EFFECTIVE CODEBOOK VECTORS SEARCH

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Abstract

This paper considers speech compression using vector codebooks. Several vector ordering methods based on majoriaztion theory were. Comparison of developed methods was held. Method of forming search window in structured codebook was developed. Experimental analysis of developed methods was held.

Introduction

Linear parameters prediction is widely used in modern digital communication systems. At the same time for more effective quantization and interpolation line prediction coefficients (LPC) generally are being transformed to linear spectral frequencies (LSF) [1]

When coding LSF best results can be achieved using vector quantization. But direct quantization of 10-dimensional vector of LSF parameters can not be used in action due to excessive memory wasting and calculations complexity.

For the purposes of decreasing necessary memory amount and for speeding-up vector search in codebook it was proposed [4] to divide 10-dimensional vector into subvectors. At a later time each subvector is coded independently with it's own codebook. In [5] different variants of vector division were investigated. It was shown that best results can be achieved using two 5-dimensional subvectors or three subvectors with following dimensions: 3, 3 and 4. But complete search of nearest vector in unstructured codebook is unsuitable for practical application.

For the purpose of decreasing search time in [6] several approaches for codebook ordering were proposed, which were called fast vector quantization. It was shown that calculations complexity for 3x3x4 codebook is 25% of full search calculations complexity. But these approaches has some weakness:

1. Results correctness can be confirmed experimentally only. There are no guaranties that it is possible to decrease calculations complexity for other input data and for codebooks with other dimensions (e.g. 5x5)

2. Calculations complexity is still high enough for practical application.

This paper proposes new approach for codebook vectors ordering, which allows further decreasing of calculation complexity. Same as in [6] this approach is based on using structured codebook.

Codebook is divided into   classes which don't overlap. Amount of vectors may differ in each class. When searching for nearest vector at first we determine to which class   input vector X belongs. It is necessary to mention that necessary class search comes to simple comparison procedure which does not require much computing cost. After necessary class is found at second stage full search of nearest to X vector is held in the set of vectors of current class and in the neighbor classes. This set of vectors hereinafter called search window.

Mathematical model of vectors ordering based on majorization relation.

Suppose we have three LSF vectors: $X=(x_1,x_2,...,x_n)$, $Y=(y_1,y_2,...,y_n)$, $Z=(z_1,z_2,\dots,z_n)$, $X, Y, Z \in \Re^n$. Division of codebook accordingly to defined criteria hereinafter called vector codebook structurization. The main aim of structurization is decreasing computing expenses on searching for quantized vector in codebook which is nearest to input X vector. During search non weighted Euclidian metric will be used where distance between vectors X and Y can be calculated in following way:

$$D^2(X,Y)=\sum_{i=1}^{n}(x_i-y_i)^2 \qquad (1)$$

Let's discover what conditions are necessary for this inequation to be true:

$$D(X,Y)\le D(X,Z) \qquad (2)$$

For this purpose we will use Karamata inequation [7]. According to which for any convex function $y = f(x)$, which is defined on some interval I, and for any set of numbers $A=(a_1,a_2,\dots,a_n)$, $B=(b_1,b_2,\dots,b_n)$ from this interval which met majorization relation ($A \prec B$) it is true that:

$$f(a_1)+f(a_2)+\ldots+f(a_n)\le f(b_1)+f(b_2)+\ldots+f(b_n) \quad (3)$$

Obviously, function (1) is convex. Let's made some replacement: $a_i = y_i - x_i$, $b_i = z_i - x_i$, now we can show that (3) is true if following set of inequations are true:

$$\begin{cases} z_i - z_{i+1} \ge x_i - x_{i+1}, \\ y_i - y_{i+1} \ge x_i - x_{i+1}. \quad i=1,2,\ldots,n-1 \end{cases} \quad (4)$$

$$\sum_{i=1}^{k} z_i \ge \sum_{i=1}^{k} y_i, \quad k=1,2,\ldots,n \quad (5)$$

Ineqations (4) and (5) can be used as codebooks structurization criteria. Graphical interpretation of search window forming in case of using (4) and (5) for codebooks structurization is shown on figure 1.

