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Voice Frequency Analysis Based on Gender and Age Using FFT & FIR

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Abstrak

Penelitian ini bertujuan untuk menganalisis karakteristik frekuensi dominan suara manusia berdasarkan gender dan tahun kelahiran menggunakan metode Fast Fourier Transform (FFT) dan filter Finite Impulse Response (FIR) berbasis Python. Data penelitian terdiri atas 90 sampel suara manusia, yaitu 45 responden laki-laki dan 45 responden perempuan dengan rentang tahun kelahiran 2002–2016. Setiap sampel diproses melalui tahap preprocessing, transformasi FFT, dan penyaringan menggunakan filter FIR low-pass dengan frekuensi cutoff 400 Hz. Hasil penelitian menunjukkan bahwa rata-rata frekuensi dominan suara perempuan lebih tinggi dibandingkan laki-laki, yaitu sebesar 377,630 Hz dan 356,877 Hz. Selain itu, responden dengan usia lebih muda cenderung memiliki frekuensi dominan lebih tinggi. Penerapan filter FIR juga berhasil meningkatkan kualitas sinyal dengan mereduksi noise, sehingga analisis frekuensi menjadi lebih akurat.

Kata kunci: *suara manusia, frekuensi dominan, FFT, FIR, pengolahan sinyal digital*

Abstract

This study aims to analyze the dominant frequency characteristics of human voices based on gender and year of birth using the Fast Fourier Transform (FFT) method and Python-based Finite Impulse Response (FIR) filters. The research data consisted of 90 human voice samples, namely 45 male respondents and 45 female respondents with a range of birth years 2002–2016. Each sample was processed through preprocessing, FFT transformation, and screening stages using a low-pass FIR filter with a cutoff frequency of 400 Hz. The results showed that the average dominant frequency of women's voice was higher than that of men, which was 377.630 Hz and 356.877 Hz. In addition, respondents with younger age tended to have a higher dominant frequency. The application of FIR filters also succeeded in improving signal quality by reducing noise, making frequency analysis more accurate.

Keywords: *human voice, dominant frequency, FFT, FIR, digital signal processing*

1. Introduction

Human voice is a form of analog signal that has distinctive acoustic characteristics and has the potential to be used as biometrics for the identification process of individuals. Each individual has unique voice characteristics, which are influenced by the anatomical structure of the vocal organs, the shape of the resonance channels, as well as the articulation patterns used when speaking. This uniqueness makes voice one of the important parameters in various technological applications, such as *speech recognition*, biometric-based security systems, and audio-based individual identification systems [1].

In the field of digital signal processing, sound analysis is generally performed by transforming signals from the time domain to the frequency domain to obtain more representative spectral information. One of the most widely used methods is *Fast Fourier Transform* (FFT), which is a Fourier transform algorithm that is able to calculate the frequency spectrum quickly and efficiently. Previous research has shown that the FFT method is effective in the process of extracting the characteristics of human voice frequencies and is capable of being used for sound classification with a good degree of accuracy [2]. In addition, the application of FFT in sound signal processing has also been proven to be able to display frequency spectrum patterns that clearly represent sound characteristics [3].

Physiologically, the difference in sound characteristics between males and females is mainly determined by the structure and size of the vocal cords. Women generally have shorter and thinner vocal cords resulting in higher base frequencies, while men have longer, thicker vocal cords resulting in lower frequencies. Research by Irtawaty *et al.* It shows that gender factors are one of the main parameters in the classification of frequency-based human voice characteristics [4].

In addition to the frequency transformation process, the quality of the input signal also plays an important role in determining the accuracy of the analysis results. Recorded sound signals generally still contain *environmental noise* and irrelevant frequency components, so a *filtering stage* is required before the analysis process is carried out. One of the widely used filtering methods is *Finite Impulse Response* (FIR), as it has linear phase characteristics that are able to maintain the original shape of the signal without causing phase distortion [5].

Previous studies have generally focused on classifying voices based on gender or specific types of voices separately [4]. However, studies examining the simultaneous influence of gender and age—represented through year of birth—on the dominant frequency characteristics of the voice are still relatively limited, especially with a simple approach based on FFT and FIR filters. Therefore, this study was conducted to fill the gap through the analysis of the relationship between the dominant frequency of voice, gender, and the year of birth of the respondents.

Based on this background, this study aims to analyze the dominant frequency characteristics of human voices based on gender and year of birth using *the Fast Fourier Transform* (FFT) method and *Python-based Finite Impulse Response* (FIR) filters. The results of this study are expected to contribute to the development of digital voice analysis methods as well as become a reference for further research in the field of voice recognition and audio-based identification systems.

