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# A New Texture Segmentation For Emotion Recognition Based On Fractals

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**ABSTRACT**

Speech waveforms are helpful in a variety of analyses. Research on emotions conveyed through speech has gained attention in recent years. This paper focuses on the recognition of emotion using fractal based texture segmentation. The signal is initially filtered using a median filter, as it is a superior noise reducing filter, especially in the removal of isolated noise spikes. Fractal Dimension of the signal is then found using Higuchi's fractal dimension method. Length of the windows crucially affects the segmentation results. The sampling rate being a uniform 16000, the samples were segmented using an optimum window length of $2^6$. Lacunarity has been evaluated as Fractal Dimension may not be enough to characterize different fractal objects. Lacunarity throws light on the heterogeneity of a texture. Objects which share the same Fractal Dimension may still look different. It is found that Fractal Dimension is capable of differentiating the emotions as well as silent zones from non-silent zones. Segments with greater Fractal Dimension show greater Lacunarity values. This is an implication that the texture is coarse in that particular segment. Choice of Lacunarity for texture segmentation is thus justified.

## INTRODUCTION

Emotions are cognitive processes related to the architecture of the human mind, such as decision making, memory or attention. Emotions use components such as subjective, cultural, physiological and behavioral that individual's perception expresses with regard to the mental state, the body and how it interacts with the environment López-de-Ipiña, K., *et al*., 2013). Speech can be defined as waves of air pressure created by air flow pressed out of lungs and going out through the mouth and nasal cavities. The resonant frequencies of the vocal tract are called formants (Al-Akaidi, M., 2004). Formants carry information about emotional content (Petrushin, V.A., 2000). Vowels and consonants characterize speech. As a result speech signal shows both periodicity and self-similarity. The measure that is most commonly associated with self-similar objects is its Fractal Dimension.Classical Mathematics and signal processing techniques have played a major role in the development of speech recognition systems. The kernel of fractal geometry is the notion of self similarity. A self-similar object appears similar at different scales. The work by Pickover (Pickover, C.A. and A.L. Khorasani, 1986). is supposed to have been the first paper on the application of fractals in speech processing. Several research is on , since then in speech and emotion analyses using fractal dimension.By analyzing the spatial fluctuations in fractal dimension obtained using a conventional moving-window approach, a digital signal can be texture segmented, which is the basic principle of fractal dimension segmentation. It is essential in the field of speech processing that an unsupervised, automatic means of extracting textural features that agrees with human sensory perception can be found. This paper focuses on applying fractal dimension as a measure of texture segmentation in the recognition of emotions. To be specific Higuchi's fractal dimension is used, as it has been successfully applied in finding the fractal dimension of irregular time series. Sets with similar fractal



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dimension might possess varying Lacunarity. So in addition to finding Higuchi's fractal dimension, Lacunarity is also evaluated.The rest of the paper is organized as follows: In section 2, the methodologies are presented. Section 3 presents the results and the last section gives the conclusions of the paper.

### *II. Description of Methods:*

Self-similarity can be quantified as a relative measure of the number of basic building blocks that form a pattern and this measure is defined as Fractal Dimension. The fractal dimension is one of the most commonly used measures to characterize the complexity of a system. Fractal Dimension of natural phenomena is only measurable using statistical approaches. For non-stationary waveforms such as speech waveforms, it is intelligible to segment the signal into various frames and then extract the information contained in each segment (Ezeiza, A., *et al*., 2013). Higuchi's fractal dimension has been chosen in this paper as it is model free.

#### *2.1. Higuchi's Fractal Dimension:*

Higuchi designed a method for finding the fractal dimension of an irregular curve, which is given below:

Consider a finite set of time series observations taken at regular intervals:

$$X(1), X(2), X(3) \ldots X(N). \tag{1}$$

From the given time series the following new time series $X_i^m$ is constructed:

$$X_i^m: X(m), X(m+i), X(m+2i) \ldots X\left(m+\left\lfloor \frac{N-m}{i} \right\rfloor i\right) \quad \text{with } m = 1, 2 \ldots i \tag{2}$$