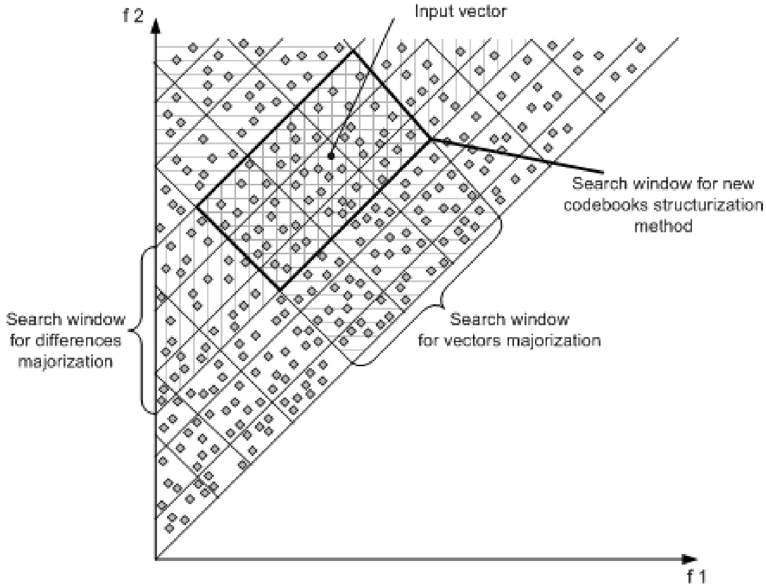

Fig.1. Graphical interpretation of codebooks structurization

Vector component differences ordering

Ordering, which is set by (4) and (5), can be used for structured codebooks creation. But for arbitrary vectors criteria (5) is not true. That's why we need to introduce majorization level concept, and unstructured codebook will be divided into classes according to this concept. Majorization levels are formed using next rule.Majorization level L_i is majored by level L_j, if for each X vector which belong to L_i, at L_j level there is Y vector, which majorize X vector:

$$\forall X, X \in L_i, \quad \exists Y, Y \in L_j, \quad X \prec_w Y \Rightarrow L_i \prec L_j \quad (6)$$

For arbitrary vectors (4) criteria also is not true. That's why different differences ordering variants were investigated except of (4) criteria (which we call differences comparison):

$$\sum_{i=1}^{k}(z_i - z_{i+1}) \ge \sum_{i=1}^{k}(y_i - y_{i+1}), \quad k=1,2,\ldots,n-1 \quad (7)$$

Criteria (7) is called differences majorizaion. Practically we transform n-dimensional vector to n-1 dimensional differences vector and after this majorization of new vector take place.

It is also possible to apply other criteria:

$$\sum_{i=1}^{n-1}(z_i - z_{i+1}) \ge \sum_{i=1}^{n-1}(y_i - y_{i+1}) \quad (8)$$

Criteria (8) is called differences sum comparison.

Researching different approaches to differences ordering

Research of different approaches to differences ordering is shown in table 1 and on figure 2. These results are for 5x5 codebook where 4096 values are stored for each subvector. For each approach spectral distortion (SD) is estimated and percentage of missed vectors (M). Under vector majorization here we mean codebooks structurization using only (6) criteria. It is obivious that best results can be achieved for differences majorization and for differences comparison.

Table 1- Research of different approaches to differences ordering

Search window (vectors amounts)	Differences majorization		Differences comparison		Sums comparison		Vectors majorization	
	M, %	SD, dB	M, %	SD, dB	M, %	SD, dB	M, %	SD, dB
100	23,88	0,8576	62,92	1,29	83,46	1,54	66,72	1,32
200	9,76	0,7965	36,07	0,8645	51,24	1,001	43,95	0,9412
300	5,23	0,7792	5,42	0,7798	30,7	0,8618	27,99	0,8595
400	2,92	0,7695	2,17	0,7695	18,42	0,8216	19,54	0,8554
500	2,04	0,7684	1,61	0,7674	10,52	0,8006	13,87	0,8125
600	1,32	0,7662	0,98	0,7661	6,26	0,7816	9,8	0,8034
700	0,97	0,7658	0,98	0,7661	3,57	0,7785	7,97	0,7868
800	0,83	0,7656	0,81	0,7654	2,03	0,7682	4,75	0,7796
900	0,55	0,7642	0,72	0,7652	1,16	0,7659	3,97	0,7791

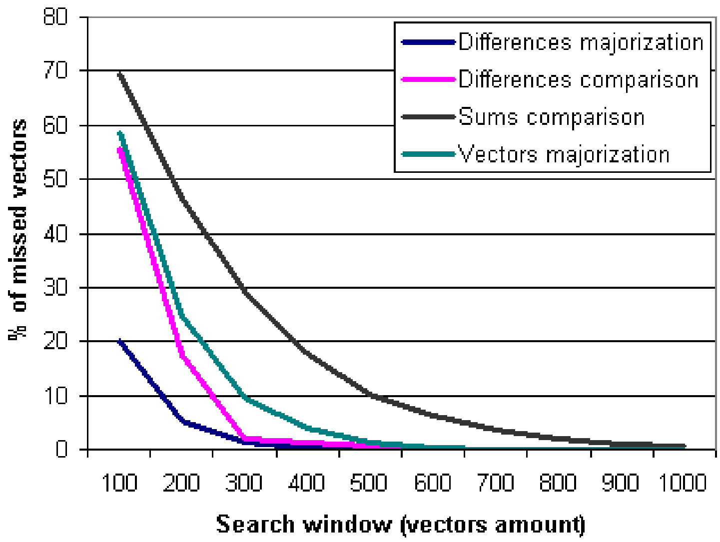

Fig.2. Research of different approaches to differences ordering

Conclusions

New codebooks structirization method were proposed. It is based on majorization theory. This allows to decrease search window. Different approaches to vector components differences ordering were proposed. It is shown that best results can be achieved in case of using differences majorization or differences comparison. This new method allows to decrease calculations complexity of vector search procedure by means of decreasing search window to 700 vectors without significant spectral distortion increasing.

References

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