Diyala Journal For Pure Sciences Vol:6 No:1
Jan. 2010

Audio Compression Using Fractal Coding

BY
Dr. Loay E. George, Huda M. Salih
Faculty of Science/ University of Baghdad, University of Diyala

Abstract

Audio Fractal Compression is based on the concept of partitioned iterated function system (PIFS). It exploits the self similarity that is commonly present in audio; this similarity could exploit as a sort of redundancy to compress the audio data. Audio fractal compression finds similar patterns that exist in different scales and different places in audio, and then eliminates as much redundancy as possible.

The introduced system consists of two major units; the first is the ***Encoding unit*** and the second one is the ***Decoding unit.*** In the ***Encoding unit***, the original audio is partitioned into range blocks (non overlapping blocks) and the domain blocks are generated using down sampling with overlapping partitioning, the partitioning step is accomplished using fixed block size audio partitioning scheme. The best matched domain block (i.e., the more self-similar blocks) must be found for each range block by applying an approximate affine transformation. The compression process is finished by storing only the affine transform parameters for every range block. The task of finding self-similarities (via the matching process) is accomplished by making search overall blocks of the domain pool, this will require high computational complexity. This considered a major drawback of the fractal audio compression method.

The ***Decoding unit*** is typically done by iteratively applying the affine transformations starting with randomly initialized audio data; this transformation repetition is continued until convergence is achieved. The decoding module is less computational demanding than the encoding module. The developed software was tested using four wave samples of data, and it gives encouraging compression result.

Key Words: Fractal Audio Compression, IFS, PIFS, Affine transform, AFC, Self - similarities.

الخلاصة:

لقد استحدث طرق ضغط عديدة باستخدام تقنيات مختلفة الغرض منها تحقيق نسب ضغط عالية مع المحافظة على جودة الصوت المضغوط، مع الأخذ بنظر الاعتبار أنجاز الضغط بأقل وقت ممكن. طريقة الضغط الكسوري (Fractal Audio Compression) هي أحدى هذه الطرق، وهي تقنية حديثة لضغط البيانات الصوتية تعتمد مبدأ التشابه الذاتي (Self – Similarity) في الصوت.هذا البحث يهدف إلى محاولة تطوير عملية الضغط (Lossy) لبيانات ملفات الصوت من النوع (Wave Files)، باعتماد طريقة الكسوريات (Fractal Method)، أذ تقوم هذه الطريقة بإيجاد الأنماط المتشابهة والتي تتواجد بقياسات مختلفة (Different Scales) وأماكن مختلفة (Different Places) في الصوت، وبعد ذلك تقوم بحذف أكثر ما يمكن من ال (Redundancy)والتي ترتبط بالتشابه الذاتي للصوت، وكما هو الحال مع بقيه طرق الضغط، النظام المعتمد يتكون من مرحلتين رئيسيتين: الأولى هي مرحلة التشفير (Encoding Unit) والثانية مرحلة فك التشفير (Decoding Unit). في مرحلة التشفير يجزأ الصوت الأصلي إلى نوعين من الكتل، كتل تدعى كتل المجال المقابل (Range Blocks) وهي كتل غير متداخلة، وكتل تدعى كتل المجال (Domain Blocks) والتي من الممكن أن تكون متداخلة. ومن ثم يتم تقطيع الصوت باستخدام طريقة التقطيع إلى كتل متساوية الكتل المتساوية الحجم. بعد ذلك يتم أيجاد أفضل كتل في المجال لكل كتلة في المجال المقابل وذلك بتطبيق احد أنواع التحويلات وتدعى (Affine Transform). تنتهي مرحلة التشفير بخزن تفاصيل (معاملات) هذه التحويلات لكل كتلة من كتل المجال المقابل. أن عملية إيجاد الكتل المتشابه تتطلب عمليات حسابية معقدة تستغرق وقت طويل وهذا ما يؤخذ على طريقة الضغط الكسوري كنقطة ضعف. أن مرحلة فك التشفير تنجز بتكرار تطبيق نتائج التحويلات الناتجة من مرحلة التشفير على أي صوت ابتدائي حتى الحصول على الصوت المسترجع، وهذه المرحلة لا تستغرق سوى وقت قصير جداً.

