ISBN: 978-1-948012-17-1

Ethics and Information Technology (ETIT)

DOI: <http://doi.org/10.26480/etit.02.2020.84.89>

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SINGER IDENTIFICATION USING STATISTICAL SIGNAL PROCESSING

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ARTICLE DETAILS

Article History:

Received 25 October 2020
Accepted 26 November 2020
Available online 03 December 2020

ABSTRACT

A song is a combination made up lyrics and music, balance feeling or emotion in connection to a particular matter. In the first study, a singer with one Vocal Hindi song is taken as data set. Spectral centroid, entropy, skewness, kurtosis and brightness are used as a musical feature of the song. One-Sample Kolmogorov-Smirnov test is used for data normality checking of those features. This procedure determines whether a sample comes from a population which is normally distributed. Then Correlation Coefficient on (spectral centroid and brightness), (spectral centroid and entropy) and (skewness and kurtosis) are proposed, concerning the singer's voice. Using the Student T- a test we have found the most significant T values of the songs of the singers. It is used to identify the singers for the song. The singer identifies his own identification test giving the most significant values of his song. Similarly, the insignificance values between two musical features of two different singers do not give the singer's identification test.

KEYWORDS

Kolmogorov-Smirnov test, Song, Musical features, Correlation Coefficient.

1. INTRODUCTION

Normality tests denotes a data set is well-modelled by a normal distribution. It is used to determine whether a random variable comes from a population which is normally distributed (Shenoy et al., 1994). For experiment purpose 5 Musical features or Audio features like spectral centroid, entropy, skewness, kurtosis and brightness are used as a dataset (mahto et al., 2014; Datta et al., 2017; Chandwadkar et al., 2013; Deshmukh et al., 2014; Masood et al., 2016). Normality test or (Kolmogorov-Smirnov test) is proposed on spectral centroid, entropy, skewness, kurtosis and brightness, concerning a singer's voice. These tests determine all the musical features are normally distributed. The singer with one vocal Hindi song is taken as data set. Then Correlation Coefficient on (spectral centroid and brightness), (spectral centroid and entropy) and (skewness and kurtosis) are proposed, concerning the singer's voice (Gupta et al., 1970). A Correlation Coefficient is a statistical relationship between two variables.

The variables denote two columns of data set observations, often called a sample. Here the samples are musical features. Student T-test is applied to these correlation values of the singer for the significance test (Gupta et al., 1970). Using the Student T-test we have found the most significant T values of the song of the singer. The singer identifies the own identification giving the most significant values of the song. Another experiment we have found the insignificance values between two musical features of two different singers.

So it does not identify the singer's song. Various types of research have been performed on normality. In statistics, it is usual to assume that the observations are normal. The entire statistical framework has followed this assumption. The inference breaks down if this assumption is violated. For this reason, it is necessary to check this assumption before any

statistical analysis of data. A brief review of normality is shown in this paper (Das et al., 2016). Normality tests can be classified in this paper (Yap et al., 2011). The machine learning algorithm used to emotion rating gives an average correlation of 0.65 (Laurier et al., 2009). Sensation Seeking and Preference of Type of Music in College Students were analyzed by the statistical independent T-test and Pearson correlation coefficient 0.28 (Heydari et al., 2012). Features correlation is used to increase the accuracy of the classification process. The highest correlation value obtained at 0.23 (Leleuly et al., 2020). The comparison of these correlation coefficient papers, our experiment gives a high correlation coefficient value (0.99). In this paper Section 2 describes methodology, Section 3 results and discussion and Section 4 conclusion.

2. METHODOLOGY

The Singer identification process block diagram is presented in Figure 1. The following steps are:

Step 1 Song excerpts are taken.
Step 2 Features like spectral centroid, entropy, skewness, kurtosis and brightness are extracted from these excerpts of songs.
Step 3 One sample KS (Kolmogorov-Smirnov) test is used on the extracted features. Using this test the data normality check is found out.
Step 4 Then we find out the Pearson correlation coefficient on (spectral centroid and brightness) of the two singer's songs. Next found out Pearson correlation coefficient on (spectral centroid and entropy) of the two singer's songs. At last, found out the Pearson correlation coefficient on (skewness and kurtosis) concerning the two singer's songs.
Step 5 For singer identification Student T-test algorithm is applied to these correlation values of the singer's songs. If the absolute value of T is greater than the tabulated T value, the singer is identified with significance.

