A Transient Signal Detection Technique Based on Flatness Measure

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Abstract— **In perceptual audio coding, it is necessary to deal with the transient signals in a frame. A reasonable transient detection is a premise of the treatment. According to the characteristics of transient signals in time domain and frequency domain, a time-frequency transient detection method which uses flatness measure is proposed in this paper. Comparing with existing transient detection methods, transient signal detection technique based on flatness measure not only has advantages to reduce missed and misused detection, but also hardly produce redundant detection in low-energy transient segment. Simultaneously, the complexity of the algorithm adaptively changes with the apparent extent of the transient signal. Simulation results show that this method is high in detection accurancy and simple in algorithm realization.**

Key words—**perceptual audio coding, transitent detection, flatness measure, pre-echo artifacts**

I. INTRODUCTION

In current audio coding, coding algorithm using block transform processing is widly applied. So-called block transform processing method is to add "window" to continuous audio signal and turn it into block data which is transformed、 quantified、encoded、restored and transmitted. Audio coding based on block transform is helpful to eliminate redundancy of signal and improve compression rate, however, eliminating pre-echo artifacts is critical. When a transient signal is transformed to frequency domain and quantified and encoded, the existence of quantizing noise cause pre-echo artifacts. If bit rate is low and compression ratio is high, pre-echo artifacts will become more obvious and severe.

The method to resolve pre-echo artifacts is to corretly detect transient signal. The transient detection methods of audio signal include time-domain energy detection、frequency-domain energy detection and time-frequency integration energy detection. But these methods have such shortcoming as complex algorithm、low accurancy and low time resolution. For example, perceptual entropy adopted in MPEG-2 ACC, because of bigger threshold difference, is complicated. And what make matters worse, it can detect low-energy transient signal. So flatness measure proposed in this paper can make up above-mentioned deficiency.

II. DEFINITION OF FLATNESS MEASURE

Using Spectral Flatness Measure(SFM)[4] judge that the transient signal is noise spectrum or tone spectrum: if $SFM \to 1$, this spectrum is flatter and this signal is close to noise; on the contrary, if $SFM \to 0$, this this spectrum is band-narrowed, and this signal is close to tone. SFM is the ratio of geometric mean μ_g and arithmetic mean μ_a of current subband signal, the formula of SFM as follows:

$$SFM = \frac{\mu_g}{\mu_a} \tag{1}$$

So according to time-domain wave and frequency-domain spectrum of a signal, definiting a rule whose name is flatness measure to judge transient signal, expression of flatness measure is described as

$$FM = \frac{\sqrt{\sum_{i=1}^{N} |X_i|^2}}{\sum_{i=1}^{N} |X_i| + A} \tag{2}$$

In formula (2), X_i stands for ith sample value of current block, $|X_i|$ stands for absolute value of X_i, N is total samples, A is very small positive constant. From formula (2), if sample X_i only has nonzero value, then $FM = 1$; if X_i has more than nonzero value, then $0 < FM < 1$; if all X_i are zeros, then $FM = 0$. The relation curve of FM and nonzero X_i is shown in figure 1.

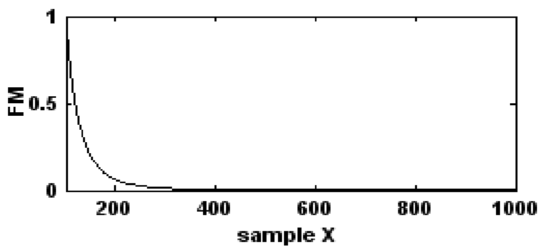


Figure 1. relation of FM and X_i

III. BASIC THEORY OF TRANSIENT SIGNAL DETECTION

Firstly, analysing the characteristics of a transient signal, a signal which contains transient changing phenomenon and unregular structure is called transient signal. According to symmetry characteristics of time-frequency domain of a signal: the flat signal in time domain is not flat in frequency domain and the not flat signal in time domain is flat in frequency domain, So a signal which is not flat in time domain and flat in frequency domain is approximately close to transient signal; on the contrary, it is similarly close to stable signal. Obviously, FM has potensial to detect transient signal. Whether a signal is transient or stable can be judged by Time Flat Measure (TFM)and Frequency Flat Measure (FFM).

