coding, and also describes parameters as being the subjects to the adaptive control. Three adaptive coding algorithms are compared, which are realized by combining the classification method with the properly selected adaptive control parameters. After the coding performances are evaluated by computer simulation, we propose an algorithm as the first priority from the viewpoints of picture quality and hardware simplicity.

2. Adaptive control

In the Ipswich meeting, demonstrations showed the effectiveness of the adaptive controls of quantizer and/or entropy coder. When the adaptive control is so designed as to change the quantizer and/or the entropy coder parameters to fit to local characteristics of the transformed coefficients, the excellent coding performance can be expected. In applying the adaptive control, however, care must be paid to the inherent side informations to be transmitted, since side information sometimes degrades total coding efficiency. The parameters listed below are the subjects of adaptive control.

a. Truncation of significant coefficients
   - zone size (coefficients outside the zone are truncated)
   - isolated coefficients, etc.

b. Quantization
   - dead zone
   - step size, etc.

c. Entropy coding
   - Huffman code table to code non-zero values
   - scanning method of run-length coding of zero values, etc.

2.1 Classification

The adaptive control is carried out by classifying the transformed coefficient block into several groups based on the characteristics of the block. We have examined several control methods and obtained three candidates for classification. These methods use either prediction error signals or prediction coding informations for classification.

Classification method 1: Vector quantization is carried out for transformed coefficients. This vector index classifies input signals.

Classification method 2: Binary labeling is carried out for transformed coefficients using certain threshold. Then binary pattern matching is carried out to detect outer edge figure, which is covered the smallest figure of predetermined shape, such as a rectangle or a triangle, containing all of significant binary signals inside. The detected result is used to decide the class. This method is similar to method 1 in the sense that both use the statistical property for classification, but very much simplified.

Classification method 3: The motion vector for interframe prediction is used to decide the class.

2.2 Coding parameters

Regarding the treatment of parameters, our experiments have shown that following parameter control is favorable to attain high coding performance.

Truncation of significant coefficients: One way is the statistical truncation method, which can be applied to classification 1 and 2. In this method the encoding area where the coefficient power is expected to be high is statistically decided and the coefficients outside the area are not encoded. Another way is the use of the fact that even the significant coefficients can be truncated as long as they don't have a large effect on the regenerated picture quality. This method is based on the human psycho-visual perception. The effects of these two methods are shown in the Annexes of this document.

Quantizer: Amplitude resolution of DC coefficient in the frequency domain needs to have the accuracy equivalent to the half of the step size in the spatial domain considering human visual perception. We have not had yet concrete idea about step size adaptation control of AC coefficients.

Entropy coding: Huffman coding is preferred to the mixed coding method of run-length coding and Huffman coding if appropriate coding zone are selected. Several Huffman coding tables should be prepared and one of them is selected by classification result in case of zonal Huffman coding.

2.3 Experimental coding algorithms

We have studied three coding algorithms shown in the table 1, which are realized by combining the classification and the adaptive control mentioned above. Algorithms 1 and 2 can be categorized as being the approach that uses the statistical property of significant coefficients. Algorithm 3 can be categorized as the approach that mainly uses the psycho-visual perception characteristics. Pictures processed by these algorithms will be demonstrated with video tapes at the meeting.

It should be noted that the method adopted in algorithm 3 can be introduced to algorithms 1 and 2, further improving the coding efficiency.

3. Proposed first priority algorithm

Based on the computer simulation results and the consideration of the relevant hardware size, we propose the adoption of technologies listed below.

a) Use of classification method for adaptive control.
Method 2, which uses binary coding and the outer edge figure detection, is the first priority proposal.

b) Adaptive selection of parameters based on the classification.
Parameters subject to the adaptive control are
- coding zone
- ~~Huffman coding table~~

c) Use of the psycho-visual perception characteristics.
Truncation of transformed coefficients based on the criteria such as motion vector information or the degree of isolation are proposed.

4. Conclusion

In this contribution we have compared three classification methods, which are essential for the adaptive control, and also picked up three parameters as being the subject to the adaptive control. We have compared three coding algorithms, which are realized by combining the classification method with the properly selected adaptive control parameters, for encoding the DCT based transformed coefficients. Based on the computer simulation we put present first priority to algorithm 2. We also proposed the use of the psycho-visual perception characteristics. In closing the contribution, we would like to add a comment that the reasonable balance between the improvement and the relevant increase of hardware size should be considered in the future study.

