Implement of a lossless audio coder using

linear prediction and entropy coding

1. Objective

The aim of the assignment is to implement a lossless audio coder in language C. The task is divided into two part: linear prediction and entropy coding. With the knowledge of these two technology, we choose to use Matlab to bulid an encoder and a decoder. The encoder should have the fuction to accept the audio file stored in WAV file format and produce a compressed file with our own compressed format. The decoder should have the fuction to decode the comprssed file and produce a WAV file containing the decoded signal.

2. Principles

2.1 Linear Prediction

Linear Prediction works as follows: Use previous samples to predict a new sample. And to get the lossless coding, a residual signal need to be calculated as the difference of the original signal and predicted signal. Then just send the predicted coefficients and the residual signal to the decoder to build the original signal back.

To obtain the best compression result, the predicted coefficients should be calculated according to the least-square method, which makes the residual signal has the least value.

2.2 Entropy Coding

Here we want to use the Golumn-Rice coding, which is based on binary codes. It compress the signal by dividing the signal into two parts. The first part is a quotient, which shows the larger part of the value of the signal. And the second part is the remainder of the value of the signal. This shows the smaller part of the value. And the quotient is showed as several ‘1’, followed by a ‘0’. The remainder is just coded to a binary value according to the chosen number of the value.

3. Implement

3.1 Guide Lines about Matlab

We use Matlab to fulfill this programme. In Matlab, there is no 16-bit 2’s complement format. We can only use vectors of 1 & 0 to represent the rice coding result, which can only be used to test if the algorithm is right or not. There are three kinds of files in Matlab. The function file includes “Ham_win”，”CalA”，”calR”，”rice” and “rice_decode”. The script file includes “monocoder” and “monodecode”.The result is included in the “final_result_data” file. The programme are divided into encoder and decoder. In the encoder, the “encode_data.dat” contains “a int”, ”a matrix”, ”en” and “en int”. In this function, “a” represents coefficient and “en” represents residual signals. In the decoder, the “decode_data.dat” contains the result of entropy coding and reconstruction. The resultant data is ended up with “_de” or “_recon”. The “a bits” and “en bits” represents the result of compression ratio. The method to run the programme is as following:

(1)Open this file with Matlab

(2)Input the audio file address (in your computer) to the function “audioread()” or “wavread()”

(3)Run the programme

3.2 Linear Prediction

We choose the forward prediction to fulfill the linear prediction. The steps are as following.

(1) convert the 2’s complement numbers of ibuf into floating point numbers and store it into the nbuf
(2) the data in nbuf is windowed with hamming window
(3) compute the autocorrelation of the windowed signal and the store it into the rbuf
(4) use Levinson-Durbin algorithm to compute the data in rbuf and store it into the abuf
(5) compute the number of N samples in the window and calculate the predictive coefficient and store it into the pbuf
(6) convert the numbers in pbuf into the 2’s complement numbers
(7) the residual equals to the difference between the signals in pbuf and ibuf, then store the residual into the ebuf
(8) quantize the signals in abuf and store them as side information

3.3 Entropy Coding

We choose Golomb-Rice Coding Algorithm to fulfill the entropy coding. The steps are as following:

(1) fix the tunable parameter M to power of 2 integer value according to the Most Frequent Value
(2) determine the plus-minus sign in front of every sample
(3) before implement rice coding, a distinguish of positive and negative value is required. The way to achieve this is by setting positive value as odd number while negative value as even number.
(4) the method of Rice coding is: Quotient q= int [x/M], Remainder r= x modulo M

    the code format is <Quotient Codes><Remainder Code> where Quotient Code (in unary coding).

    write a q-length string of 1 bits

    write a 0 bit

Remainder Code (in the binary coding)
write b=$\log_2 M$ bits of binary code for remainder

(5) Since there is no 2's complement manipulation in the Matlab, we use the "cell" to store the 2's complement results computed by entropy coding.