2. Research Method

This study uses an experimental quantitative method with a digital signal analysis approach that aims to identify differences in the characteristics of human voice frequencies based on gender and year of birth through the application of *the Fast Fourier Transform* (FFT) method and *Finite Impulse Response* (FIR) filters.

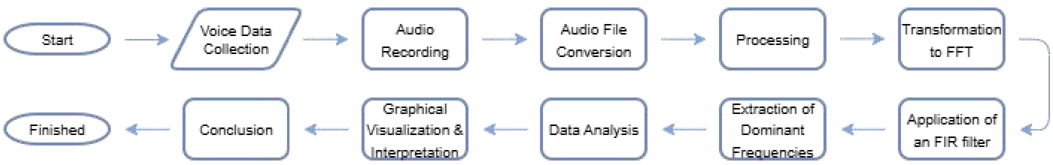

Figure 1. Research methodology flowchart for human voice frequency analysis using FFT and FIR

The data used in this study was in the form of 90 human voice samples, consisting of 45 male respondents and 45 female respondents. All respondents were grouped based on the year of birth from 2002 to 2016, with each group consisting of three male respondents and three female respondents. The sound recording process is carried out using a lavalier microphone connected to a smartphone as a recording device. Each respondent was asked to say the same sentence, namely *"mata kuliah pengolahan data digital"*, with a recording duration of about 3 seconds. The use of uniform sentences and durations aims to maintain data consistency and minimize variations due to differences in speech between respondents. The entire recording process is carried out in a relatively quiet environment to reduce the influence *of noise* from the surrounding environment.

The recorded sound data is then converted into WAV format with a *sampling* frequency of 44.1 kHz to ensure uniformity of the data format during the analysis process. The *preprocessing* stage is carried out through several processes, namely reading audio files to obtain signal data from each sample, converting stereo signals to mono to simplify the analysis process by using one signal channel, and amplitude normalization to uniformize the amplitude level of all samples so that the analysis results are not affected by differences in recording volume. This stage is carried out to ensure the quality and consistency of data before entering the frequency analysis stage.

After going through the *preprocessing* stage, each sound signal is analyzed using the Fast Fourier Transform (FFT) method. After going through the *preprocessing* stage, each sound signal is analyzed using the Fast Fourier Transform (FFT) method. This method is used to transform the signal from the time domain to the frequency domain, so that the main frequency components contained in the sound signal can be identified more clearly. The frequency with the highest amplitude in the transformed spectrum is then determined as the dominant frequency of each sound sample.

To improve signal quality before further analysis, a Finite Impulse Response (FIR) filter with a low-pass filter type is applied. These filters are used to reduce irrelevant high-frequency components, such as environmental and harmonic noise that have the potential to interfere with the identification process of dominant frequencies. In this study*, a cutoff frequency* of 400 Hz was used, because this range still covers the basic frequency area of the human voice. The selection of FIR filters is based on the characteristics of linear phase response, so that the original shape of the signal can be maintained without experiencing phase distortion during the filtering process.

After the *filtering* process is completed, the next stage is to extract the dominant frequency from each sound sample by determining the value of the frequency that has the largest amplitude in the transformed spectrum. To improve the accuracy of the analysis, the frequency search process is limited to the range of 80 Hz to 400 Hz, as this range is the basic frequency range of the human voice, in both men and women. The dominant frequency values obtained from each sample are then stored for use in the next stage of analysis.

The dominant frequency data from the entire sample was then analyzed by calculating the average value based on gender category and year of birth. The results of the calculation are then visualized in the form of graphs to facilitate the interpretation of the pattern of changes in sound frequency characteristics based on gender and age differences. As a final stage, the results of the analysis are compared with the physiological theory of the human voice and the results of previous research to obtain a more comprehensive scientific interpretation.

3. Result and Discussion

3.1. Data Processing Results

In this study, 90 human voice samples have been successfully analyzed, consisting of 45 male voice samples and 45 female voice samples, using the Fast Fourier Transform (FFT) method and Finite Impulse Response (FIR) filters. All voice data is processed through the stages of preprocessing, FFT transformation, and filtering using the FIR filter to obtain the dominant frequency, which is the frequency with the highest amplitude in the basic frequency range of the human voice.

The dominant frequency values obtained from each sample were then grouped by gender and year of birth for further analysis to identify patterns of differences in sound characteristics.

Table 1. Average frequency of dominant responses by gender across the entire sample

Gender	Total Sample	Rata-rata Frekuensi Dominan (Hz)
Perempuan	45	377,630
Laki-laki	45	356,877

Based on Table 1, it is obtained that the average dominant frequency of women's voices is higher than that of men's. These findings show that there are consistent differences in sound frequency characteristics by gender.