Secondly, strength and weakness of a transient signal can be used to determine judging threshold so that transient signal can be judged more simply and correctly. Method proposed in this paper uses three thresholds to judge transient signal with different complexity degree. If the transient strength of a signal is stronger, then comparing TFM with threshold 1 or comparing FFM with threshold 2. When TFM >threshold 1 or FFM <threshold 2, this signal is transient signal; if the transient strong of a signal is not obvious, using FFM and TFM to determine time-frequency integration judging criteria $TFSFM$ and threshold 3, comparing $TFSFM$ with threshold 3 to judge transient signal. The definition of $TFSFM$ as follows:

$$TFSFM = \frac{FFM}{TFM + A} \tag{3}$$

In formula (3), A is very small positive constant, the smaller $TFSFM$ is, signal is closer to transient; on the contrary, the signal is closer to stable.

Flow chart of a transient detection based on flatness measure is shown in figure 2.

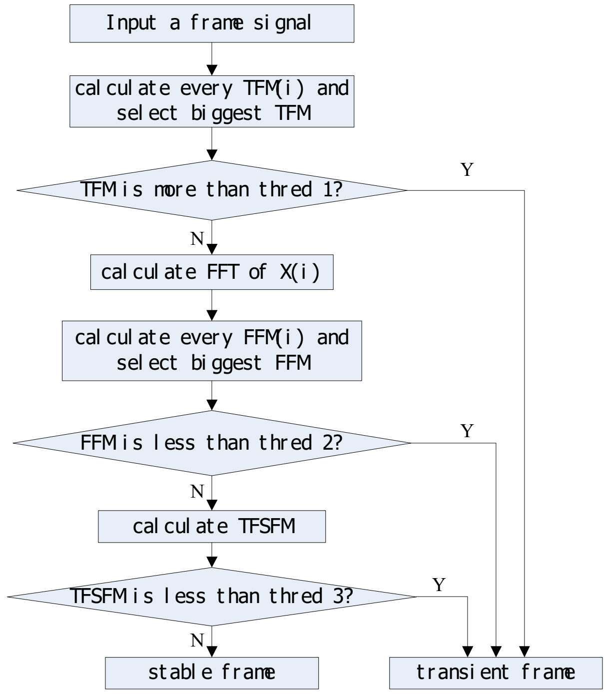


Figure 2. Flow chart of transient detection

IV. DESCRIBTION OF DETECTION ALGORITHM

Taking a frame signal with 1024 points for example, calculate TFM 、 FFM and $TFSFM$ respectively, and then compare them with threshold1 、 threshold2 and threshold3 to determine that this signal is transient or not. Concrete steps as follows:

Step 1: divide the signal into N parts, $X = \{X(1), X(2), ..., X(N)\}$;

Step 2: According to formula (2), calculate $TFM(i)$ of $X(i)$ and find out the biggest TFM ;

$$TFM = \{TFM(1), TFM(2), ..., TFM(N)\} \tag{4}$$

Step 3: If TFM >threshold 1, then this signal is transient and judgement end, otherwise, continue.

Step 4: Making Fast Fourier Transform(FFT) of every $X(i)$, calculate $FFM(i)$ and find out the smallest FFM.