إن البرامجيات التي تم بناؤها لهذا الغرض تم اختبارها باستخدام أربعة نماذج لبيانات صوتية و قد أعطت نتائج مشجعة كما هي مبينة في هذا البحث. إذ أظهرت النتائج إن الزمن المستغرق لعملية ضغط بيانات ملفات الصوت تتأثر بحجم كتلة تقطيع ملفات الصوت المعالج، وهذا يعني إن زيادة حجم الكتلة ستؤدي إلى زيادة الوقت المستغرق لعملية الضغط.

1. Introduction

The term fractal derived from the latin word fractus ("fragmented" or"broken"). It was coined by the polish born mathematician Mandelbrot(1,2). To describe objects that were too irregular to fit into a traditional geometrical setting. Mandelbrot provides both a description and a mathematical-model for many of the seeming complex forms and patterns in nature and the science(3). The spirit of the fractals lay in the following fact; in one way or another, fractals are built up by overlaying smaller copies of themselves(4). It is most natural to think of these fractal in term of probability measure associated with functional equations. Fractals have blossomed enormously in the past few years and have helped to reconnect pure mathematics research with both natural science and computing. Computer graphics has played an essential role both in its development and rapidly popularity(5).An informal definition of fractal set sufficient for our purposes is: a fractal is a geometrical shape that possess detail at all scales of magnification. In other words, one can magnify a fractal repeatedly and more details will appear with each magnification(6,7).The use of fractals in engineering became popular also it helps to improve the graphic capabilities of modern computers, which enabled an easy way to visualize fractal shapes, with its richness of details(8,9).In this papear we will show that the properties of self similarity and the related notion of fractal-dimension, exist in Iterated Function System (IFS) coding.

2. Proposed System

a demonstration for suggest system (Audio Compression System Using Fractal method) used for compression audio file will presented. The encoding unit of the implemented audio fractal compression (AFC) is based on partitioned iterated function system (PIFS), which is basically based on affine transformation. So, for encoding the audio data it is necessary to divide it into non-overlapped blocks called (ranges, R), and then each block is transform separately. By partitioning the audio data into blocks (called ranges), the partitioning will let the encoding of a wave with complicated shaped is mostly possible, taken into consideration that audio is not composed of copies and doesn't imply exact similarity, so it can't be coded as one single piece by using the IFS. So, the PIFS is used in the suggested system to find for each range block the best approximation is found by searching in the domain pool, compute the corresponding PIFS parameters and storing these parameters in the compression file. The steps of the implemented algorithms for two units of fractal audio compression system (Encoding unit and Decoding unit) are shown in the figure (1) and (2).

