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Gabor Filter Methods to Analyze the Influence of Geographic Distance and Folk Song in Java Indonesia

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***Abstract*— Gabor filter as a prominent filter approach ever done in digital audio signal to find cultural diffusion patterns in Indonesia by analyzing folk songs. The topic is interesting and rarely discussed, but unfortunately, several weaknesses still exist in the research, which are the folk songs used is biased, one of the primary theoretical basis is invalid, and the most unfortunate is the sourcebook of the dataset does not have International Standard Book Number, which means the book is unregistered. Therefore, by using identical methods (Gabor filtration), present research would perform some development from the lack of prior research to get better results. This research specified the testing area to improve focus - which is only used provinces in Java Island folk songs, used a valid dataset source, and added several different spectrogram sizes to improve accuracy. Compared to previous, recent research hit better results since it has more significant features and directly proportional relations than before.**

Keywords*— *Audio Signal, Cultural Diffusion, Folk Songs, Gabor Filter, Java Island

I. Introduction

Gabor filter is a prominent filter approach that finds applications in various domains, especially optical imaging techniques such as Optical coherence tomography (OCT) [1-3]. As a texture-suited algorithm, Gabor no exception is used to detecting fuzziness level which determines defect fabrics [4], recognize palm print by the robustness [5], and even categorize pork quality from filtered hyperspectral images [6]. In the health sector, Gabor useful for locating the nipple position in mammograms [7] and analyzing retinal blood vessels to detect and prescribe appropriate treatment to the diabetic patient [8]. Gabor also performs well in filtering the audio signal [9] which leads to speech enhancement from noise filter process [10] and filter unknown, non-stationary signals embedded in unknown noise [11].

Interestingly, the filter also possible to be used in digital music audio and one of them was using Indonesian folk songs as an object to know how cultural diffusion happened [12]. Diffusion itself is a spreading process of cultural factors from one to another social group. The diffusion process goes on using either mimicking or imitating technique because imitating existing things is more comfortable than producing [13]. The research was sure that unique features in folk songs have their region characteristic and are related to each geographical distance. The study conducted using Gabor by changing audio music signals to a specific size spectrogram image. Unfortunately, the research has some lacks:

1. Data is sufficient because only one or two songs are chosen to represent each region in Indonesia as a diverse country [14], possibly to bias and inaccurate results are likely to happen.
2. The research claim Mustika Group music book that used as the primary resource is on the Indonesian curriculum standard or known as Kurikulum Tingkat Satuan Pendidikan (KTSP) 2006, but KTSP 2006 not mention the book [15]. Moreover, the book has no International Standard Book Number (ISBN) is an international valid book identity [16].

To complete the prior research, present research conducts using ISBN resource book as the folk songs data primary reference, focus only on the Java Island region, and adding more songs that enough to represent each region.

II. The Proposed Method

To increase the comparison accuracy from prior research, the present study is still using the same method approach, which is song data identification using Gabor Filter and identify the final result qualitatively using Linear Regression. Yet, because the dataset different from used before, there are several things adjusted to match the present condition.

The research flow is consists of 3 main steps with adding one more step to determine the final decision. The data collected tested by the Gabor Filtration method for each respected spectrogram pixel size, as mentioned before, then perform Linear Regression to the best result obtained. Good or bad Linear Regression results judged based on total significant p-value appear (p-value below 0.05), which is the more below 0.05 value appears in the respected size means that the result better than the other.

Besides, as the measurement of linear regression results, p-value also used as the determinant to continue research to the next step. If the total significant p-value is not greater than prior research, then a new data will be used to re-work with the algorithm. Else if vice versa, the last step will be the result comparison of the prior and present research.