Here $\lfloor\ \rfloor$ denotes Gauss' notation and both '*i*', '*m*' are integers. They represent the interval time and initial time respectively. For a time interval '*i*', a total of '*i*' new sets of time series are obtained. The series is so constructed that there are no overlaps. If '*i* ' = 4 and *N* =100, the four time series obtained for Higuchi's procedure is:

$$\begin{aligned}
X_4^1 &: X(1),\ X(5),\ X(9), \cdots\cdots\cdots,\ X(97) \\
X_4^2 &: X(2),\ X(6),\ X(10), \cdots\cdots\cdots,\ X(98) \\
X_4^3 &: X(3),\ X(7),\ X(11), \cdots\cdots\cdots,\ X(99) \\
X_4^4 &: X(4),\ X(8),\ X(12), \cdots\cdots\cdots,\ X(100)
\end{aligned} \tag{3}$$

The length of the curve $X_i^m$ is defined as follows:

$$L_m(i) = \left\{ \left( \sum_{l=1}^{\left\lfloor \frac{N-m}{i} \right\rfloor} \left| X(m+l\,i) - X(m+(l-1).i) \right| \right) * \frac{N-1}{\left\lfloor \frac{N-m}{i} \right\rfloor i} \right\} * \frac{1}{i} \tag{4}$$

The term $\dfrac{N-1}{\left\lfloor \frac{N-m}{i} \right\rfloor i}$ represents the normalization factor for the curve length of subset time series.

Let $\langle L(i) \rangle$ be the average value over '*i* ' sets of. If:

$$\langle L(i) \rangle \; \alpha \; i^{-D} \tag{5}$$

then the curve is fractal with the dimension *D*. Using the method of least squares a straight line is fitted. The maximum value of *'i'* is eight (Higuchi, T., 1988).

#### *2.2. Lacunarity:*

The Fractal Dimension which characterizes an object's geometry may not be enough to differentiate between two fractal objects. The reason is that they may share the same Fractal Dimension but still look very different. Lacunarity throws light on the heterogeneity of a texture. The higher the value of Lacunarity, higher is the heterogeneous nature of the object. Lower value of Lacunarity indicates the homogenous nature of the object.

If $P(a,\varepsilon)$ denotes the probability of finding *'a'* points in a box of side $\varepsilon$, then for a fixed size $\varepsilon$, the Lacunarity[7].

$$\Lambda(\varepsilon) = \frac{\langle M^2(\varepsilon)\rangle - \langle M(\varepsilon)^2\rangle}{\langle M(\varepsilon)^2\rangle} \quad (6)$$

Where the statistical moments $M(\varepsilon)$ and $M^2(\varepsilon)$ are calculated using:

$$M(\varepsilon) = \sum_{a=1}^{N} a\ P(a,\varepsilon)$$

$$M^2(\varepsilon) = \sum_{a=1}^{N} a^2\ P(a,\varepsilon) \quad (7)$$

### *III. Description of the Emotion Recognition Tasks:*

The aim of this paper is to recognize emotion using texture segmentation based on Fractal Dimension. Berlin emotional database (Burkhardt, F., *et al*., 2005) is considered for the purpose. The process is as follows:

Step 1: Read the signal.

Step 2: Use a $10^{th}$ order median filter to filter the signal.

Step 3: Evaluate Higuchi's Fractal Dimension and Lacunarity for the filtered signal, by segmenting into various windows.

Noise reduction algorithms aim to reduce noise while attempting to preserve the information content of the signal. Median filter is used here, as it is a superior noise reducing filter especially in the removal of isolated noise spikes (Al-Akaidi, M., 2004). Choice of corpora adds essence to any processing mechanism. The selected database consists of a male and female speaker both aged 31. Two emotion states, anger, happiness and a neutral state are chosen. Three texts common to the speakers are identified and used for analysis. A collective of 14 utterances are used.