TABLE1. THREE CODING ALGORITHMS

Item \ Algorithm	Algorithm 1		Algorithm 2		Algorithm 3	
Classification method	①VQ matching (lower 20 coefficients excluding DC coefficient)		①Binary pattern matching		①Prediction error power ②Motion vector	
Number of classes	1024		64 or 16		3	
a. Quantizer	Non Adaptive.		Non Adaptive.		Adaptive. (according to ①and ②)	
b. Truncation of significant coefficients	Truncate the coefficients outside of the zone decided by the class		same to the left		Truncate the coefficients adaptively inside of the zone decided by the criteria mentioned in the annex Truncate the coefficients outside of the zone decided by ②	
c. Entropy coder	Adaptive. Huffman code (changing code table according to ①)	Non Adaptive.	Adaptive. Huffman code (changing code table according to ①)	Non Adaptive. Huffman code	Adaptive.	Non Adaptive. Huffman code EOB
Demonstration of processed picture	×	—	×	×	—	×

ANNEX 1/Doc.#79

SIMULATION RESULTS OF ADAPTIVE CONDING USING STATISTICAL CHARACTERISTICS OF SIGNALS

This annex describes evaluation results of coding efficiency of adaptive coding in which input signals are classified into several categories according to their characteristics such as power distribution in the coefficient domain. The simulation pictures are also demonstrated in this meeting. The configuration and parameters other than classification methods are the same so that strict comparison can be achieved.

1. Methods of classification

The configuration of the simulated coding algorithms are shown in Figure 1/Document #78. Two classification methods, classification method 1 (VQ classification) and classification method 2 (binary classification), are compared.

1) Classification method 1 (VQ classification)

The idea was described in document #43 and #61. In this method, prediction errors are first segmented into blocks and then discrete cosine transformed. Each transformed block is classified into plural number of categories using vector quantization technique. Namely the most approximate vector for each input block is chosen by matching to pre-defind vector set based on a minimum power criterion. The vector index is coded and the residua of input coefficients and represented vector are sent to the following scalar quantizer. The residua are then quantized, and quantized values are variable word length coded.

Each category has its own variance table which is designed by a long run test sequence. The variance table and scaling factor specify the code set assign table in which one specific Huffman code set is determined among several available code sets. In the experience, six Huffman code sets are desinged and used. Then, a code set is assigned for each coefficient in a block.

In the simulation work,

The number of VQ index : 1024 for interframe mode blocks
The number of VQ index : 1024 for intraframe mode blocks
The number of VQ dimensions : lower 20 sequencies in a block
coefficients except DC coefficient.

To simplify the DCT/VQ coding algorithm which was demonstrated in the Ipswich meeting, Tree search VQ matching is introduced. Matching process is devided into three stages.

1st stage : 16 division
2nd stage : 8 division
3rd stage : 8 division

2) Classification method 2 (Binary classification)

The idea of classification was originated in document #37. In the experiments here, the idea is applied only on classification criteion. Namely, the most approximate binary pattern or predefined shape for each input block is chosen. Rectangle-shaped sets are defined as predefined shape. For classification, input coefficients are first quantized into binary "1 or 0" code by comparing their absolute level to a certain threshold, then the binary pattern is compared with predefined pattern, so as to find a minimum sized rectanglar pattern in which all coefficients exceeding the threshold are included. Each rectangle corresponds to classification category. The input coefficients are sent to the scalar quantizer and quantized, then quantized values are variable word length coded. The variance table which is assigned to each category and scaling factor gives a Huffman code set to each coefficient.

In the simulation work, the number of categories are 64.

2. Method of adaptive entropy coding

When classification is performed, it is necessary to evaluate coding efficiency of adaptive entropy coding in which classification information is effectively used. In this simulation, we test adaptive variable length coding. Namely, one of the Huffman code set is assigned to a coefficient among previously defind Huffman code sets according to the result of classification. The Huffman code sets are designed by a long term test sequence. The parameters other than Huffman codes are the quite same in this comparison of adaptive and non-adaptive entropy coding.