Quick Response Code	This paper was presented at	Access this article online	
	International Conference on Contemporary Issues in Computing (ICIC-2020) - Virtual IETE Sector V, Salt Lake, Kolkata From 25th-26th July 2020	Website: www.intelcomp-design.com	DOI: 10.26480/etit.02.2020.84.89

Figure 1: Singer identification process block diagram

2.1 Database collection

In this research, we have recorded the singer's vocal Hindi songs. For recording purpose, we used Behringer mic, Behringer mixer, creative 5.1 sound card and sonic foundry sound forge 7.0 software.

In this experiment, a singer with one Hindi vocal song in WAV format is taken as data set. This song is clipped 10 divisions with 5-sec duration. The audio files have various attributes such as file type (.wav), sampling rate (44.1k), audio type (mono) bit rate etc. The framing process is done by the MATLAB14 and MIRTOOLBOX.

2.2 Feature Extraction

In this research, we have found out spectral centroid, Shannon entropy, skewness, kurtosis and brightness for this experiment.

Spectral Centroid gives the weighted mean of the frequencies present in a signal, using their amplitudes as weights.

$$\text{Centroid} = \frac{\sum_{n=0}^{N-1} c(n)x(n)}{\sum_{n=0}^{N-1} x(n)} \quad (1)$$

$c(n)$ = central frequency of the audio signal
 $x(n)$ = frequency values of the audio signal

Shannon Entropy gives the following equation in information theory.

$$H(x) = -\sum_{i=1}^N P(x_i) \log_2 p(x_i) \quad (2)$$

Spectral entropy gives information about the signal and indicates whether it contains predominant peaks or not.

Skewness is the measure of the symmetry or asymmetry of a signal.

$$\text{Skewness} = \frac{\sum_{i=1}^N (Y_i - \bar{Y})^3}{(N-1)s^3} \quad (3)$$

where $\bar{Y}$ is the mean, s is the standard deviation and N is the number of data points.

Kurtosis is a measure of the noisiness of a signal. It shows whether the data is peaked or flat relative to a normal distribution.

$$\text{Kurtosis} = \frac{\sum_{i=1}^N (Y_i - \bar{Y})^4}{(N-1)s^4} \quad (4)$$

Where $\bar{Y}$ is the mean, s is the standard deviation and N is the number of data points

Brightness can be defined as a proportion of the energy above a certain frequency value in a sound signal. Default

value of frequency value is 1500 Hz.

2.3 One Sample Kolmogorov-Smirnov Test for Normality

The one-sample Kolmogorov-Smirnov test is used to determine whether a sample comes from a population which is normally distributed.

Hypothesis Testing

Let $x_1, \dots, x_n$ be an ordered sample with $x_1 \leq \dots \leq x_n$. $S_n(x)$ is given this equation.

$$S_n(x) = \begin{cases} 0, & x < x_1 \\ k/n, & x_k \leq x < x_{k+1} \\ 1, & x \geq x_n \end{cases} \quad (5)$$

The sample comes from a population with cumulative distribution function $F(x)$. D_n is given this equation

$$D_n = \sup_{x \in \mathbb{R}} |F(x) - S_n(x)| \quad (6)$$

The important point of this distribution is the critical values which can be found in the Kolmogorov-Smirnov Table.

If $D_{n,\alpha}$ is the critical value from the Kolmogorov-Smirnov Table, then $P(D_n \leq D_{n,\alpha}) = 1 - \alpha$. A random sample came from a population with a specific distribution function $F(x)$, D_n can be used to test the hypothesis. If $\sup_{x \in \mathbb{R}} |F(x) - S_n(x)| \leq D_{n,\alpha}$

then the sample data is a good fit with $F(x)$.