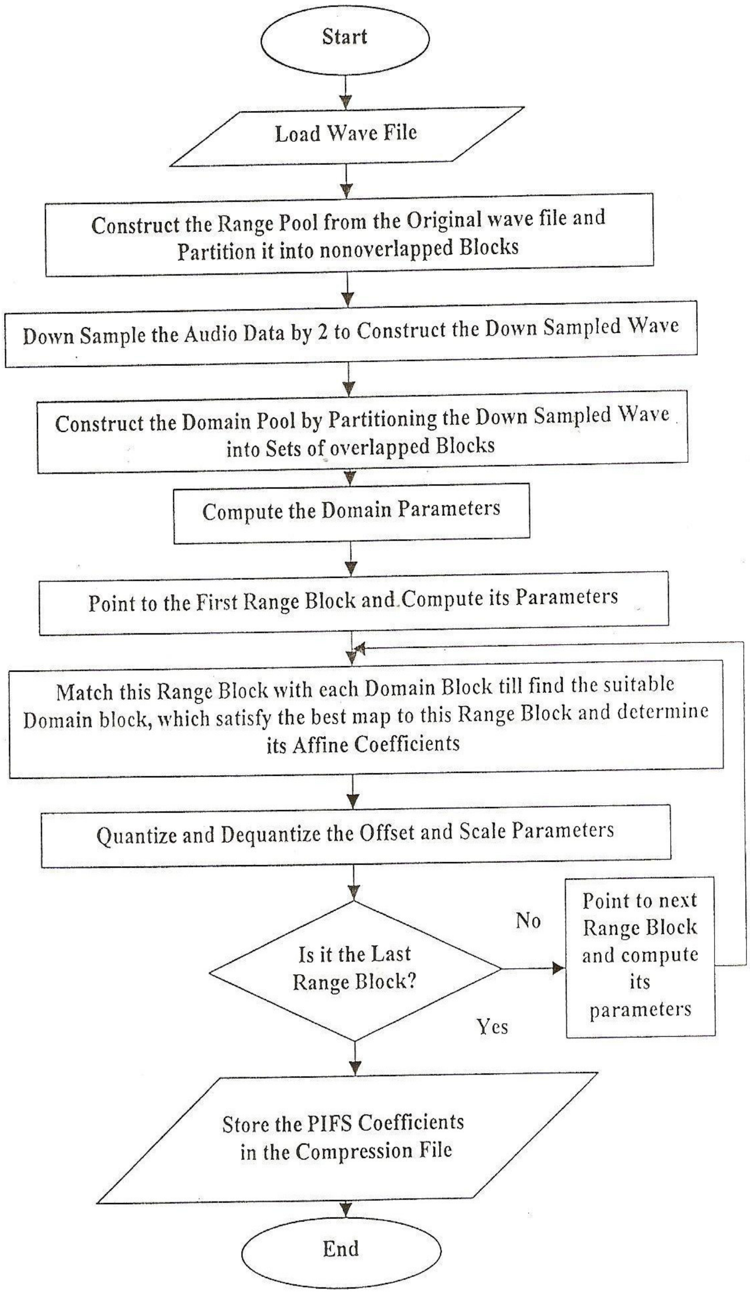


Figure (1) The Flow Chart of The Fractal Audio Encoding Unit.