3. Simulation parameters

(1) Picture size to be coded

Y signal : 360 samples x 288 lines
B-Y signal : 60 samples x 144 lines
R-Y signal : 60 samples x 144 lines

(2) Preprocessing

Temporal filtering with non-linear characteristics

(3) Significant/insignificant block mode

Insignificant block in which the power of frame difference is below certain threshold Th1 is not coded. Only 1 bit code indicates significant/insignificant.

(4) Interframe/Intraframe mode

Intraframe mode is employed when the power of frame difference in a block exceeds certain threshold Th2. Interframe mode is used otherwise. Th2 equals to 400 in this case.

(5) Quantization

Linear quantization is introduced. Instead of changing quantizer characteristics, input coefficients are divided by scaling facter so as to keep the fixed data rate. Scaling factor is derived from buffer memory ocupancy and classification result. Scaling factor holds its value during a frame period. This control is equivalent to change step size of the quantizers to keep the data rate.

(6) Variable length coding

Quantized data are varible length coded. For each coefficient in a classified block, one variable length code set is chosen and a varible length code is assigned. Each category pattern has a map which assigns a variable length code set to each coefficient. The map is modified according to the information generation rate.

(7) Codes to be transmitted

a) Significant/insignificant block idetification : 1 bit/block

b) Intraframe/interframe block
indintification : 1 bit/singnificant-block

c) Moving vector : variable word length coded according to the table used in Part 3 codec

d) Classification index : Fixed length code.
10 bit/significant block for VQ classification
6 bit/significant block for binary classification

e) Scalar index for DCT coding :
- 9 bit/coefficient (512 level linear quantization) of (0,0) sequence (average value) for both intraframe and intrerframe block
- adative variable word length coded according to a table which is derived from statistical characteristics. An example of bit-length of variable length coding is shown in Figure 1.

4. Simulation results

1) Comparison of VQ classification and Binary classification

As shown in Figure 2, the difference of efficiency is not large for moderate movement sequence. When the movement in the scene becomes large, VQ classification is much more efficient than Binary classification.

2) Comparison of plural code set and single code set

Figure 3 shows that improvement of efficiency for adaptive entropy coding is not large when a moderate scene such as "Miss America" is input. When the movement area becomes large, however, efficiency is much improved. Figure 4 shows the coding efficiency vs. signal to noise ratio when scene change occurs. When signal to noise ration is the same, it is shown that use of plural code set improves coding efficiency.

5. Conclusion

1) VQ or Binary

For moderate pictures such as "Miss America" and "Checked jacket", difference of picture quality between VQ classification and Binary classificaiton is not large. For rapid motion and scene chage pictures, VQ classification clearly shows better quality. Selection should be made by considering picture quality and hardware simplicity.

2) Plural Huffman code set or single set

Adapitve variable length coding which is controlled by classification results improves coding efficiency by 5 percent in average compare with non adaptive coding in which a single Huffman codes are used. For rapid movement pictures, efficiency is much more improved. Adaptive coding should be employed since this gain can be obtained only by using statistical characteristics without any degrading picture quality.

