The Identification of Dog’s Identity via GM(0,N) And Regression Analysis

Mao-Lin Chen, Chien-Tien Fang and Kuo-Chuan Lin

ABSTRACT

The main purpose of the paper is applied the GM(0,N) model in grey system theory to identity the same kinds of dog barking voice in difference order, and also use regression analysis to verify the final result. Firstly, the paper uses Speech Filing System software to transfer the dog voice into the eigen-value state. Secondly, use Gold Wave to filter the voice signal, and translate the value of eigen-value state into digital type, to build up the inspected dog’s barking voice. Finally, through GM(0,N) model to identity the dog barking voice. And use the maximum weighting to identity which one is the most closely to the inspected dog, also use regression analysis to double check the result. Through the real example by using four differences shibu inu, show the method that in our paper is quite successfully.

Keywords: GM(0,N), Dog barking, Regression analysis, Gold Wave, weighting

1. Introduction

Because the sound is the best means of communication to convey the messages; and then people develop the recognition of human voice. Moreover, the main purpose of voice recognition is to achieve communication between the difference species. Hence, the paper used the voice recognition features to identify dogs. As far as dogs are concerned, people distinguish them from their appearances. However, it is difficult to distinguish the dog with same species and age. Therefore, the paper hoped to convert dog’s barking into sound waves. Then the voice recognition app was used to improve the traditional method which uses eyes to distinguish appearances.

There are many papers had published in the past, such as noise reduction, voice enhanced design and voice recognition[1~6], however, the object for the dog was seldom appear. As we know, the main part of the voice recognition is based on the characteristics of sound waves; the existing environment will decrease the rate of voice recognition. Therefore, the paper uses the Speech Filing System software to transfer the voice signal into the type of characteristic parameters at first. Second, use the Gold Wave software to filter the voice signal and to establish the inspected object voice. Finally, the GM(0,N) model and regression analysis are used to get the classification and sorting for objects[7-10].

In the real example, this paper presents to four of the same species shiba inu as the analysis object, record their barking voice, then, use GM(0,N) model and regression analysis to find which dog is the most closest to the inspected voice in database. Through the actual verification, we find that the method in our paper in the dog barking identification is feasible.

The second section is the mathematical model of GM(0,N) and regression analysis, which is mainly to explain the analysis steps. Section 3 introduces the voice recognition, which includes the basic concept of voice recognition and how to get the Mel cepstrum parameter. Section 4 is a real example of dog’s voice identification, and substitutes the measurement data into the mathematical model to derive the results. The final section is conclusion and recommendations for future research.

2. Mathematics Model

2.1 GM(0,N) Model

This research used GM(0,N) as the mathematical models of quantification firstly, among many studies published in the past[5~7], only one article related to this research[11]. Since GM (0,N) model is a special case of GM (1,N) model, it represents zero is differential, while inputting N numbers as the variable, the main function is to study the quantifying relationship between the N numbers of variables, it belongs to the analysis of the static factors[12]. According to the
of GM(0,N), the equation can be presented as
\[ a^{(i)}_j(z^{(i)}(k)) = \sum_{j=2}^{N} b_{j} x^{(i)}(k) \quad k = 1,2,3,\ldots N \quad (1) \]
where: \( z^{(i)}(k) = 0.5x^{(i)}(k) + 0.5x^{(i)}(k-1), k \geq 2 \)

The analysis steps are listed below
1. Substitute the data into Eq. (1), then, we have
   \[ a^{(i)}_j(z^{(i)}(2)) = b_{2} x^{(i)}(2) + \cdots + b_{N} x^{(i)}(2) \]
   \[ a^{(i)}_j(z^{(i)}(3)) = b_{2} x^{(i)}(3) + \cdots + b_{N} x^{(i)}(3) \]
   \[ a^{(i)}_j(z^{(i)}(4)) = b_{2} x^{(i)}(4) + \cdots + b_{N} x^{(i)}(4) \]
   \[ \vdots \]
   \[ a^{(i)}_j(z^{(i)}(n)) = b_{2} x^{(i)}(n) + \cdots + b_{N} x^{(i)}(n) \]
2. Divide \( a_j \) in both sides, and transfer into matrix form
   \[ \begin{bmatrix} 0.5x^{(i)}(1) + 0.5x^{(i)}(2) \\ 0.5x^{(i)}(2) + 0.5x^{(i)}(3) \\ 0.5x^{(i)}(n-1) + 0.5x^{(i)}(n) \end{bmatrix} = \begin{bmatrix} x^{(i)}(2) \\ x^{(i)}(3) \\ x^{(i)}(n) \end{bmatrix} = \begin{bmatrix} h_{1} \\ h_{2} \\ h_{3} \\ \vdots \\ h_{N} \end{bmatrix} \quad (3) \]