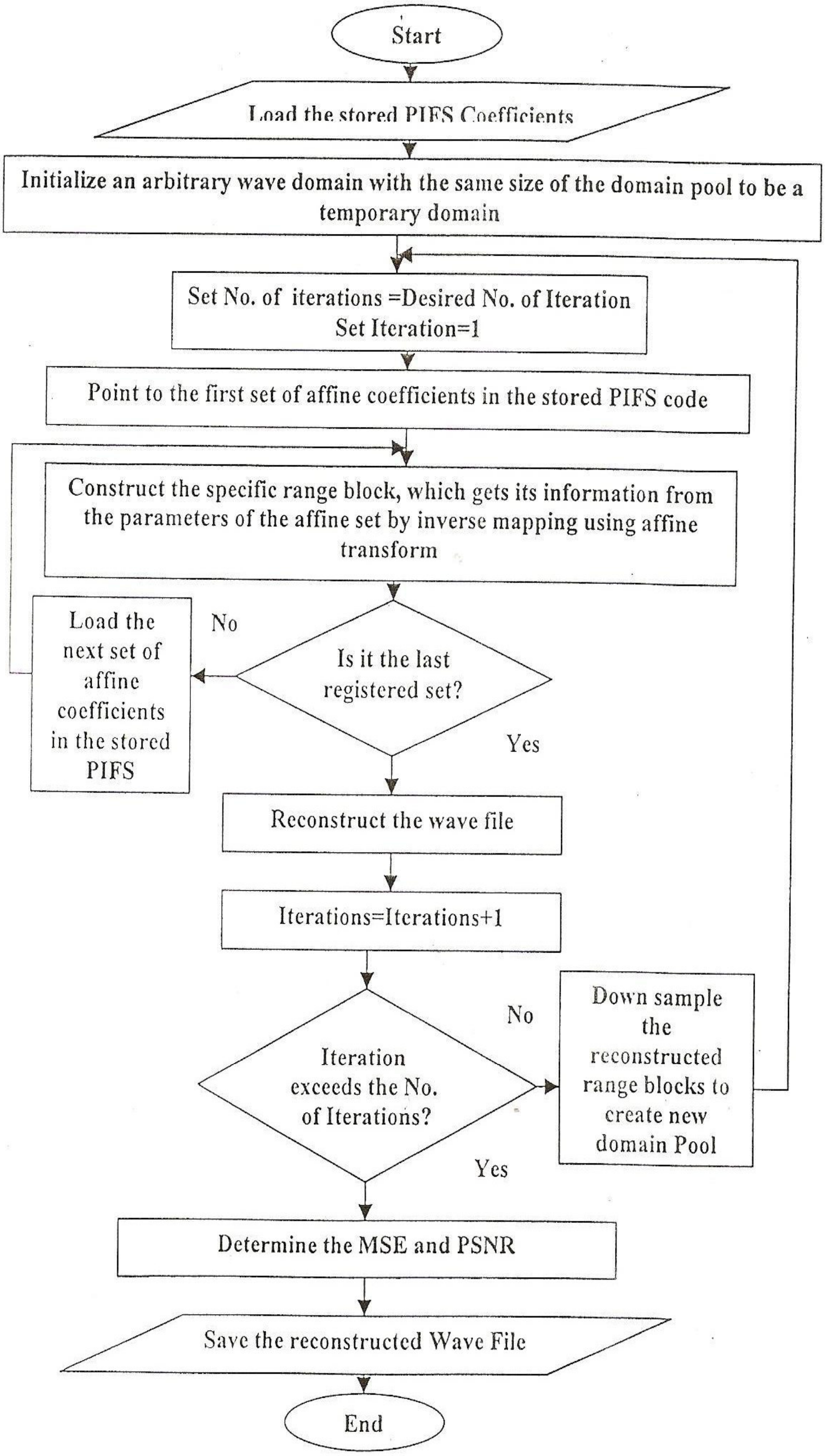


Figure (2): The Flow Chart of The Fractal Audio Decoding Unit

3. Test Results

We present the result of applying fractal audio compression method on several audios in order to evaluate the performance of the suggested audio compression. For evaluation the objective quality measures (such as the Mean Square Error MSE and the Peak Signal to Noise Ratio PSNR) were utilized. Audio compression system using fractal method has been built by using the programming language, visual basic version (6), and all tests were implemented on Pentium-4 computer under xp windows operating system. Four audio files (PCM, mono and 8-bit per sample with different sizes) were used as the test material. And, a number of experiments were conducted to study the system behavior using different performance criteria. Several parameters were taken into consideration to study the performance of the suggested fractal audio compression system. The consider control parameters are: the block size, jump size, MaxScale, MaxOffset, MinOffset, and Quantization steps for both scale and offset. Some performance measures were taken in consideration to evaluate the performance efficiency of the suggested fractal audio compression system. The adopted parameters are the compression ratio and the fidelity criteria PSNR, MSE. The results of four examples will presented, the results are presented in terms of figures and tables to demonstrate the effect of the control parameters on the performance of audio compression system. Table (1) presents the attributes of the adopted four test files. The results of the adopted four test files. Tables (2) to (5) show the MSE and PSNR results of Audio test samples.Figures (3) to (6) show the waveform of test samples, and their corresponding down sampled by waveform.

Table (1): The Properties of the Audio Test Samples

	Block size	Jump size	Max. scale	Min. Scale	Max. offset	Min. offset	Bit/ Scale	Bit/ Offset	PSNR	MSE
Wave1	10	3	1	-1	128	-128	8	8	45.63	28.92
Wave2	10	3	1	-1	128	-128	8	8	45.63	28.92
Wave3	10	3	1	-1	128	-128	8	8	45.63	28.92
Wave4	10	3	1	-1	128	-128	8	8	45.63	28.92

Table (2): The Resulted PSNR and MSE after Reconstruction of the Test Wave Sample