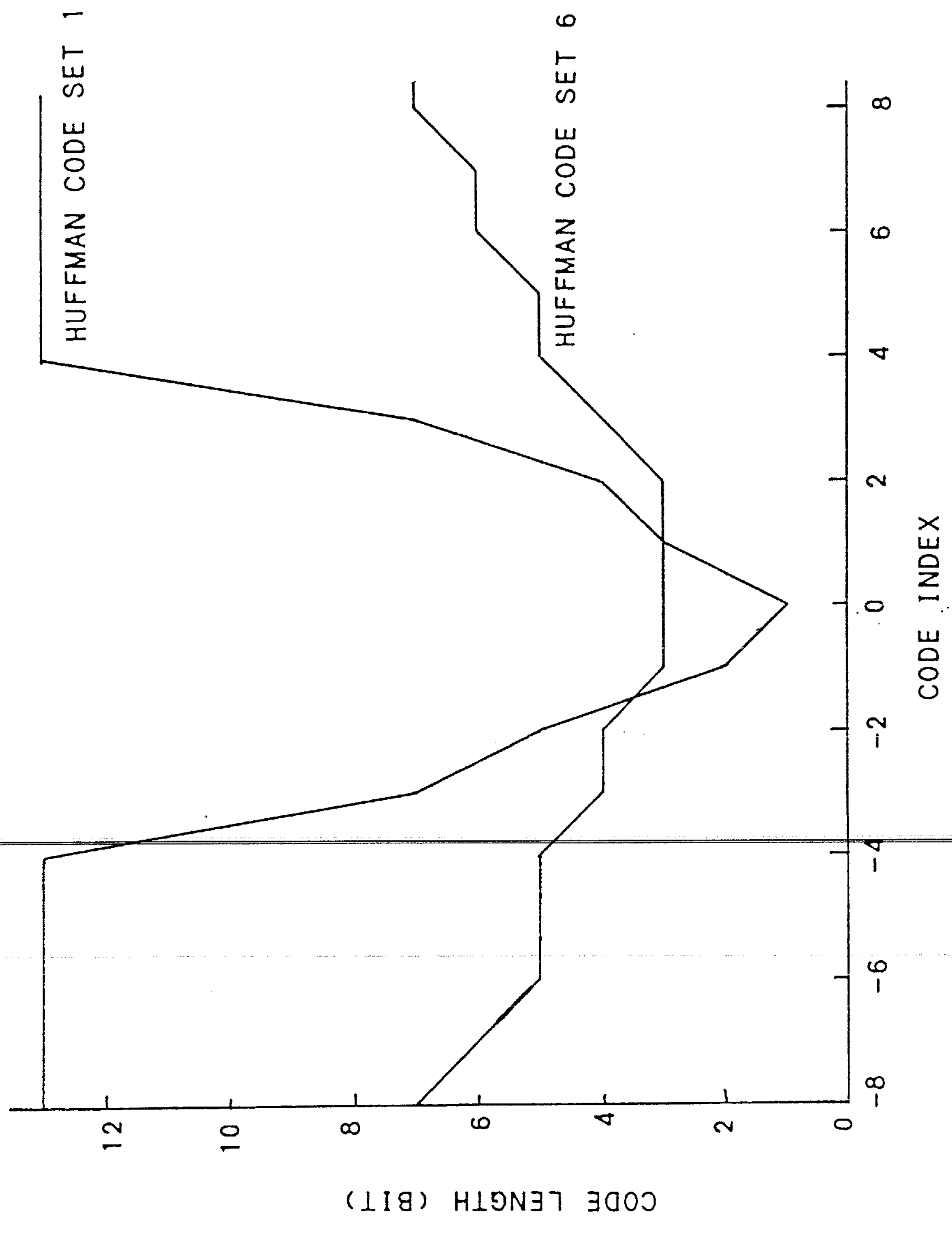


Figure 1 An example of bit-length of variable length coding

