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A Variable bit Rate Lattice Vector Quantization Method for Audio Coding

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***Abstract*—This paper proposed a lattice vector quantization method for audio coding. The method uses energy priority, with basic code book and the ball-type expansion, which is applicable to the low rate of the variable-rate vector quantization coding. The method uses the lattice characteristics to resolve rapid index distribution problem, as well as the compression of the basic code book. The experiment results show that the proposed method is as good as vector quantization method in ITU-T standard G729.1 in quality, with lower storage cost and computational complexity.**

***Index Terms*—lattice vector quantization, variable rate, basic code book, index distribution**

I. INTRODUCTION

The traditional statistical vector quantization (VQ) methods, such as VQ designed by LBG algorithm, have highly compression capacity and thus implement widely in the field of data compression and quantified. But the quantization computing complexity grows with exponential relation with dimension. And it is usually not able to get the best codebook to train sequence with the clustering algorithm. In recent years lattice VQ is studied to get rid of the disadvantage of traditional VQ. Lattice VQ based on the lattice point in space lattice to quantify signals. As space lattice is inerratic, the lattice point and the cell is also regular, the codebook of the lattice VQ method can be constructed merely through algebra computing with very little storage space, and with low complexity of computing, and high quantization precision [1].

This paper proposed a lattice vector quantization construction method, based on even lattice, shown as follows, a_i is even.

$$E_n = \{(a_1, a_2, ..., a_n) \in Z_n\} \quad (1)$$

Basic code book covers spherical shell with the radius of not more than four. The selection of expansion code book is based on the algebra relations between the vectors. All En lattice vector with a radius of no more than 16 can be determined by basic code book with expansion code book. The index search method uses permutation; combination and sigh alter in basic code book to search quickly and save storage space. As a result of multi-code-books, the method has a variable rate feature, which means flexible quantization based on the number of bits can be allocated.

This paper firstly proposes the principle of quantization, and then the design methods of basic code book and expansion code book are introduced. After that, the index allocation algorithm, code stream and the codec structure are presented. At last, some experimental results are shown.

II. PROPOSED QUANTIZATION METHODS

The quantization system consists of a basic code book and two expansion code books. All vectors are E8 grid. The largest spherical shell radius of the basic code book is 4 (that is, {a1, a2,…, a8} ai <= 4). The first order expansion of the code book can include shell with the largest radius of 8. the second order expansion can include spherical shell with largest radius of 16. The basic book is divided into four small sub code book based on energy.

The following is the quantization methods in different lattice point location scenarios.

A Basic code book

When the lattice point is in the basic code book, its energy is less than 128, because the basic code book can only cover the spherical shell with a radius of 4. Because the basic book is divided into four sub code book based on energy, we must calculated the energy of the 8-dimensional vector firstly, and then find the corresponding sub code book number, select the appropriate code book to quantify the vector at last.

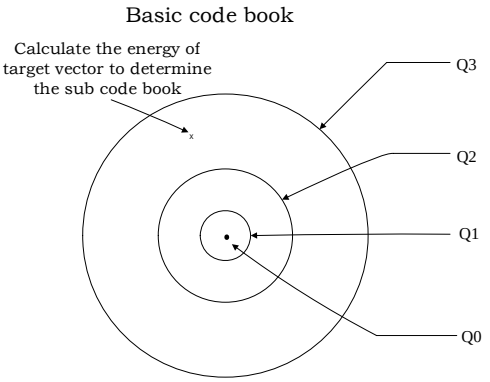

Figure1. Lattice point in the basic code book

B First order expansion

When the lattice point is out of the basic code book, its energy is more than 128 of less than 512. we need expand the code book, to search first order expansion of the code book. The first order expansion code book can cover the spherical shell with a radius of 4. Therefore, we calculate the distance between the energies of target vector and vector of expansion code book. When the distance is less than 128, the vector is a suitable first order extension quantization vector for the target vector.

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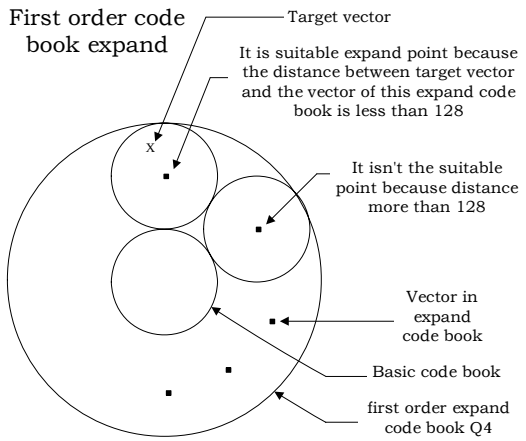


Figure2. A grid in order to expand in the code

C Second order expansion

Similarly, when the lattice point is out of the basic code book, within the second order extension of the code book, its energy greater than 512 and less than 4096. Firstly calculate the distance between the energies of target vector and vector of the second expansion of code book. if their energy distance is less than 512, the vector is suitable second order vector. Then, the margin of the two vectors is taken as new target vector, to compute the first order expansion vector and basic vector, with method shown in scenario B.