	Block size	Jump size	Max. scale	Min. Scale	Max. offset	Min. offset	Bit/ Scale	Bit/ Offset	PSNR	MSE
Wave1	20	8	2	-2	255	-255	5	7	35.76	69.90
Wave2	20	8	2	-2	255	-255	5	7	35.76	69.90
Wave3	20	8	2	-2	255	-255	5	7	35.76	69.90
Wave4	20	8	2	-2	255	-255	5	7	35.76	69.90

Table (3): The Resulted PSNR and MSE after Reconstruction of the Test Wave Sample

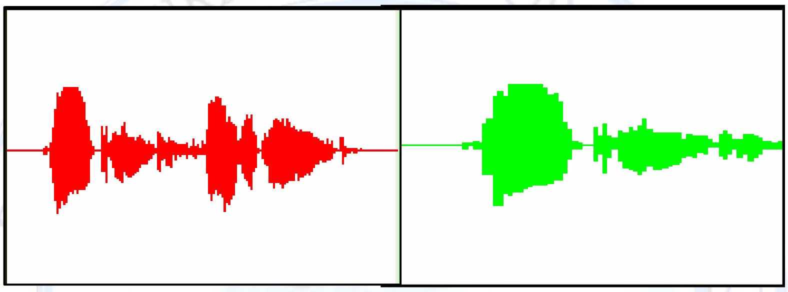
	Block size	Jump size	Max. scale	Min. Scale	Max. offset	Min. offset	Bit/ Scale	Bit/ Offset	PSNR	MSE
Wave1	40	1	1	-1	128	-128	7	7	31.53	726.8
Wave2	40	1	1	-1	128	-128	7	7	31.53	726.8
Wave3	40	1	1	-1	128	-128	7	7	31.53	726.8
Wave4	40	1	1	-1	128	-128	7	7	31.53	726.8

Table (4): The Resulted PSNR and MSE after Reconstruction of the Test Wave Sample

Name	Wave1	Wave2	Wave3	Wave4
Type	Wave sound	Wave sound	Wave sound	Wave sound
Size	34.1KB	80.6KB	146KB	70.3KB
Bit Rate	176 kbps	88 kbps	88 kbps	88kbps
Sample Size	8 bits	8 bits	8 bits	8 bits
Channels	1(mono)	1(mono)	1(mono)	1(mono)
Sample Rate	22kHz	11kHz	11kHz	11kHz
Format	PCM	PCM	PCM	PCM

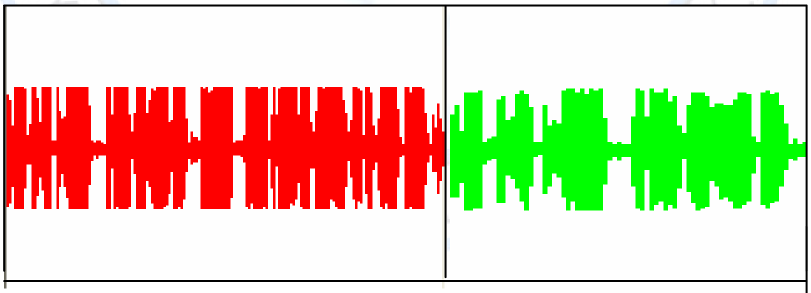
Table (5): The Resulted PSNR and MSE after Reconstruction of the Test Wave Sample

	Block size	Jump size	Max. scale	Min. Scale	Max. offset	Min. offset	Bit/ Scale	Bit/ Offset	PSNR	MSE
Wave1	6	4	1	-1	128	-128	5	8	48.96	154.7
Wave2	6	4	1	-1	128	-128	5	8	48.96	154.7
Wave3	6	4	1	-1	128	-128	5	8	48.96	154.7
Wave4	6	4	1	-1	128	-128	5	8	48.96	154.7



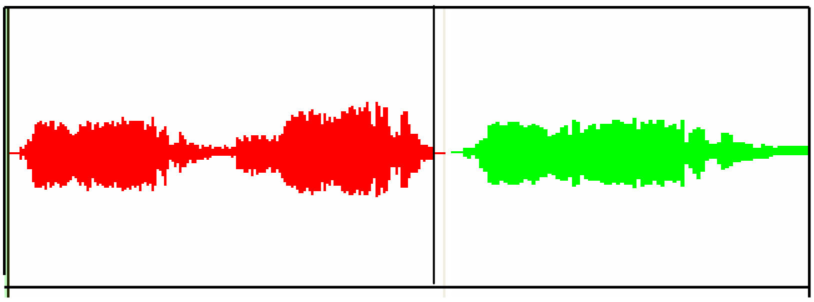
a. Original **b. Down Sample by 2**

Figure (3) The Waveform of the Sample Wave1.



