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MUSICAL NOTE IDENTIFICATION USING DIGITAL SIGNAL PROCESSING

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Abstract
Signals and Sounds are a part of our everyday life. These sound waves resonate through our ears as we carry a conversation or simply listen to the everyday sounds of life. Songs contains basically two things, vocal and background music. Where he characteristics of the voice depend on the singer and in case of background music, it involves mixture of different musical instruments like piano, guitar, drum, etc. To extract the characteristic of a song it becomes more important for various objectives like learning, teaching, composing. This paper aims to create an application that recognizes the musical sound waves and determines the note's pitch and octave. The middle scale 'C' is chosen as the central frequency. Fundamental frequencies of all the notes which are above and below the central frequency are identified and mapped to their respective notes. To achieve this, techniques like Fourier transform, spectrogram, windowing and power analysis are used. The final output will be a waveform and musical notes which will be displayed in the GUI.
This paper takes song as an input, extracts the features and detects and identifies the notes, each with a duration. First the song is recorded and digital signal processing algorithms used to identify the characteristics. The experiment is done with the several piano songs where the notes are already known, and identified notes are compared with original notes until the detection rate goes higher.

Keywords:
smart farming, Artificial intelligence, Internet of Things, sensors.

I. Introduction

The ability to derive the relevant musical information from a live or recorded performance is relatively easy for a trained listener, but highly non-trivial for a learner and computer. For a number of practical applications, it would be desirable to obtain this information in a quick, error-free, automated fashion. This is discussing the design of a software system that accepts as input a digitized waveform representing an acoustical music signal, and that attempts to derive the notes from the signal so that a musical score could be produced. This signal processing algorithm involved include event detection, or precisely where within the signal the various notes actually begin and end, and pitch extraction, or the identification of the pitches being played in each interval. The event detection is carried out using the time domain analysis of the signal, where the problem arises with different speed. The pitch detection is (nothing but frequency identification) is more complicated because of a situation we call harmonic ambiguity; this occurs when one pitches whose fundamental frequency is an integer multiple of another pitch. The problem is solved by the careful signal processing in both the time domain signals and frequency domain signals.
The main objective of this paper is to create an aid tool for learning for Musicians, Producers, Composers, DJs, Remixer, Teachers and Music Students. This paper can be treated as a box, where you give any song as input and get the features of the song out. The aim of this paper is to propose methods to analyze and describe a signal, from where the musical parameters can be easily and objectively obtained, in a sensible manner. A common limitation find in the musical literature is that

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the way in which such parameters are obtained is intuitively satisfactory but, to our view, not very sound from a signal processing perspective.

Musical Notes

Human can hear signal frequency ranging from 20Hz - 20 kHz. From this wide range some part is associated with piano. Different pianos are having different ranges. Each tone of piano is having one particular fundamental frequency and represented by a note like C, D, ...etc. as shown in Figure-1. The later C is 12 half steps away the previous one and having double the fundamental frequency. Hence this portion (from one C immediate next C) is called one octave. Different octaves are differentiated by C1, C2, etc.

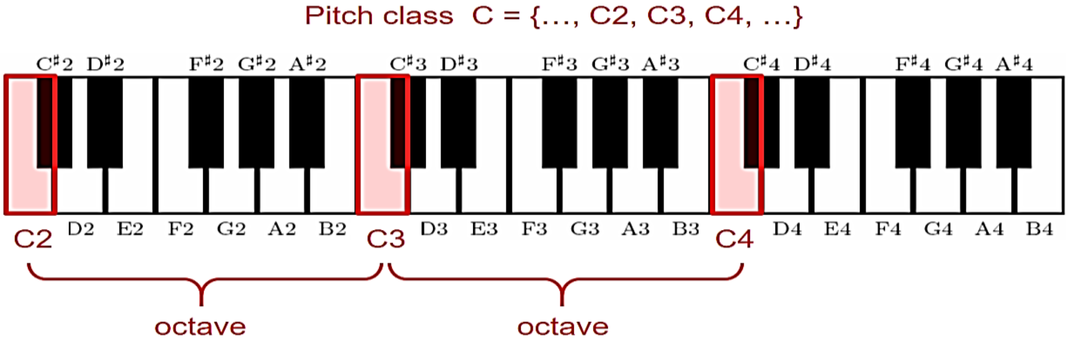

Fig 1. An octave of a piano

Mathematical Expression for the frequency

The basic formula for the frequencies of the notes of the equal tempered scale is given by

$f_n = f_0 \, . \, a^n$

where, f_0 *is* frequency of one fixed note which must be defined.

A common choice is setting the A above middle C(A_4) at f_0 =440Hz.

n = the number of half steps away from the fixed note you are.