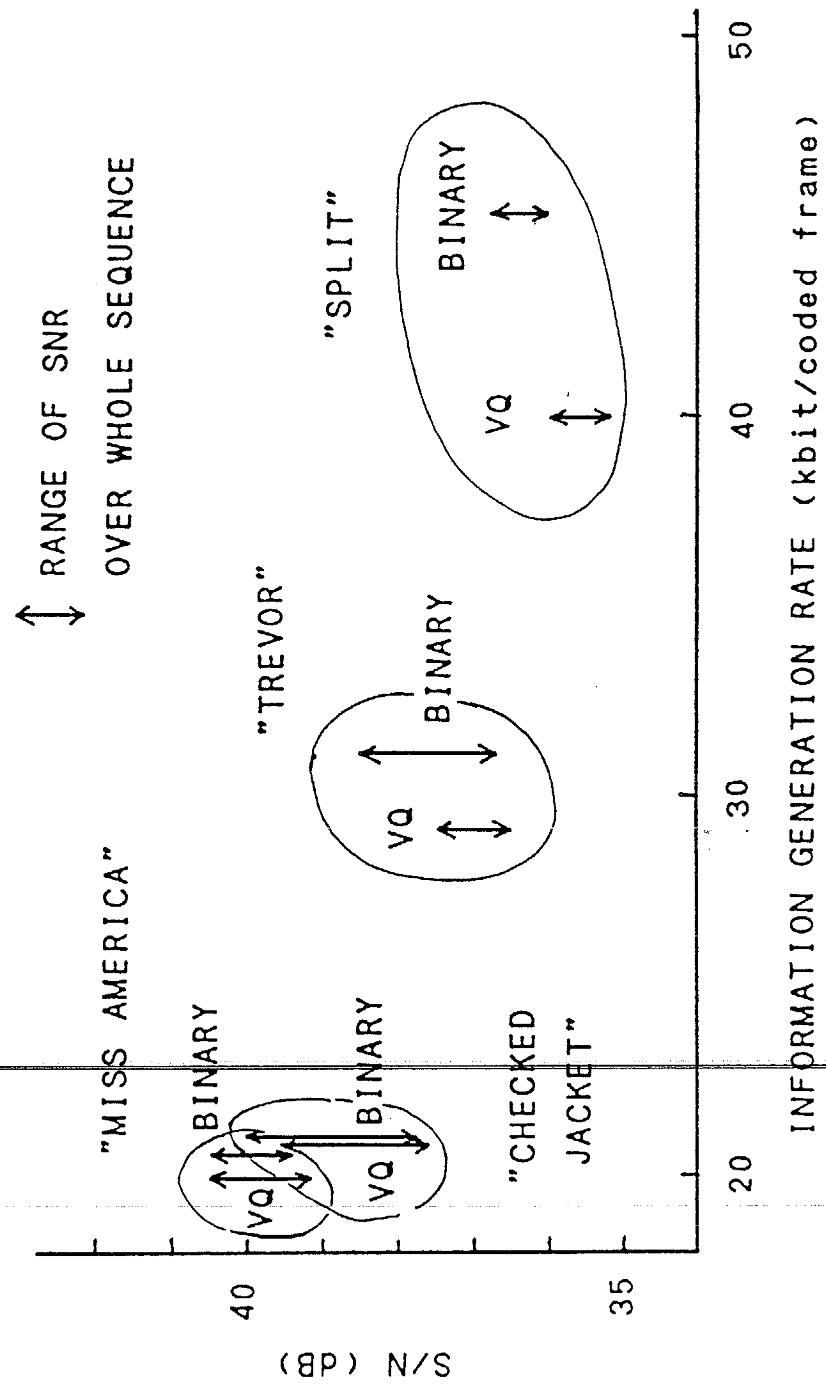


Figure 2 Comparison between VQ and Binary classification