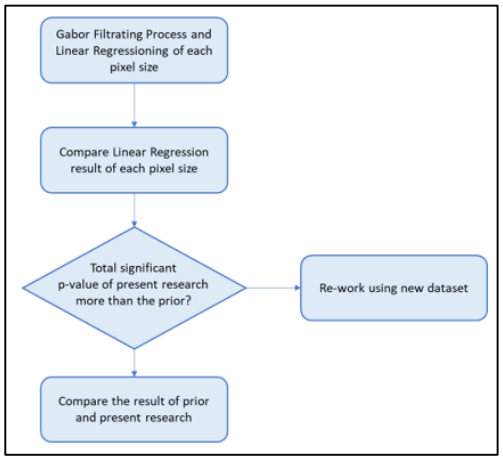

Fig. 1. Research Flow

III. Research Method

A. Audio Data

This study uses a total of 45 folksongs from 6 regions in Java Island. Each area has three until 11 representation songs. Song list is taken from RPUL Indonesia Book by Erlangga [17]. Song from the list one by one goes through the Spotify availability check. Spotify was chosen because the platform provides trusted and only from the distributor or recording label exclusive data [18]. Song files have the WAV extension with 180 seconds maximum duration.

B. Geographical Distance Data

Longitude and latitude used to calculate geographical distance are taken from Google Maps [12] which use the middle point of an area:

TABLE I. Longitude and Latitude of Java Island Region

Region	Longitude	Latitude
Banten	106.064018	-6.405817
Jakarta	106.865036	-6.17511
West Java	107.668884	-7.090911
Center Java	110.140259	-7.150975
East Java	112.238403	-7.536064
Yogyakarta	110.369492	-7.79558

Using Haversine formula (1), longitude and latitude then calculated to get the geographical distance of each region in km:

$$d = 2r \arcsin\left(\sqrt{hav(\varphi_2 - \varphi_1) + \cos(\varphi_1)\cos(\varphi_2)\, hav(\lambda_2 - \lambda_1)}\right) \quad (1)$$

$$= 2r \arcsin\left(\sqrt{sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + \cos(\varphi_1)\cos(\varphi_2) sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right)$$

This study uses the Gabor Filter method for music extraction. Gabor is a linear filter that is usually used for analysis of a texture. Analysis of images with Gabor has similarities with perceptions on the human visual system [19].

$$g\lambda, \varphi, \sigma, \gamma(x, y) = exp\left(-\frac{x^2 + \gamma^2 y^2}{2\sigma^2}\right) cos\left(2\pi \frac{x'}{\lambda} + \varphi\right)$$
$$x' = xcos\theta + ysin\theta \quad (2)$$
$$y' = -xsin\theta + ycos\theta$$

In this equation, lambda is the length of the window, theta is the orientation of the Gabor function, sigma is the standard deviation of the Gaussian blur, and gamma is the spatial aspect ratio which also defines the ellipticity of the Gabor function.

After Gabor Filtration, Linear Regression for identifying the relation between music tones and geographical distance as used in prior research [12] with some changes. The main steps could be seen in the figure below.

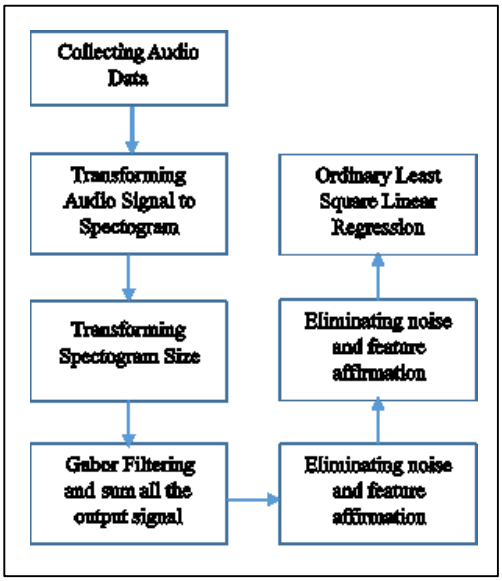

Fig. 2. The whole flow of the research methodology

First, Audio data was collected in the form of a one-channel WAV extension. The audio should be able to identify, so each file labeled using region name and the folksong title. Next, the audio signal WAV changed into a spectrogram image. Each music has a unique spectrogram feature, as could be seen in figure 3.