2.4 Pearson correlation coefficient

The Pearson correlation coefficient defines the covariance of two variables divided by the product of the standard deviations.

Pearson correlation coefficient denotes by the r .

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\left\{ \sum_{i=1}^n (x_i - \bar{x})^2 \right\} \left\{ \sum_{i=1}^n (y_i - \bar{y})^2 \right\}}} \quad (7)$$

$$= \frac{\text{cov}(x, y)}{S_x S_y}$$

where $x_i, i=1, \dots, n$ and $y_i, i=1, \dots, n$ are two sample variables. Sample means are $\bar{x}$ and $\bar{y}$. And Standard deviations are S_x and S_y . Covariance denotes by "cov".

2.5 Student T-test

The significance of a sample correlation, r , depends on the sample size and also on the size of r .

Three assumptions follow to Significance test of a t-test. These are

- The samples, x and y , are drawn from populations that follow a bivariate normal distribution
- The samples are random samples from the population
- The population correlation coefficient is zero: $\rho=0$

$$T = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}} \quad (8)$$

This equation follows t-distribution with $N-2$ degrees of freedom, where N is the sample size. The null and alternative hypotheses for a test (two-sided) are:

$H_0: \rho = 0$

$H_1: \rho \neq 0$

To apply the algorithm in the singer identification test,

At first, compute the statistic T . Then decide on an α -level (e.g., $\alpha = 0.05$ for a 95% confidence interval). Then compare the computed T with the $1-\alpha/2$ probability point of the cdf of Student's t-distribution.

If the absolute value of T is greater than the probability point, reject H_0 .

3. RESULTS AND DISCUSSION

In this experiment, we have found out the one-sample Kolmogorov-Smirnov test of 5 musical features (spectral centroid, entropy, skewness, kurtosis and brightness) of first singer using the equation (5) and (6).

Table 1 to Table 5 shows the Kolmogorov-Smirnov test of first singer's musical features.

Here the musical features are used as a dataset. From these tables we see the maximum difference value (0.214947, 0.173837, 0.144005, 0.153408 and 0.204535) is lower than the critical value $D_{n,\alpha} = 0.40925$.

The critical value is taken from the Kolmogorov-Smirnov (KS) table.

All results of the tables are normally distributed. So the all musical features of the singer are normally distributed.

Table 1: First singer's Kolmogorov-Smirnov test using Spectral Centroid

X	x (small to large)	Frequency	Cumulative frequency	$S_n(x)$	Z score	F(x)	Difference
3045.457	2052.36	1	1	0.1	-0.88324	0.188554	0.088554
2069.702	2069.702	1	2	0.2	-0.8547	0.19636	0.00364
2559.866	2126.298	1	3	0.3	-0.76154	0.223167	0.076833
2815.066	2209.259	1	4	0.4	-0.62499	0.265988	0.134012
2243.949	2243.949	1	5	0.5	-0.56789	0.285053	0.214947
2126.298	2559.866	1	6	0.6	-0.04792	0.480891	0.119109
2052.36	2766.233	1	7	0.7	0.29175	0.614761	0.085239
2209.259	2815.066	1	8	0.8	0.372126	0.645101	0.154899
2766.233	3045.457	1	9	0.9	2.325065	0.773775	0.126225
4001.588	4001.588	1	10	1	2.325065	0.989966	0.010034
2588.978 Mean	607.5574 Standard Deviation						

Table 2: First singer's Kolmogorov-Smirnov test using entropy

X	X (small to large)	Frequency	Cumulative Frequency	$S_n(x)$	Z score	F(x)	Difference
0.867096	0.826997	1	1	0.1	-1.45711	0.072543	0.027457
0.838961	0.838961	1	2	0.2	-0.84298	0.199621	0.000379
0.853266	0.842836	1	3	0.3	-0.64407	0.259765	0.040235
0.866622	0.84656	1	4	0.4	-0.4529	0.325312	0.074688
0.84656	0.850296	1	5	0.5	-0.26114	0.396993	0.103007
0.842836	0.853266	1	6	0.6	-0.10866	0.456735	0.143265
0.826997	0.864176	1	7	0.7	0.451372	0.674139	0.025861
0.850296	0.866622	1	8	0.8	0.576889	0.717993	0.082007
0.864176	0.867096	1	9	0.9	0.60125	0.726163	0.173837
0.897021	0.897021	1	10	1	2.137343	0.983715	0.016285
0.855383 Mean	0.019481 Standard Deviation						