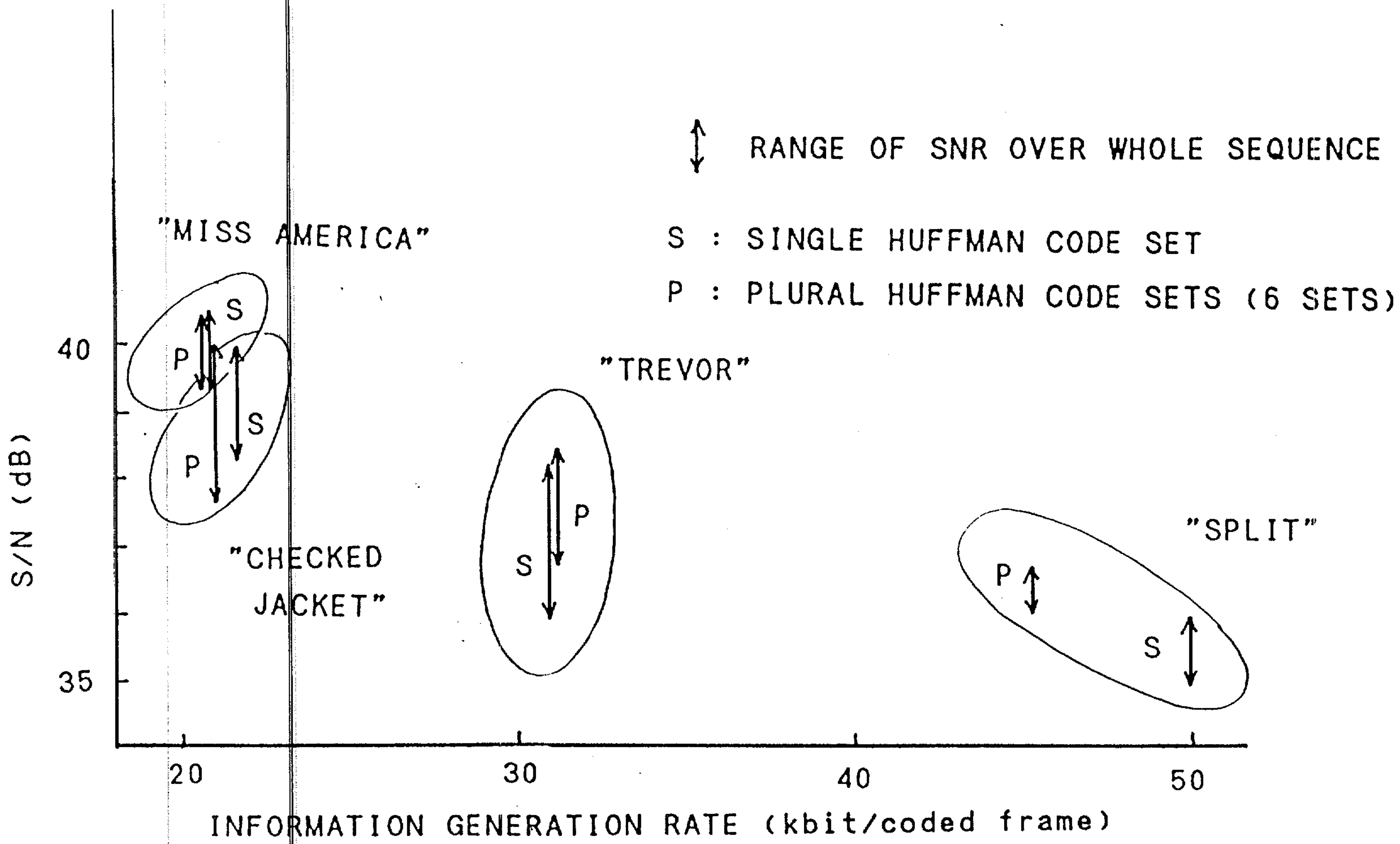


Figure 3 Comparison between single code set and plural code set (except scene change)