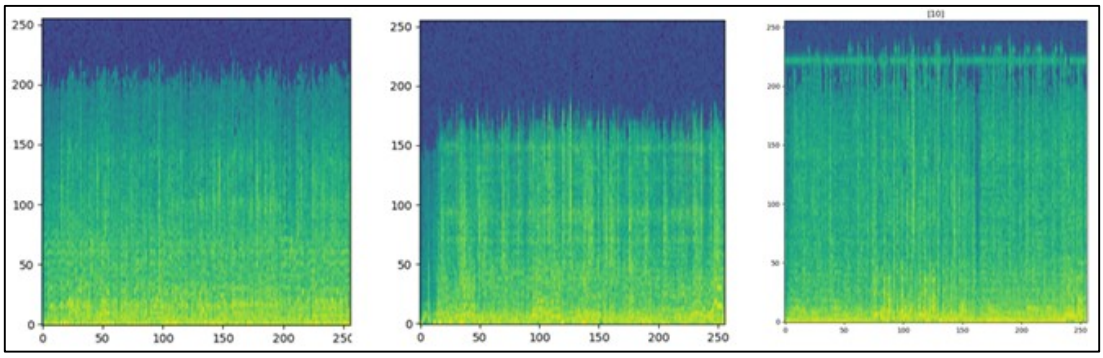

Fig. 3. Spectrogram from 3 different folk songs

The spectrogram is a signal spectrum visualization that will produce different outputs based on affecting variation. Spectrogram variation could be time, space, and else [20]. Spectrogram produced by using Short Time Fourier Transform (STFT) as one of the signal decoder types from Fourier Transform [21].

The spectrogram then transformed to maintain accuracy and eliminate noise. Moreover, this step also affects the algorithm processing efficiency. This study uses three

different size dimension, which is 256x256, 512x512, and 1024x1024 pixels. The differences are shown below.

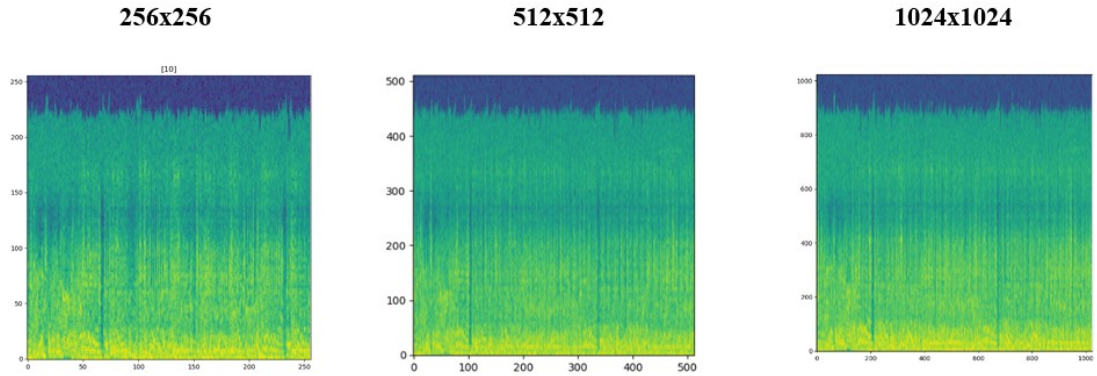

Fig. 4. The different pixels' spectrogram size

The resized spectrogram still has remaining noise and not firm features. This obstacle could be a bad influence on the result. Therefore, rounding the spectrogram color binary is a must. Next, recoloring also applied to the spectrogram using white and black tones as the first and last order in the color spectrum [22]. Gaussian Filter then applied to firm the robust spectrogram features.