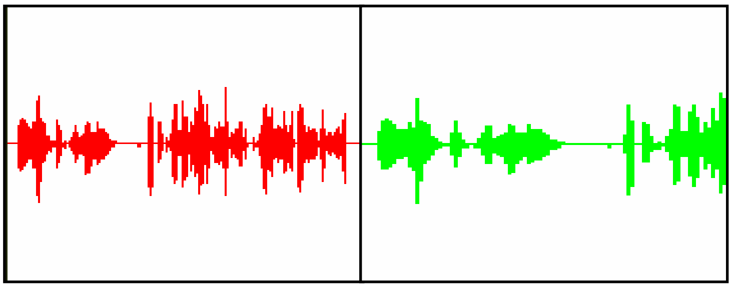
a. Original **b. Down Sample by 2**

Figure (4) The Waveform of the Sample Wave2.



a. Original **b. Down Sample by 2**

Figure (5) The Waveform of the Sample Wave3.



a. Original **b. Down Sample by 2**

Figure (6) The Waveform of the Sample Wave4.

4. Discussion and Conclusions

In this work an attempt is made to design a fractal audio compression system, which can process a PCM wave file data. This work covers the use of transform coding technique to compress the audio signal. From the test results which were done on some selected wave samples, a number of conclusion remarks were drawn:

1. The results of encoding unit are affected by two factors; they are the Block size and Jump size factors. The effects of these two factor could be described as:
   a. The encoding time is inversely proportional with both Block size and Jump size.
   b. PSNR is inversely proportional with both Block size and Jump size.
   c. MSE is proportional with both Block size and Jump size.
   d. Compression Ratio is proportional with both Block size and Jump size.
2. In this work, the fractal audio compression method was implemented. This method has the disadvantage of a very long encoding time. This can considered as the main weak point in fractal compression method.
3. The IFS coefficients (scale and offset) highly affect the compression ratio and it was improved when they are quantized. But these coefficients do not have any affect on the encoding time.
4. Fractal method can provide good compression performance for sound.
5. The encoding step in fractal compression involves very high time complexity (i.e. long encoding time). This weak aspect makes the fractal compression method still not widely used as standard compression, although it achieves a high compression performance, since time is one of the most considerable factors in any compression method.

References

1. Abbas M., "Genetic algorithm and vector quantization for image compression", (PHD. THE), Computer Science and Information System dep., Baghdad, 2002.

2. Al-Shameri W.F., "Some Results on Fractal", M.Sc. Thesis, University of Baghdad, 1997.

3. Barnsley M.F., "Fractal Image Compression", Notice of the AMS, Vol.43, No.6, June, 1996.

4. Barnsley M.F., "Fractals Everywhere", Academic Press Professional, Cambridge, MA, second edition, 1993.

5. Barnsley M.F., and Demko S., "Iterated Function System and the Global Constriction of Fractals", Proc. R. Soc. London, Ser. A399, pp.243-275, 1985.

6. Barnsley M.F., Slaon A.D., "Chaotic Compression", Computer Graphics World, Nov., 1987.

7. Cherbit G., "Fractals Non-Integral dimensions and applications", John wiley & sons Ltd Baffins Lane, Chichester West Sussex Po19 1UD, England, 1991.

8. Davisson L.D., and Gray R.M., "Data Compression", Published by Dowden, Hutchinson& Ross, Inc., 1976.

9. Falconer K., "Fractal Geometry Mathematical Foundation and Application", John Wiley and Sons Ltd., Chichester, 1999.