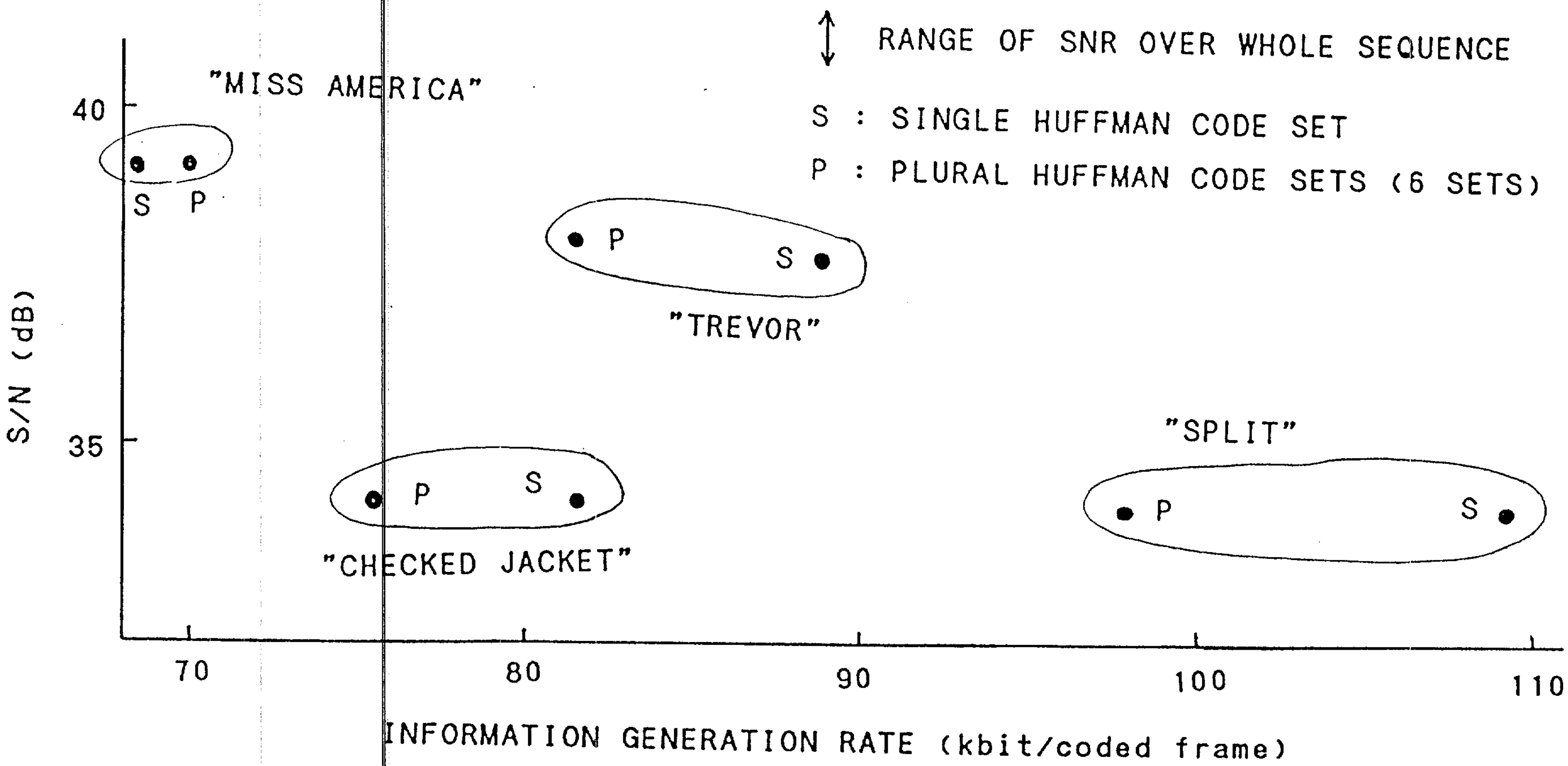


Figure 4 Comparison between single code set and plural code set (scene change)

Annex 2/ Doc. #79

Simulation results of adaptive coding using human phyco-visual perception: VCR

The simulation results presented in this annex are founded on "DCT-BASED CODING ALGORITHM" in document #60, and obtained by using algorithm 3 on TABLE 1 in document # 79. Comparison between latest results and previous results demonstrated for simplyfied type at Ipswich meeting is shown in TABLE 1, and can be seen by VCR.

The feature of this method is truncation of significant coefficients using phsyco-visual perception effect mentioned below.

- It is well known that the human visual perception becomes insensitive in moving area. This fact means that motion vectors are available for classification, by which the encoding zone and the quantizer step are decided.

- The low energy coefficients can be considered to have little effect on the reproduced picture quality. As for the coding efficiency, the truncation processing seems to give a large bit rate reduction effect, especially when the truncation coeficient is the isolated one and some special encoding methods, such as run length coding or the use of end of block code, are applied to amplitude "0" coefficients. Therefore the isolated and a low energy significant coefficients in the encoding zone can be truncated to reduce the information of "0" coefficient.