Assume \( b_{j} = \hat{b}_{m} \), where: \( m = 2,3,4,\ldots, N \), then, Eq. (3) can be changed into Eq. (4)
\[ \begin{bmatrix} 0.5x^{(i)}(1) + 0.5x^{(i)}(2) \\ 0.5x^{(i)}(2) + 0.5x^{(i)}(3) \\ \vdots \\ 0.5x^{(i)}(n-1) + 0.5x^{(i)}(n) \end{bmatrix} = \begin{bmatrix} x^{(i)}(2) \\ x^{(i)}(3) \\ \vdots \\ x^{(i)}(n) \end{bmatrix} = \begin{bmatrix} \hat{b}_{2} \\ \hat{b}_{3} \\ \vdots \\ \hat{b}_{N} \end{bmatrix} \quad (4) \]

use \( \hat{b} = (Y^{T}Y)^{-1}Y^{T}X \) to find out the values of \( \hat{b}_{m} \)
\[ X = \begin{bmatrix} 0.5x^{(i)}(1) + 0.5x^{(i)}(2) \\ 0.5x^{(i)}(2) + 0.5x^{(i)}(3) \\ \vdots \\ 0.5x^{(i)}(n-1) + 0.5x^{(i)}(n) \end{bmatrix}, \]
where:
\[ Y = \begin{bmatrix} x^{(i)}(2) \\ x^{(i)}(3) \\ \vdots \\ x^{(i)}(n) \end{bmatrix}, \hat{b} = \begin{bmatrix} \hat{b}_{2} \\ \hat{b}_{3} \\ \vdots \\ \hat{b}_{N} \end{bmatrix} \]
\[ \begin{bmatrix} a^{(i)}_{1} \\ a^{(i)}_{2} \\ \vdots \\ a^{(i)}_{N} \end{bmatrix} \]

and the values of \( \hat{b}_{m} \) are the weighting of inspected sequences corresponding to standard sequence \( x_{i} \).

### 2.2 Regression Analysis

Regression analysis is a statistical method for analyzing the behavior of data, the major aim is through the established of mathematical model to understand the correlation, and its direction between two or more variables[13]. In our study, it uses multi-variables regression analysis, and the is shown in Eq.(5).
\[ y_{i}(k) = \sum_{j=1}^{N} a_{j} x_{j}(k) \quad (5) \]

i = 1,2,3,\ldots, m, k = 1,2,3,\ldots,n

rearrange Eq. (5), then we have
\[ y_{i}(1) = a_{1}x_{1}(1) + a_{2}x_{2}(1) + \cdots + a_{N}x_{N}(1) \]
\[ y_{i}(2) = a_{1}x_{1}(2) + a_{2}x_{2}(2) + \cdots + a_{N}x_{N}(2) \]
\[ y_{i}(3) = a_{1}x_{1}(3) + a_{2}x_{2}(3) + \cdots + a_{N}x_{N}(3) \]

\[ \vdots \]
\[ y_{i}(n) = a_{1}x_{1}(n) + a_{2}x_{2}(n) + \cdots + a_{N}x_{N}(n) \]