Table 3: First singer's Kolmogorov-Smirnov test using skewness

X	x (small to large)	Frequency	Cumulative frequency	$S_n(x)$	Z score	F(x)	Difference
1.966469	1.483249	1	1	0.1	-1.75989	0.039214	0.060786
3.055801	1.966469	1	2	0.2	-0.85929	0.19509	0.00491
2.353909	2.004284	1	3	0.3	-0.78882	0.21511	0.08489
2.004284	2.075685	1	4	0.4	-0.65574	0.255995	0.144005
2.572004	2.353909	1	5	0.5	-0.13721	0.445433	0.054567
2.850287	2.572004	1	6	0.6	0.26926	0.606135	0.006135
3.066053	2.84756	1	7	0.7	0.782821	0.783134	0.083134
2.84756	2.850287	1	8	0.8	0.787905	0.784624	0.015376
2.075685	3.055801	1	9	0.9	1.170928	0.879186	0.020814
1.483249	3.066053	1	10	1	1.190035	0.882984	0.117016
2.42753 Mean	0.536558 Standard Deviation						

Table 3: First singer's Kolmogorov-Smirnov test using skewness

X	x (small to large)	Frequency	Cumulative frequency	$S_n(x)$	Z score	F(x)	Difference
6.893201	4.461876	1	1	0.1	-1.60425	0.054329	0.045671
13.50631	6.794496	1	2	0.2	-0.89538	0.185291	0.014709
8.884226	6.893201	1	3	0.3	-0.86539	0.193413	0.106587
6.794496	7.485957	1	4	0.4	-0.68525	0.246592	0.153408
10.53564	8.884226	1	5	0.5	-0.26033	0.397305	0.102695
12.75024	10.53564	1	6	0.6	0.241527	0.595426	0.004574
13.83319	12.26355	1	7	0.7	0.766626	0.778348	0.078348
12.26355	12.75024	1	8	0.8	0.914527	0.81978	0.01978
7.485957	13.50631	1	9	0.9	1.144294	0.873749	0.026251
4.461876	13.83319	1	10	1	1.243629	0.893182	0.106818
9.740868 Mean	3.290628 Standard Deviation						

In experiment 1 we have found out correlation coefficient on (spectral centroid and brightness), (spectral centroid and entropy) and (skewness and kurtosis) concerning same singer's songs using the equation (7). Two singer's songs are used here. First singer's song's correlation coefficient on (spectral centroid and brightness) is (0.97053). First singer's song's correlation coefficient on (spectral centroid and entropy) is (0.96568). First singer's song's correlation coefficient on (skewness and kurtosis) is (0.99598). Table 6 to Table 8 shows the different values of correlation coefficients of the first singer's song These positive results of correlation

coefficient determine that the features are the same for the same singer. Using the Student T-test equation (8) we find the most significant T values. The first singer's first song's T value of correlation coefficient on (spectral centroid and brightness) is (11.42). The first singer's first song's T value of correlation coefficient on (spectral centroid and entropy) is (11.42). The first singer's first song's T value of the correlation coefficient on (skewness and kurtosis) is (2.82). The tabulated $t_{0.05}$ for (10-2)=8 df is 2.31. Since calculated T value is much greater than the tabulated T =2.31, it is significant and H_0 is discredited at a 5% level of significance. Same singer's