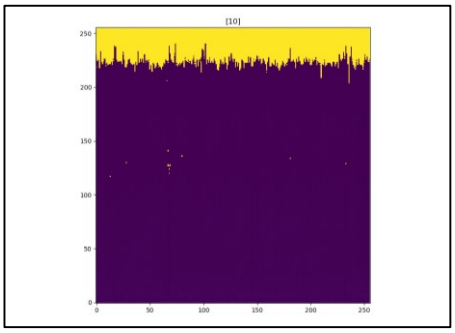

Fig. 5. Rounding spectrogram binary using uint8

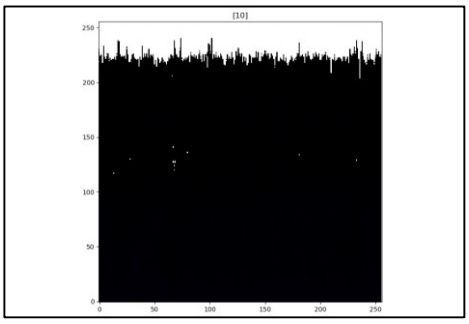

Fig. 6. Reducing noise using black and white contrast color

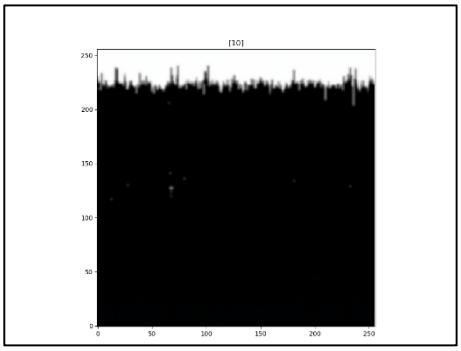

Fig. 7. Reducing noise using Gaussian Filter

Gabor Filter then applied to get the folksongs tones pattern. The parameter has chosen based on prior research [23] to maintain the comparison accuracy:

TABLE II. PARAMETER OF GABOR FILTER

Spatial Harmony	Theta	Offset
0.05	0 to 180 degree, 10-degree increment	0.5

The result of the Gabor Filter is two dimensions, which is a real and imaginary number. Spectrogram Gabor value based on each orientation degree then summed up to collect how much information on each orientation has.

All data from 19 orientations then calculated using Ordinary Least Square (OLS) Linear Regression alongside geographical distance. The result display significance of folk song features and what tone fluctuation pattern relation to geographic reach.

IV. RESULT AND DISCUSSION

Observation of 45 folk songs was done with 256x256, 512x512, and 1024x1024 pixels spectrogram size. First, the 256x256 size result is 10 out of 19 orientations turn to be significant toward distance (p-value < 0.05) that could be seen in table 3.

TABLE III. SIGNIFICANCE FEATURES IN 256X256 PIXELS

Feature	Gabor Orientation	P-Value
2	10	0.000
3	20	0.000
4	30	0.000
5	40	0.014
10	90	0.038
11	100	0.009
12	110	0.037
14	130	0.009
15	140	0.004
16	150	0.005
Total		10

Observation continues, 512x512 size result was weaker with only 5 out of 19 orientations significance. The lower effect itself can be caused by noise, which affects the accurate result. Another observation using 1024x1024 size turns out to deliver the best result. 12 out of 19 orientations have been significant toward the distance, as shown in table 4.

TABLE IV. SIGNIFICANCE FEATURES IN 1024X1024 PIXELS

Feature	Gabor Orientation	P-Value
1	0	0.002
3	20	0.003
4	30	0.029
9	80	0.030
10	90	0.001
11	100	0.004
12	110	0.001
13	120	0.000
14	130	0.003
15	140	0.044
16	150	0.000
19	180	0.002
Total		12

The 1024x1024 result also has the most directly proportional feature, which is means folk songs' tone will be more similar towards each other if the geographical distance is closer—the relation of tunes and length pictured in figure 8. This result indicates higher pixel size will produce higher accuracy.

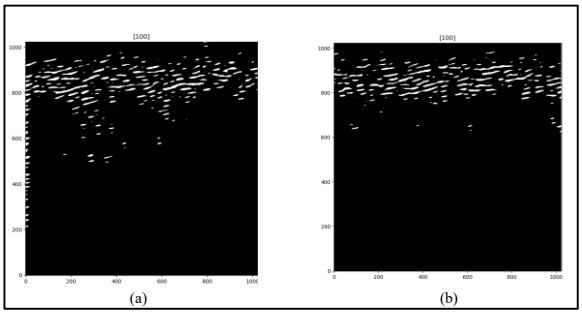

Fig. 8. 100-degree orientation of (a) Kicir-Kicir - Jakarta, (b) Dayung Sampan - Banten

Song Kicir-Kicir from Jakarta has a similar pattern with Dayung Sampan from Banten as the nearest region distance. Meanwhile, figure 9 pictured differently.