A similar approach has been applied in previous studies that have shown that the FFT method is effective in accurately extracting the dominant frequency characteristics of the human voice, particularly in the classification process based on individual vocal characteristics [2].

3.2. Comparative Analysis of Dominant Frequencies by Gender

The results of the comparison of the average dominant frequencies of male and female voices by year of birth are shown in Figure 2.

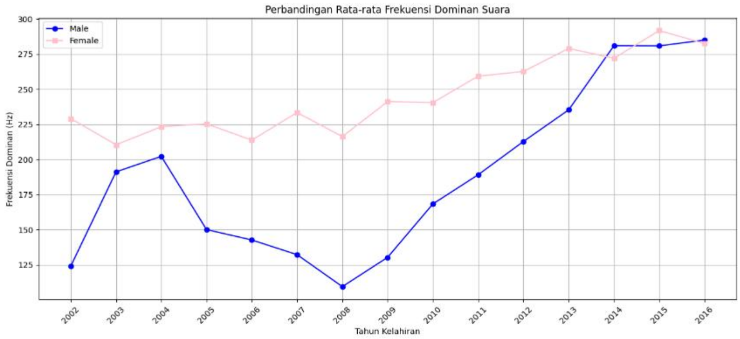

Figure 2. Comparison of the average dominant frequencies of male and female voices by year of birth

Based on Figure 2, it can be seen that in most of the birth year groups, the female voice shows a higher dominant frequency value than the male voice.

Overall, the average dominant frequency was 377.630 Hz for the female group and 356.877 Hz for the male group, with a difference of 20.753 Hz. These results show that gender has an influence on the characteristics of human voice frequencies.

Physiologically, these differences are related to the anatomical structure of the vocal cords. Women generally have shorter and thinner vocal cords, resulting in higher vibration frequencies. In contrast, men have longer, thicker vocal cords, which causes the frequency of the voice to tend to be lower [5].

The results of this study are in line with previous research which stated that women's voices have a higher basic frequency than men's voices due to differences in the anatomical structure of the vocal cords [5]. In addition, other studies using the FFT method for gender classification of voices also showed a consistent pattern of frequency distribution between male and female groups [3].

Thus, the results of this study are not only in accordance with the physiological theory of the human voice, but also reinforce the findings of previous research.

3.3. Comparative Analysis of Dominant Frequencies by Gender

In addition to being analyzed by gender, this study also evaluated the influence of birth year on the dominant frequency characteristics of the voice.

Table 2. Average dominant frequency by year of birth

Year of Birth	Male Frequency (Hz)	Female Frequency (Hz)
2002	379,870	229,195
2003	191,224	368,024
2004	202,253	304,946
2005	293,655	305,602
2006	189,396	213,810
2007	347,680	385,138
2008	182,774	216,352
2009	130,398	439,595
2010	338,557	311,643
2011	233,349	259,331
2012	336,974	262,665
2013	599,111	493,115
2014	560,416	563,950
2015	669,199	493,435
2016	698,294	817,664

Based on Table 2, there is a tendency that respondents with younger birth years tend to have a higher dominant frequency than respondents with older birth years.

This phenomenon can be explained through the development of the anatomy of the vocal system. In younger individuals, the size of the larynx and the length of the vocal cords are generally not optimally developed, resulting in higher vibration frequencies.

These changes are more evident in the male respondent group, because during puberty there is a process of voice mutation, which is a change in the structure of the larynx that causes the vocal cords to become longer and thicker, so that the frequency of the voice decreases gradually [5].

However, the number of samples in each group of birth years in this study is still relatively limited, so further research with a larger sample number is needed to obtain stronger statistical validity.

3.4. The Effect of FIR Filters on Analysis Quality

In this study, *a Finite Impulse Response* (FIR) filter was used as an advanced *preprocessing stage* to improve the quality of the sound signal before the dominant frequency extraction process was carried out.

Recorded sound signals generally still contain disturbances in the form of *environmental noise*, interference from recording devices, and high-frequency components that can affect the accuracy of the identification of the dominant frequency.

To overcome this problem, a low-pass type FIR filter was applied, which functions to maintain the low-frequency component as the main component of human voice while suppressing irrelevant high frequencies.

An example of the results of the application of the FIR filter on the male voice sample of 1 year born in 2002 is shown in Figure 3.