features give high positive correlation values for every three songs. The calculated T values are greater than the tabulated $T=2.31$ value. So we can say all calculated T values are significant. The singer identifies his own identification test giving the most significant values of his song. Similarly, the second singer's song is used to calculate the correlation coefficient value. Second singer's song's correlation coefficient on (spectral centroid and brightness) is (0.94717). Second singer's song's correlation coefficient on (spectral centroid and entropy) is (0.75964). Second singer's song's correlation coefficient on (skewness and kurtosis) is (0.99150). Table 9 to Table 11 shows the different values of correlation coefficients of the second singer's song. These positive results of correlation coefficient determine that the features are the same for the same singer. Using the Student T-test equation (8) we find the most significant T values. The Second singer's first song's T value of correlation coefficient on (spectral

centroid and brightness) is (8.50). The Second singer's first song's T value of correlation coefficient on (spectral centroid and entropy) is (3.30). The Second singer's first song's T value of the correlation coefficient on (skewness and kurtosis) is (19.85). The tabulated $t_{0.05}$ for (10-2)=8 d.f. is 2.31. Since calculated T value is much greater than the tabulated $T=2.31$, it is significant and H_0 is discredited at a 5% level of significance. Same singer's features give high positive correlation values for every three songs. The calculated T values are greater than the tabulated $T=2.31$ value. So we can say all calculated T values are significant. The singer identifies his own identification test giving the most significant values of his song. Figure 2, gives the graphical representation of correlation coefficient values of two singer's different three Hindi songs.

Table 5: First singer's Kolmogorov-Smirnov test using brightness

X	x (small to large)	Frequency	Cumulative frequency	$S_n(x)$	Z score	F(x)	Difference
0.497692	0.313938	1	1	0.1	-1.1227	0.130782	0.030782
0.313938	0.347305	1	2	0.2	-0.77567	0.218971	0.018971
0.405374	0.360967	1	3	0.3	-0.63359	0.263176	0.036824
0.420793	0.366632	1	4	0.4	-0.57467	0.282758	0.117242
0.360967	0.375868	1	5	0.5	-0.47861	0.316108	0.183892
0.366632	0.405374	1	6	0.6	-0.17173	0.431825	0.168175
0.347305	0.420793	1	7	0.7	-0.01137	0.495465	0.204535
0.375868	0.494295	1	8	0.8	0.753081	0.774299	0.025701
0.494295	0.497692	1	9	0.9	0.78842	0.784774	0.115226
0.635995	0.635995	1	10	1	2.226831	0.987021	0.012979
0.421886 Mean	0.09615 Standard Deviation						

Table 6: First singer's song's correlation coefficient using spectral centroid and brightness

Song's spectral centroid	Song's brightness	Correlation coefficient
3045.457	0.497692	
2069.702	0.313938	
2559.866	0.405374	
2815.066	0.420793	0.970538
2243.949	0.360967	
2126.298	0.366632	
2052.36	0.347305	
2209.259	0.375868	
2766.233	0.494295	
4001.588	0.635995	

Table 7: First singer's song's correlation coefficient using spectral centroid and entropy

Song's spectral centroid	Song's entropy	Correlation coefficient
3045.457	0.867096	
2069.702	0.838961	
2559.866	0.853266	
2815.066	0.866622	0.965681
2243.949	0.84656	
2126.298	0.842836	
2052.36	0.826997	
2209.259	0.850296	
2766.233	0.864176	
4001.588	0.897021	

Table 8: First singer's song's correlation coefficient using skewness and kurtosis

Song's skewness	Song's kurtosis	Correlation coefficient
1.966469	6.893201	
3.055801	13.50631	
2.353909	8.884226	
2.004284	6.794496	0.995984
2.572004	10.53564	
2.850287	12.75024	
3.066053	13.83319	
2.84756	12.26355	
2.075685	7.485957	
1.483249	4.461876	

Table 9: Second singer's song's correlation coefficient using spectral centroid and brightness

Song's spectral centroid	Song's brightness	Correlation coefficient
3611.426	0.402041	
3164.162	0.341627	
4117.268	0.526889	
5047.692	0.734654	0.94717
5243.122	0.691873	
3971.346	0.508735	
3810.373	0.48763	
3364.682	0.369903	
3130.839	0.44016	
3318.524	0.451839	

Table 10: Second singer's song's correlation coefficient using spectral centroid and entropy