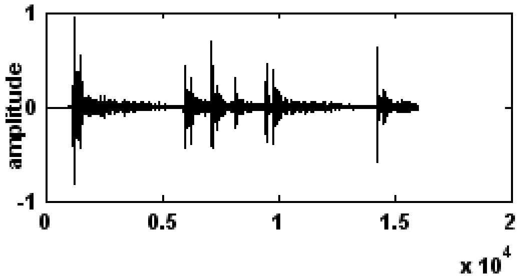
$$FFM = \{FFM(1), FFM(2), ..., FFM(N)\} \tag{5}$$

Step 5: If FFM <threshold 2, then this signal is transient and judgement end, otherwise, continue.

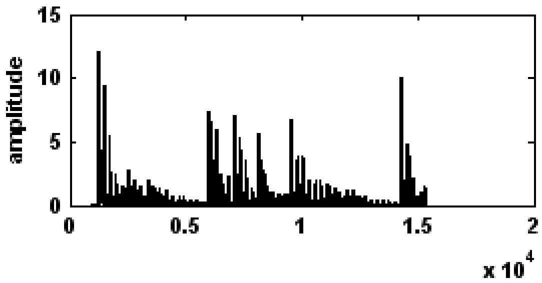
Step 6: According to formula (3), calculate $TFSFM$. If $TFSFM$ <threshold 3, then this signal is transient, otherwise, it is stable, and judgement end.

V. SIMULATION RESULT AND ANALYSIS

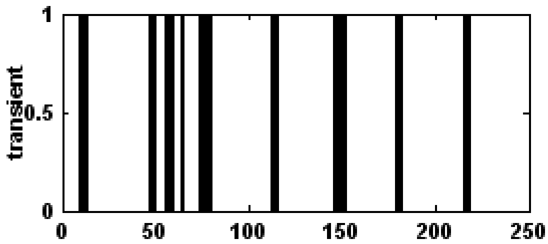
This paper selected smlsplas.wav as tested audio signal. According to above-mentioned detection steps, the graphs of the audio signal which is detected by the means of perceptual entropy and flatness measure and tested by MATLAB in time and frequency domain are shown in figure 3. In figure 3, (a) graph and (b) graph are respectively time domain wave and frequency domain wave of audio signal; (c) diagram and (d)diagram are detection results of audio signal with different detecting method. Comparing (c) and (d) graphs, flatness measure in detecting transient signal is superior to perceptual entropy. Missed 、 misused and redundant detection is obviously reduced, which can decrease following coding complexity and increase coding efficiency.



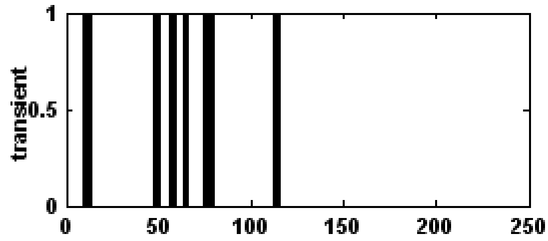
(a) Time domain wave of audio signal



(b) Frequency domain wave of audio signal



(c) transient detection based on perceptual entropy



(d) transient detection based on flatness detection

Figure 3. Simulation result of transient detection

In the meanwhile, the following four audio signals(100 frames) are detected by flatness measure and perceptual entropy. Detection result is displayed in table 1.

TABLE I. COMPARE OF TRANSIENT DETECTION ACCURANCY

audio signal type	**transient describtion**	**perceptual entropy detection (missed/misused/redundant)**	**flatness measure (missed/misused/redundant)**
smlsplas	34	1/3/16	2/1/1
piano	17	1/1/8	1/0/2
glockenspiel	4	0/1/1	0/1/1
castanets	43	2/3/12	2/2/3
summary	98	4/8/37	5/4/7

VI. CONCLUSION

In sum, the transient signal detection technique based on flatness measure has such advantages as less missed and misused detection, scarcely redundant detection, higher accurancy and lower complexity. Besides, the complexity of algorithm varies from difficulty to easiness of the detection. However, because of the random of audio signal, different audio signal has different property diffierence, so deficiency of the method proposed in this paper can't guarantee correctly detect transient segment of every audio signal.

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