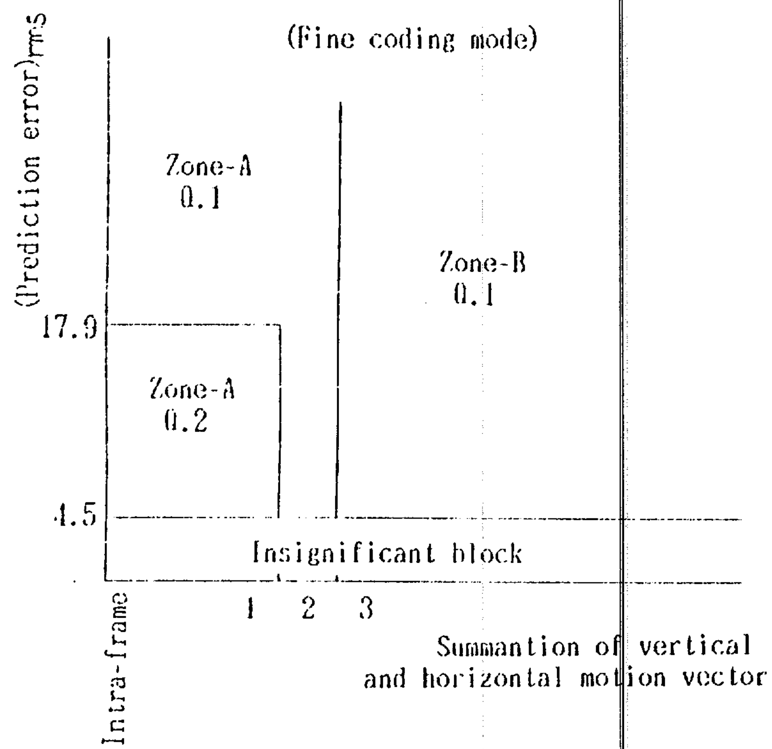
In this simulation a quantizer and a coding zone are decided by the table 2, and further truncation is applied to the coefficients in a coding zone which have minimum step size and surrounded with insignificant coefficients. Entropy coding for transformed coefficient is carried out using Huffman code and EOB(end of block).

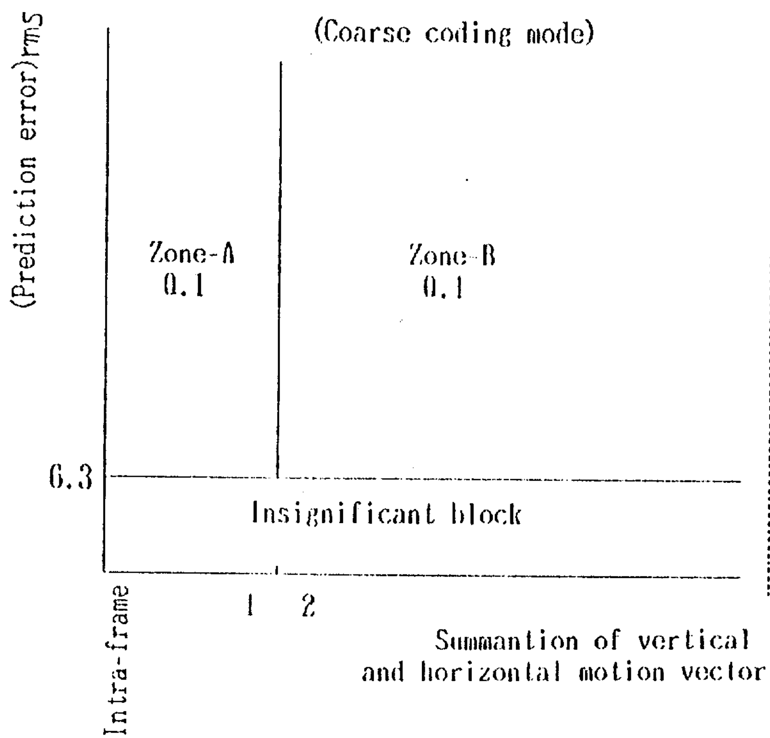
Table1. Simulation Results of DCT-based Coding Using Algorithm 3

Test sequence	Number of coding frames	SNR [ref. frame]
Miss America	75 / 150	40.0 [59th]
	66 / 150	39.9 [61th]
Checked Jacket	33 / 59	39.4 [41th]
	31 / 59	39.3 [41th]
Split Screen	13 / 60	34.6 [29th]
	12 / 60	34.5 [30nd]
TREVOR	28 / 89	38.3 [100th]
	24 / 89	38.6 [100th]

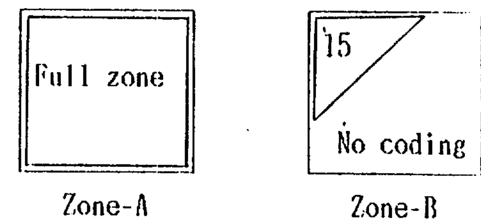
up : latest simulation results
down: previous simulation results at Ipswich

TABLE 2 ZONE PATTERN AND QUANTIZER FOR DCT COEFFICIENTS





Zone pattern



Quantizer

	0.1	0.2
Dead zone	3.0	2.0
Step size	3.0	2.0