(6) The entropy coding will be encoded frame by frame. The "M" in every frame is stored in the "sign_a" and "sign_en" as the form of 16 bit. The encoding result will be transferred to the decoder with "M".

3.4 Combination

We write all the algorithm into the file and put the last W-N samples to the first N samples in ibuf.

4 Assignment Result

4.1 Mesured Entropies

We use the Matlab function wentropy() to compute the entropy. The equation is entropy = wentropy(en, 'shannon'). The entropy of original signal is 7.5739e+04, the entropy of matlab function signal is -1.1169e+06 and the entropy of self-defined function signal is -6.4674e+07.

4.2 Compression ratio achieved

The compression result is 13.7741bits and the compression rate is 84.04%.

4.3 Audio Wave Pictures

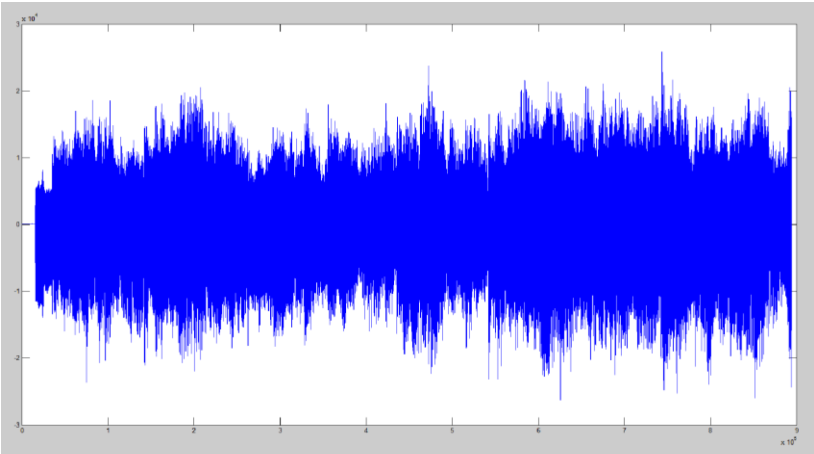

Figure 1. Original Signal Samples

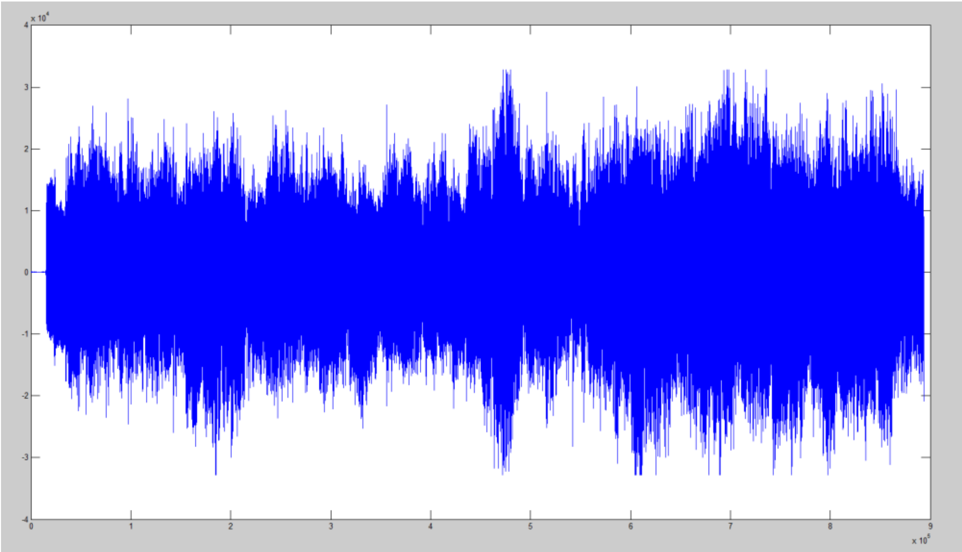

Figure 2. Residual Signal Samples

5 Working Division

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