transfer Eq.(6) into matrix form
\[ \begin{bmatrix} y_{i}(1) \\ y_{i}(2) \\ \vdots \\ y_{i}(m) \end{bmatrix} = \begin{bmatrix} x_{1}(1) \\ x_{2}(1) \\ \vdots \\ x_{N}(1) \end{bmatrix} a_{1} + \begin{bmatrix} x_{1}(2) \\ x_{2}(2) \\ \vdots \\ x_{N}(2) \end{bmatrix} a_{2} + \cdots + \begin{bmatrix} x_{1}(n) \\ x_{2}(n) \\ \vdots \\ x_{N}(n) \end{bmatrix} a_{N} \quad (6) \]

and use \( A = (X^{T}X)^{-1}X^{T}Y \) to find out the values of \( a_{N} \), where:
\[ Y = \begin{bmatrix} y_{i}(1) \\ y_{i}(2) \\ \vdots \\ y_{i}(m) \end{bmatrix}, \quad X = \begin{bmatrix} x_{1}(1) \\ x_{2}(1) \\ \vdots \\ x_{N}(1) \\ x_{1}(2) \\ x_{2}(2) \\ \vdots \\ x_{N}(2) \\ \vdots \\ x_{1}(n) \\ x_{2}(n) \\ \vdots \\ x_{N}(n) \end{bmatrix}, \quad A = \begin{bmatrix} a_{1} \\ a_{2} \\ \vdots \\ a_{N} \end{bmatrix} \]

the values of \( a_{N} \) are the weighting of inspected sequences corresponding to independent sequence \( y_{i} \).
3.1. Voice Signal Pre-processing

The steps of pre-processing are listed below:
1. Use GoldWave to record the dog voice, the sampling frequency is 8,000Hz, recording time 1.6 seconds and single tone.
2. Use linear prediction coefficient algorithms to calculate the input voice signal, the formula is shown in Eq. (8)
   \[ \hat{y}[n] = \sum_{k=1}^{n} a_k \hat{y}[n-k] + e[n] \]  
   (8)
3. Use the voice signal noise elimination method to enhance the voice.
4. Use the linear prediction coefficient method to evaluate the coefficient of the voice in normalized signal, and calculate the sampling value in the frame, to minimize the errors.
   \[ E = \sum_{k=1}^{n} [\hat{y}[n] - a_k \hat{y}[n-k]]^2 \]  
   (9)

Hence, it can get the effect of voice recognition, as shown in Fig. 2.

3.2 Calculation of Parameter

The calculation steps of characteristic parameter are:
1. For the frequency in spectrum of each component, take its logarithmic, and do the inverse Fourier transform, return to the time domain, then it can get a new set of parameters, namely cepstral coefficients.
2. Mel scale: Mel scale is a unit of measure the frequency, according to the experiment, if the frequency less than 1kHz, then the voice sensing in linear, if the frequency over 1kHz, then it is logarithm relationship.
3. Mel cepstrum parameter (MFCC): Because the value in logarithmic intensity spectrum is real number and is symmetrical, therefore, in Fourier transform, only use cosine transform, then the Mel cepstrum parameter can be got.

4. Real Example

For voice recognition, The Experiments of this paper are via Goldwave software and SFSWin program, the design steps are listed below[15].
1. Using GoldWave to record the dog barking sound of four isoforms shiba inu.
2. Filtering the bark waveform, spectrum are shown from Fig. 4 to Fig. 7
3. Finding the cepstrum coefficient (MFCC) of the four isoforms shiba inu, as shown in Table 1.
4. Calculation steps

(1) Build the analysis sequence: Transpose the data in Table 1, and the result is shown in Table 2 [16].

<table>
<thead>
<tr>
<th>MFCC value and dog</th>
<th>K₁</th>
<th>K₂</th>
<th>K₃</th>
<th>K₄</th>
<th>K₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspected shibu inu</td>
<td>1.99</td>
<td>0.23</td>
<td>0.92</td>
<td>0.73</td>
<td>0.75</td>
</tr>
<tr>
<td>Shibu inu-1</td>
<td>1.83</td>
<td>2.19</td>
<td>1.34</td>
<td>2.08</td>
<td>0.99</td>
</tr>
<tr>
<td>Shibu inu-2</td>
<td>3.97</td>
<td>2.48</td>
<td>0.72</td>
<td>1.43</td>
<td>0.04</td>
</tr>
<tr>
<td>Shibu inu-3</td>
<td>0.74</td>
<td>3.43</td>
<td>0.21</td>
<td>1.39</td>
<td>1.32</td>
</tr>
<tr>
<td>Shibu inu-4</td>
<td>0.67</td>
<td>0.62</td>
<td>1.49</td>
<td>0.73</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Table 1 The MFCC value of dog voice