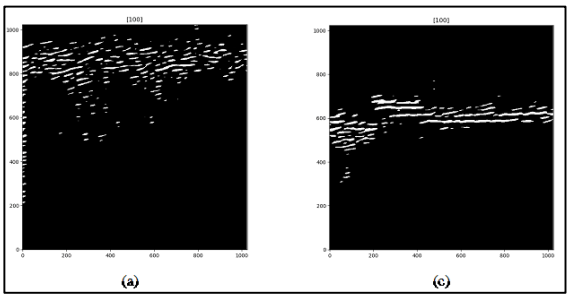

Fig. 9. 100-degree orientation of (a) Kicir-Kicir - Jakarta, (b) Ole Olang – East Java

Jakarta - East Java is way further than Jakarta – Banten, so both patterns look different. As the best outcome of this research, 1024x1024 pixels size result compared to prior research. Table 5 shows the coefficient and p-value difference.

TABLE V. THE COMPARISON BETWEEN PRIOR AND PRESENT RESEARCH

Feature	Gabor Orientation	Prior Research		Present Research	
		Coefficient	P-Value	Coefficient	P-Value
1	0	103.8654	0.218	-84.8965	0.002
2	10	-229.7174	0.015	-20.5402	0.562
3	20	55.9243	0.279	79.0030	0.003
4	30	38.1164	0.322	-34.5792	0.029
5	40	-75.6047	0.013	21.9949	0.122
6	50	101.4224	0.009	-16.3354	0.238
7	60	-164.0584	0.005	1.0743	0.951
8	70	164.1863	0.018	-3.2700	0.875
9	80	-46.1114	0.526	51.1878	0.030
10	90	272.0100	0.001	-94.2185	0.001
11	100	-314.3916	0.001	90.8885	0.004
12	110	4.0931	0.953	-80.6187	0.001
13	120	33.6802	0.537	70.9736	0.000
14	130	0.2214	0.996	-40.3579	0.003
15	140	51.9948	0.113	22.0542	0.044
16	150	-84.6027	0.023	-50.7230	0.000
17	160	17.0402	0.734	34.9216	0.096
18	170	46.9098	0.564	-12.1635	0.669
19	180	38.2849	0.607	66.2214	0.002
Total Significance		8		12	

This study has more significance p-values and more directly proportional features. As can be seen, prior research only has three directly proportional features, which are 50, 70, and 90, while this study has six, which is 20, 80, 100, 120, 140, and 180 degrees.

Directly proportional relationship means that closer the geographical distance between two regions, their folk songs tone will be more similar. The inversely proportional relationship that occurs possibly caused by immigrants that came has a strong desire to retain their identities when pluralism is encouraged or accepted [24]. Two regions have similar folk song features, although their far geographical distance is possible.

V. CONCLUSION

Research has been done using three different spectrogram size on Gabor Filter. Compared to prior research, the present study has a better outcome since it has more p-value significance and an inversely proportional relationship between song pattern and distance.

Directly proportional relationship means that closer the geographical distance between two regions, their folk songs tone will be more similar. Otherwise, the inversely proportional relationship means further the geographical distance; their folk songs tone will be more similar.

Proportional relationships can occur because of cultural spreading from group to group interaction process continuously, so they influence each song's characteristics and cultures. The inversely proportional relationship can happen because immigrants that came have a strong desire to retain their identities, conclusively they made a new social group with similar cultural characteristics from its origin.

The present study also found that different pixel sizes spectrogram images used in Gabor Filtration affecting the result, which comes out 1024x1024 pixels size has the best result among all of them. This result indicates higher pixel size will produce higher accuracy.

The study surely still very explorable as future works can challenge the data using different algorithms, increase the vary of pixel sizes, and use different testing areas beside Java Island. In addition, further research can analyze the result from different perspectives that have not done in this study, such as genre and song release period, so the result can be more impactful to see music trends in the researched region.

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