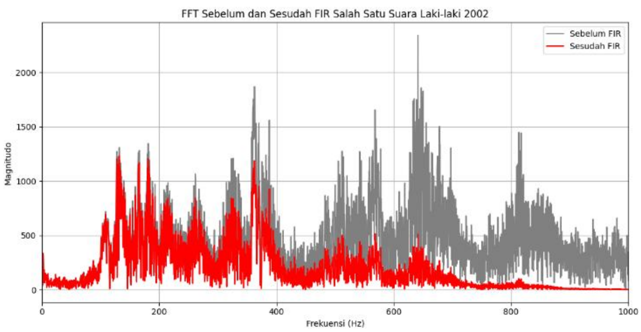

Figure 3. Comparison of the sound frequency spectrum of Male 1 in 2002 before and after the application of the FIR filter

Based on Figure 3, it can be seen that before the filtering process, the frequency spectrum still showed many high-frequency components with small amplitudes spread over various frequency ranges. These components are *noise* that can interfere with the identification process of the dominant frequency.

After the application of the FIR filter, the amplitude at the high frequency was significantly reduced so that the frequency spectrum became cleaner and the peak of the main frequency was more clearly visible. This shows that FIR filters are able to increase the Signal-to-Noise Ratio (SNR) in sound signals.

These results are in line with research that states that the *filtering* process is an important stage in digital signal processing because it can improve data quality and improve the accuracy of feature extraction. In addition, FIR filters have the advantage of linear phase response, so that the original shape of the signal can be maintained without experiencing phase distortion during the filtering process [6].

3.5. Relevance to Previous Research

In general, the results of this study show consistency with various previous studies in the field of sound signal processing.

The application of the FFT method in this study has been proven to be effective in extracting the dominant frequency of sound as reported in previous studies [2]. In addition, the differences in sound frequency characteristics by gender found in this study are also in line with the results of previous studies [3], [5].

The success of FIR filters in improving signal quality before the analysis process also supports previous findings regarding the importance of *filtering* stages in digital signal processing [6].

Thus, this study not only replicates the results of previous research, but also makes an additional contribution in the form of simultaneous analysis between gender factors and year of birth, resulting in a more comprehensive perspective in understanding the characteristics of human voice frequencies.

5. Conclusion

Based on the results of the study, the *Fast Fourier Transform* (FFT) method and *the Finite Impulse Response* (FIR) filter proved to be effective in analyzing the dominant frequency characteristics of the human voice. The results showed that women's voices had a higher average dominant frequency than men's voices, thus showing that there was a gender influence on voice characteristics. In addition, respondents with younger birth years tended to have higher dominant frequencies, indicating an influence of age on sound frequency. The application of FIR filters has also succeeded in improving signal quality by reducing noise, so that the extraction process of dominant frequencies becomes more accurate. Thus, the combination of FFT and FIR methods can be used as a reliable approach in the analysis of human voice signals.

References

[1] Q. P. Li, *Speaker Authentication*. Berlin, Germany, 2012. doi: 10.1007/978-3-642-23731-7.

[2] A. A. G. R. K. Pattraksha and A. Muliantara, “Klasifikasi Suara Pria Menggunakan Metode Fast Fourier Transform (FFT),” *JNATIA J. Nas. Teknol. dan Apl.*, vol. 1, no. 2, pp. 755–760, 2023.

[3] H. Sujadi, I. Sopiandi, and A. Mutaqin, “SISTEM PENGOLAHAN SUARA MENGGUNAKAN ALGORITMA FFT (FAST FOURIER TRANSFORM),” *Pros. SINTAK*, vol. 1, 2017.

[4] S. Y. Hartono, Husain, B. A. Ashad, and B. P. Asmara, “Analisis Sinyal Wicara (Speech) Perekaman Dalam Ruangan Kedap Suara Dengan Algoritma Fast Fourier Transform (FFT),” *Pros. Semin. Ilm. Sist. Inf. DAN Teknol. Inf.*, vol. 11, no. 1, pp. 82–88, 2022.

[5] A. S. Irtawaty, M. Ulfah, and R. S. Fathmala, “Pengembangan Aplikasi Pembeda Suara Laki-Laki dan Perempuan Berdasarkan Gender, Range Usia, Kelas Frekuensinya Berbasis FFT dan K-Means,” *J. ECOTIPE*, vol. 9, no. 1, pp. 32–39, 2022.

[6] M. Syahroni and M. Nasir, “APLIKASI FILTER DIGITAL FIR DAN IIR UNTUK MENGHILANGKAN NOISE PADA SINYAL SUARA,” *J. Teknol.*, vol. 14, no. 2, 2014.

[7] N. Izzah, “Klastering Suara Berdasarkan G ender Menggunakan Algoritma K-Means Dari Hasil Ekstraksi FFT (Fast Fourier Transform),” *J. Ilm. SOULMATH*, vol. 6, no. 1, pp. 47–58, 2018.