Therefore, the inspected shiba inu is

\[ x_1^{(0)} = (1.99, 0.23, 0.92, 0.73, 0.75, 1.52, 0.98, 0.23, 0.41, 0.02) \]

\[ x_1^{(1)} = (1.99, 2.22, 3.14, 7.12, 7.35, 7.76, 7.78) \]

Shibu inu-1: \[ x_2^{(0)} = (1.83, 2.19, 1.34, 2.08, 0.99, 0.98, 0.02, 0.48, 0.11, 0.42) \]

\[ x_2^{(1)} = (1.83, 4.02, 5.36, 9.41, 4.93, 4.91, 10.02, 10.44) \]

Shibu inu-2: \[ x_3^{(0)} = (3.97, 2.48, 0.72, 1.43, 0.04, 0.66, 0.05, 0.36, 0.09, 0.12) \]

\[ x_3^{(1)} = (3.97, 6.45, 7.17, 8.6, 6.84, 9.3, 9.35, 9.7, 9.8, 9.92) \]

Shibu inu-3: \[ x_4^{(0)} = (0.74, 3.43, 0.21, 1.39, 1.32, 0.63, 0.02, 0.45, 0.38, 0.32) \]

\[ x_4^{(1)} = (0.74, 4.17, 4.38, 5.77, 7.09, 7.72, 7.74, 8.19, 8.57, 8.89) \]

Shibu inu-4: \[ x_5^{(0)} = (0.67, 0.62, 1.49, 0.73, 0.22, 1.03, 0.88, 0.61, 0.22, 0.04) \]

\[ x_5^{(1)} = (0.67, 1.29, 2.78, 3.51, 3.73, 4.76, 5.64, 6.25, 6.47, 6.51) \]

(2) Substitute into Eq. (4) to find the weighting for each factor.

\[ \hat{b}_m = (Y^T Y)^{-1} Y^T X \]

Use \( \hat{b}_m \) to find out the values of \( \hat{b}_m \), where:

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then, we have $\hat{b}_2 = 0.7109$, $\hat{b}_3 = 0.1478$, $\hat{b}_4 = 1.0406$ and $\hat{b}_5 = 1.1396$, as shown in Table 3, also use toolbox to verify it[17].

Table 3 The results from GM(0,N) model

<table>
<thead>
<tr>
<th>Dog</th>
<th>Weighting</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shibu inu-1</td>
<td>0.7109</td>
<td>----</td>
</tr>
<tr>
<td>Shibu inu-2</td>
<td>0.1478</td>
<td>----</td>
</tr>
<tr>
<td>Shibu inu-3</td>
<td>1.0406</td>
<td>----</td>
</tr>
<tr>
<td>Shibu inu-4</td>
<td>1.1396</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig. 8 The verification by using GM(0,N) toolbox

(3) Substitute into Eq. (7) to find the weighting for each factor.

The inspected shiba inu is $y=(1.99, 0.23, 0.92, 0.73, 0.75, 1.52, 0.98, 0.23, 0.41, 0.02)$

Shibu inu-1: $x_1 = (1.83, 2.19, 1.34, 2.08, 0.99, 0.98, 0.02, 0.48, 0.11, 0.42)$

Shibu inu-2: $x_2 = (3.97, 2.48, 0.72, 1.43, 0.04, 0.66, 0.05, 0.36, 0.09, 0.12)$

Shibu inu-3: $x_3 = (0.74, 3.43, 0.21, 1.39, 1.32, 0.63, 0.02, 0.45, 0.38, 0.32)$