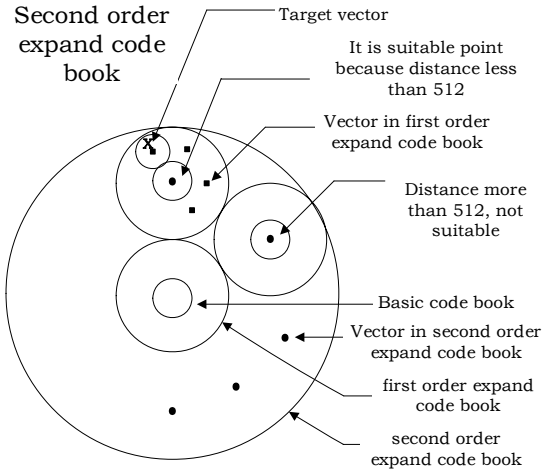


Figure3. Grid points in the second extension of the code

III. THE CODE BOOK DESIGN

A The basic code book design

The basic code book covers spherical shell with a radius of 4, including a total of more than 390,000 basic vectors, and need 19-bit for coding. The maximum energy of code vector is 128.

According to the characteristics of lattice, we only need to consider absolute guide items when design the code book. Other vectors can be calculated by the absolute symbol of the changes in the composition and with the changes to generate [3]. The basic code book includes about 390,000 vectors, but there are only 45 of the absolute guide items. Most voice encoder bit rate is not high, can not guarantee that every 8-dimensional vector can get at least 19-bit to code. Therefore, the basic code book should be divided into sub code books to improve coding efficiency. The following table gives the energy and corresponding coding bits of the four sub code books.

TABLE I THE CODE BOOK AND CORRESPONDING ENERGY

Code book	Max energy	Bits need
0	0	1
1	27	13
2	43	16
3	128	19

All of this code is nested between the relationships that are the code book $Q_0 \subset Q_1 \subset Q_2 \subset Q_3$, including each of the code is part of the guide, and to energy as the boundary demarcation to open.

B The design of the expansion code book

There are two level expansions in the proposed quantization systems. The first order expansion can include all vectors, which are in the spherical shell with the radius of not more than 8. The second order expansion can include all vectors, which are in the sphere shell with the radius of not more than 16.

The code vectors of the first order expansion code book are in the following set:

$$(a_1, a_2, ..., a_8) \quad a_i = 4 \mid -4. \tag{2}$$

There are 256 vectors in the first order expansion code book, need for 8-bit for coding.

The code vectors of the first order expansion code book are in the set (b1, b2,…, b8) bi = 8, or -8. On the base of the first order expansion code book, the second order expansion of the code book can determine all vectors in the spherical shell within a radius of 16.

As descript above, each level expansion need additional 8-bit to code the vector of expansion code book. Since the basic code book needs 19-bit to encode, the first order expansion need 27-bit, the second order expansion need 35-bit for coding .

IV. IMPLEMENT IN AUDIO CODEC

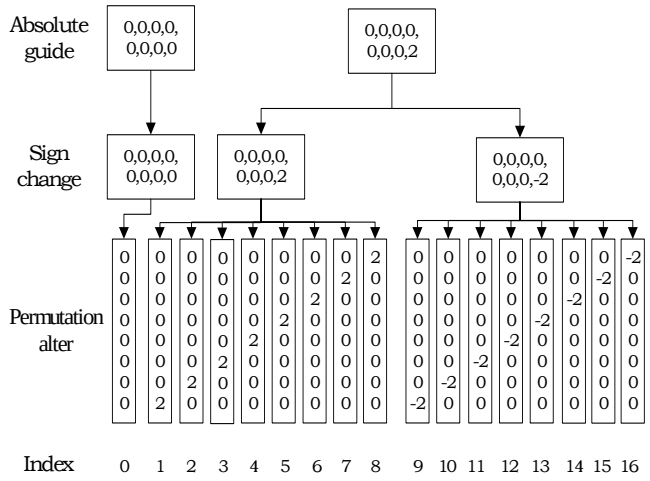
This sector introduces the index allocation algorithm; designs bit stream structure and present the quantization flow implemented in the audio codec.