## RESULTS AND DISCUSSION

A new texture segmentation approach has been applied to the recognition of emotion based on fractals. Fractal dimension distinguishes between silent zones and the rest. Fractal dimension ranges between 1 and 1.9. The lowest value corresponds to silent zones. Thus Fractal dimension demarcates major peaks. Higuchi's Fractal Dimension of male in happy mood is greater than in neutral mood. At the same time for female the value is less than in neutral mood. In case of angry mood, the Higuchi's Fractal Dimension of male is much greater than in neutral mood. But for female, when compared with angry mood, Higuchi's Fractal Dimension is higher for happy mood. In both male and female Higuchi's Fractal Dimension of neutral mood is less in comparison to the other moods, namely angry and happiness. It is also interesting to note that for male HFD is higher in angry mood and for female it is higher in happy mood (Table 1). This demonstrates that HFD is capable of differentiating emotions, which is a special case of speech. Segments with similar HFD show different Lacunarity values (Table 2). This is an implication that texture varies in that segment. Choice of Lacunarity for texture segmentation is thus justified. The fractal dimension vale remains in the correct range 1 to 2, which proves the efficiency of HFD. Various speech segments show different fractal dimension values. This justifies the use of fractal dimension segmentation. The sampling rate being uniform 16000 in all cases, the samples were segmented into $2^6$ windows. This number was arbitrarily chosen. The original speech waveform for a text spoken by male in happy mood and the corresponding HFD values in various segments are presented in Figure.1, Figure.2 respectively.

**Table 1:** Higuchi's Fractal Dimension(HFD) Values*

| | | Male | Female |
|---|---|---|---|
| Text 1 | Happy | 1.151 ± 0.202 | 1.229 ± 0.238 |
| | Neutral | 1.110 ± 0.190 | 1.167 ± 0.220 |
| Text 2 | Happy | 1.149 ± 0.208 | 1.162 ± 0.165 |
| | Angry | 1.149 ± 0.196 | 1.178 ± 0.224 |
| | Neutral | 1.103 ± 0.147 | 1.118 ± 0.167 |
| Text 3 | Happy | 1.170 ± 0.266 | 1.181 ± 0.167 |
| | Neutral | 1.121 ± 0.215 | 1.161 ± 0.220 |

*expressed as mean ± standard deviation

Australian Journal of Basic and Applied Sciences, 10(1) January 2016, Pages: 546-549

**Table 2:** Similar HFD with varying Lacunarity

| | Male | | Female | |
|---|---|---|---|---|
| HFD | 1.0537 | | 1.1095 | |
| Lacunarity | 2264.3 | 935.534 | 2120.8 | 76.3032 |

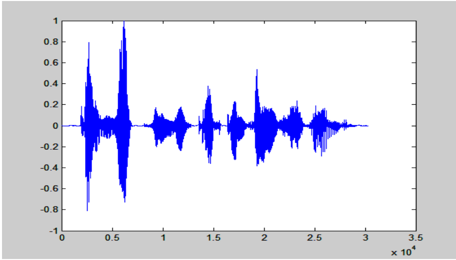

**Fig. 1:** Actual waveform for a text spoken by male in happy mood

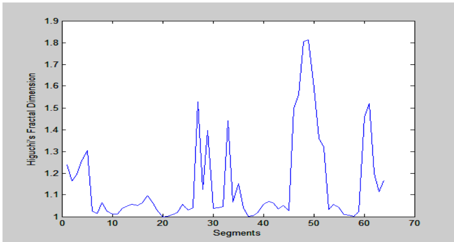


**Fig. 2:** Higuchi's Fractal Dimension values of various segments for a text spoken by male in happy mood

***Conclusion:***

In this paper Fractal dimension has been used for texture segmentation. Signals of emotions carry erratic ups and downs. These are to be filtered properly for effective segmentation. Median filter is used in this paper, which is a superior noise reducing filter. The value of fractal dimension varies for each segment. It reflects on the complexity of the signal and also on the multi fractal nature of speech signal, in particular on signals of emotions. Window size has been chosen as $2^6$. This may be varied, which might yield different fractal dimension value. However this would not affect the inferences of the work. A measure of degree of coarseness or smoothness, Lacunarity has been used in this paper, which is combined with fractal dimension for texture segmentation. There are cases where fractal dimensions of segments coincide, but with different Lacunarity values. This helps in discriminating the textures. Future work may be aimed at experimenting emotions by using different filters and window sizes with more utterances.

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