Shibu inu-4: $x_4 = (0.67, 0.62, 1.49, 0.73, 0.22, 1.03, 0.88, 0.61, 0.22, 0.04)$

use $A = (X^TX)^{-1}X^TY$ method to calculate the values of $a_1 \sim a_4$, where:

$$Y = \begin{bmatrix} 1.99 \\ 0.23 \\ 0.92 \\ 0.73 \\ 0.75 \\ 1.52 \\ 0.98 \\ 0.23 \\ 0.41 \\ 0.02 \end{bmatrix}, \quad A = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix}$$

the values of $a_1 = 0.0672$, $a_2 = 0.3057$, $a_3 = -0.2246$ and $a_4 = 0.7882$, as shown in Table 4, also use toolbox to verify the final results[17].

Table 4 The results from regression analysis

<table>
<thead>
<tr>
<th>Dog</th>
<th>Weighting</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shibu inu-1</td>
<td>0.0672</td>
<td>----</td>
</tr>
<tr>
<td>Shibu inu-2</td>
<td>0.3057</td>
<td>----</td>
</tr>
<tr>
<td>Shibu inu-3</td>
<td>-0.2246</td>
<td>----</td>
</tr>
<tr>
<td>Shibu inu-4</td>
<td>0.7882</td>
<td>1</td>
</tr>
</tbody>
</table>
5. Conclusion

They are many kinds of dog in the world, and each dog has his unique barking voice, it seems difficult to distinguish the voice. However, after careful observation, it still has some similarities, and by using the Fourier transfer method, we can through the mathematics and science method to resolve this problem.

This article uses Gold Wave software to do the record and filter of the dog’s voice, then use SFSWin to transfer the voice signal into characteristic parameter that to build up the inspected voice database. Finally, GM(0,N) and regression analysis are used to identify the identity the dog’s identity. Through the actual verification, the result show that the fourth shiba Inu is the most closest to inspected dog, means use GM(0,N) model and regression analysis in the identification of dog barking voice is feasible.

Although the paper only use four dogs to the analysis, the seems a little number, the algorithms provided in this field is quite reasonable and feasible, if we can expand the database, and combine with others software and then developed into a hardware set, believe it can improve the efficiency in the dog’s identification.

Acknowledgement

The authors would to thank Chienkuo Technology University, for the supporting in experiment equipment and financial.

References

Table The transpose of the MFCC value of dog voice

<table>
<thead>
<tr>
<th>MFCC value and dog</th>
<th>Shibu inu-1(x1)</th>
<th>Shibu inu-2(x2)</th>
<th>Shibu inu-3(x3)</th>
<th>Shibu inu-4(x4)</th>
<th>Inspected shibu inu(x5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K₁</td>
<td>1.83</td>
<td>3.97</td>
<td>0.74</td>
<td>0.67</td>
<td>1.99</td>
</tr>
<tr>
<td>K₂</td>
<td>2.19</td>
<td>2.48</td>
<td>3.43</td>
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</tr>
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<td>K₄</td>
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<td>1.39</td>
<td>0.73</td>
<td>0.73</td>
</tr>
<tr>
<td>K₅</td>
<td>0.99</td>
<td>0.04</td>
<td>1.32</td>
<td>0.22</td>
<td>0.75</td>
</tr>
<tr>
<td>K₆</td>
<td>0.98</td>
<td>0.66</td>
<td>0.63</td>
<td>1.03</td>
<td>1.52</td>
</tr>
<tr>
<td>K₇</td>
<td>0.02</td>
<td>0.05</td>
<td>0.02</td>
<td>0.88</td>
<td>0.98</td>
</tr>
<tr>
<td>K₈</td>
<td>0.48</td>
<td>0.36</td>
<td>0.45</td>
<td>0.61</td>
<td>0.23</td>
</tr>
<tr>
<td>K₉</td>
<td>0.11</td>
<td>0.09</td>
<td>0.38</td>
<td>0.22</td>
<td>0.41</td>
</tr>
<tr>
<td>K₁₀</td>
<td>0.42</td>
<td>0.12</td>
<td>0.32</td>
<td>0.04</td>
<td>0.02</td>
</tr>
</tbody>
</table>

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