A Index allocation algorithm

This section introduces how to generate the all code vectors from the absolute guide items. All vectors can be gotten by sign change and permutation alteration of absolute guide items. The following figure shows how to generate index items from the first two absolute values.

In figure 4, there are two layers, the first is the sign change, and the second layer is the alteration of permutation and combination. All components value of E8 lattice is even, so, for all vectors (a1, a2,… a8), their sign change total number is 2N, N is the number of

non-zero value in (a1, a2,… a8). The rank of alteration of permutation and combination can be compute from Schalkwijk formula [2] calculated. So, for any vector, its index value I can get by these means. In the other hand, the target vector can be solved from an absolute guide items index table (only Including 45) and the vector index I.



Figur4. Index distribution diagram

B *Bit stream design*

When this code book number is 0, it is a whole 0 vector, the bit stream only contain code book number. When the code book number is 1, 2, 3, it means it is a basic code vector. the bit stream will include basic code book index, but no expansion code book index. When the code book number is 4, the first order expansion index will be added into bit stream. And when the code book number is 5, the second order expansion index will be further added into bit stream

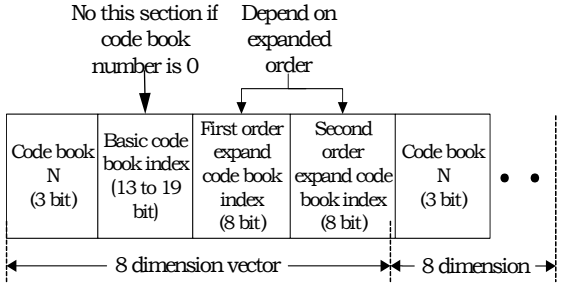


Figure5. Bit Stream structure

V. EXPERIMENTS

To verify the quality of the quantization method, we compare it with the quantization method in G729.1 algorithm [4]. The tests include subjective hearing tests and SNR comparison tests. The 12 test sequences are selected from MPEG recommended sequences, including voice and audio, with the bit rate of 24 kbps, sampling rate of 16 kHz.

A *Subjective Listening Tests*

The abscissa is test sequence name. A solid point for the sequence test shows that the average rate, the up and down lines showed that 95 percent confidence interval.

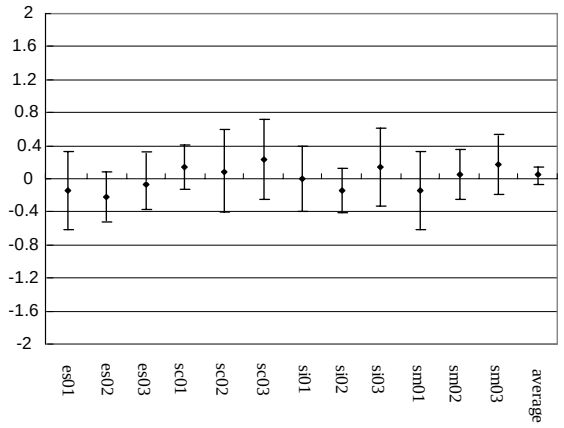


Figure6. Subjective listening test results

B *Objective Tests - SNR comparison*

The variable $f_{i,j}$ is the original signal, variable $f_{i,j}^{'}$ is quantified signal, the signal to noise ratio (SNR) is calculated as follows:

$$SNR = 10 \log_{10} \frac{\left\| f_{i,j} \right\|^2}{\left\| f_{i,j}^{'} - f_{i,j} \right\|^2} \quad (3)$$

TABLE II OBJECTIVE TEST - SNR COMPARISON

Sequence	G729.1 (SNR)	Proposed (SNR)	proposed -G729
es01	9.166	8.935	-0.231
es02	7.152	7.000	-0.152
es03	8.190	8.156	-0.034
sc01	7.898	8.071	0.173
sc02	6.605	6.819	0.214
sc03	6.005	6.267	0.262
si01	7.802	7.664	-0.138
si02	11.403	11.303	-0.100
si03	7.009	7.203	0.194
sm01	12.834	12.561	-0.273
sm02	12.094	12.146	0.052
sm03	6.428	6.531	0.103
Average	8.549	8.555	0.006

The objective test results show that the SNR values of the propose method and G.729.1 are very close.

VI. CONCLUSIONS

From the above objective test and subjective hearing test, we can see that the proposed method can get nearly same audio quality compared with G729.1, but with the advantages of lower storage cost and computational complexity.

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