Song's spectral centroid	Song's entropy	Correlation coefficient
3611.426	0.820682	
3164.162	0.854206	
4117.268	0.854095	
5047.692	0.871456	0.759646
5243.122	0.90473	
3971.346	0.87085	
3810.373	0.864763	
3364.682	0.844794	
3130.839	0.845446	
3318.524	0.849531	

Table 11: Second singer's song's correlation coefficient using skewness and kurtosis

Song's skewness	Song's kurtosis	Correlation coefficient
1.52227	4.407414	
1.918026	6.022229	
1.300187	3.933574	
1.219483	3.598132	0.991505
0.8732	2.763993	
1.40274	4.126734	
1.423186	4.233415	
1.932774	5.938269	
1.780762	5.671323	
1.738909	5.386435	

In experiment 2 we have found out correlation coefficient on (spectral centroid and brightness),(spectral centroid and entropy) and(skewness and kurtosis) concerning two singer's songs using the equation (7). Two different singer's songs are used here. At first, we have found out the correlation coefficient of first singer's song's spectral centroid and second singer's song's brightness.

Next, we have found out the correlation coefficient of first singer's song's spectral centroid and second singer's song's entropy. Then we have found out the correlation coefficient of first singer's song's skewness and second singer's song's kurtosis. Table 12 to Table 14 shows the correlation coefficient of two features of two singers. The correlation values are (-0.00432, -0.38686 and 0.037553).

These negative and zero value results of correlation coefficient determine that the features are not the same singers. Using student T-test equation (8) the T values are(-0.0121,-1.1977 and 0.0848).

The tabulated $t_{0.05}$ for (10-2)=8 d.f. is 2.31. Since calculated T value is much lesser than the tabulated T =2.31, it is insignificant and H_0 is not discredited at a 5% level of significance. These three T values are insignificant. So different singer's features do not give significance value.

Table 12: Correlation Coefficient in between first singer's song's spectral centroid and second singer's song's brightness.

First singer's song's spectral centroid	Second singer's song's brightness	Correlation coefficient
3045.457	0.402041	
2069.702	0.341627	
2559.866	0.526889	
2815.066	0.734654	-0.00432
2243.949	0.691873	
2126.298	0.508735	
2052.36	0.48763	
2209.259	0.369903	
2766.233	0.44016	
4001.588	0.451839	

Table 13: Correlation Coefficient in between first singer's song's spectral centroid and second singer's song's entropy.

First singer's song's spectral centroid	Second singer's song's entropy	Correlation coefficient
3045.457	0.820682	
2069.702	0.854206	
2559.866	0.854095	
2815.066	0.871456	-0.38686
2243.949	0.90473	
2126.298	0.87085	
2052.36	0.864763	
2209.259	0.844794	
2766.233	0.845446	
4001.588	0.849531	

Table 14: Correlation Coefficient in between first singer's song's skewness and second singer's song's kurtosis.

First singer's song's skewness	Second singer's song's kurtosis	Correlation coefficient
1.966469	4.407414	
3.055801	6.022229	
2.353909	3.933574	
2.004284	3.598132	0.037553
2.572004	2.763993	
2.850287	4.126734	
3.066053	4.233415	
2.84756	5.938269	
2.075685	5.671323	
1.483249	5.386435

Figure 2: Graphical representation of correlation values of two singer's different three Hindi songs.

4. CONCLUSION

In this paper, we have done a normality test of musical features of a singer. We used this procedure to determine whether a sample comes from a population which is normally distributed. We found out the musical features are normally distributed. In the first experiment, the correlation coefficient of the two singers' own features gives high positive values. All high positive correlation values for the same singer's song. Using these correlation coefficient values we calculate the T values of the song whose all values are significant. So we can say all the significant values of the song determine that the singer is the same. This is an identification process of a singer. In this way, we can identify the singer's individuality. The second experiment gives the insignificant values of the two different singer's songs. Different singer's features are not used to identify the singer's individuality. So it does not identify the singers.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the University Grant Commission (Ministry of Human Resource Development) for financial support in carrying out the research work.

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