If you are at a higher note, *n* is positive. If you are on a lower note, *n* is negative.

f_n is frequency of the note n half steps away.

$$\begin{aligned} a &= (2)^{\frac{1}{12}} = \textit{the twelth root of } 2 \\ &= \textit{the number which when multiplied by itself } 12 \textit{ times equals } 2 \\ &= 1.059463094359. \end{aligned}$$

The wavelength of the sound for the notes is found from

$$W_n = \frac{c}{f_n}$$

where *W* is the wavelength and *c* is the speed of sound. The speed of sound depends on temperature, but is approximately 345 m/s at *room temperature*.

Frequencies for Equal Tempered Scale at A4 = 440 Hz

n	Note	Fundamental Frequency (Hz)
-4	F3	174.61
-3	F3#	185
-2	G3	196
-1	G3#	207.65
0	A4	220
1	A4#	223.08
2	B4	246.94
3	C4	261.63

4	C4#	277.18
5	D4	293.66
6	D4#	311.13

Table 1. Notation to Frequency Mapping [Middle C is C4]

Finding Frequency and Assigning Notation

After padding zeroes, the DFT of the resultant signal is found. Then the corresponding frequency of a particular note is found and the actual note is assigned using table 1

II. Design

In this, we designed and implemented an effective and user-friendly musical note recognition software using MATLAB which can identify the exact note by finding the frequency of the input note. This paper is implemented by using Fourier Analysis, Windowing technique to separate and match the note as per the given one, along with plotting of the note in the graph in time and frequency domain. The musical piece is fed to the system which processes the audio signal. The frequency and pitch of the signal is determined thereby identifying the type of musical note by comparing it with the standard musical notes available.

The first step involves the input of a sequence of desired musical sounds. The sequence of sounds is digitally recorded. In the second step, the signal is analyzed using Matlab. In Matlab, the series of notes are plotted in the time domain. The third step requires a bit more analysis and programming. We designed a windowing technique that determines the window of each note in the sequence. This technique first involved a method to determine when a note begins and ends.

This program takes in a double array specified by the data and outputs a vector of division points that correspond to separate and distinct notes. In other words, trying to find when one note stops and another starts. The returned vector will include the midpoint of the end of note and the beginning of each note. The fourth step involves the analysis of the signal in the frequency domain. Now that the windows of each note have been determined, each individual note is converted to the frequency domain. Hence, the use of the Fast Fourier Transform (FFT). The fifth step involves determining the fundamental frequency of each note. A standard musical note played by standard instruments is described by a fundamental frequency, which is the maximum frequency, along with other smaller harmonics. Based on the frequency of the pitches in the middle C octave, the octave above middle C, the program determines whether the input frequency is above or below this range. If the frequency is below the middle C octave range it multiplies the input frequency by 2, adds one to a counter that keeps track of how many times the process has recurred and then calls the process on the input frequency times 2. If the frequency is above the middle C octave range, it divides the input frequency by 2 and goes through the same process but now it divides by 2 instead of multiplying. If the frequency is in the middle C octave range, it determines what pitch it is based on some accepted ranges/values for pitches and return the pitch. Finally, the program returns the pitch and the octave above or below the middle C octave.

III. OPERATING PROCEDURE

Steps involved in the procedure are described below.

1. The input is the sequence of desired musical note (digitally recorded) whose frequency is to be found
2. The signal is analyzed using Matlab. The series of notes are initially plotted in the time domain
3. We designed a Windowing Technique that determines the window of each note in the sequence. This technique first involved a method to determine when a note begins and ends. The program

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takes in a double array specified by the data and outputs a vector of division points that correspond to separate and distinct notes. In other words, trying to find when one note stops and another starts. The returned vector will include the midpoint of the end of note and the beginning of the next. It can be easily noticed in a note sequence that there is a visible drop in energy between notes i.e. a small gap from one note to another note. This fact is used in determining the actual window of a note.

4. The analysis of the signal in the frequency domain is done here. Now as that the windows of each note have been determined in the step above mentioned, each individual note is converted to the frequency domain. Hence, here comes the application of fast fourier series to get the frequency domain of our input signal. (The **Fast Fourier Transform (FFT)** is a discrete Fourier transform algorithm which reduces the number of computations needed for points from to, where log is the base-2 logarithm.)
5. The **Fundamental Frequency** of each note is identified in this step. (A standard musical note played by standard instruments is described by a fundamental frequency, which is the maximum frequency, along with other smaller harmonics). Therefore, to determine the fundamental frequency, we find the maximum frequency for each signal.
6. Now to determine the actual note, we find the pitch of the note using the method mentioned below. Based on the frequency of the pitches, the program determines whether the input frequency is above or below this range

- Frequency < Middle C octave range - It multiplies the input frequency by 2, adds one to a counter that keeps track of how many times the process has recurred and then calls the process on the input frequency times 2.
- Frequency > Middle C octave range - It divides the input frequency by 2 and goes through the same process but now it divides by 2 instead of multiplying.
- Frequency ~ Middle C octave range - It determines what pitch it is based on some accepted ranges/values for pitches and return the pitch. Finally, the program returns the pitch and the octave above or below the middle C octave. (Positive for octaves above, negative for octaves below).

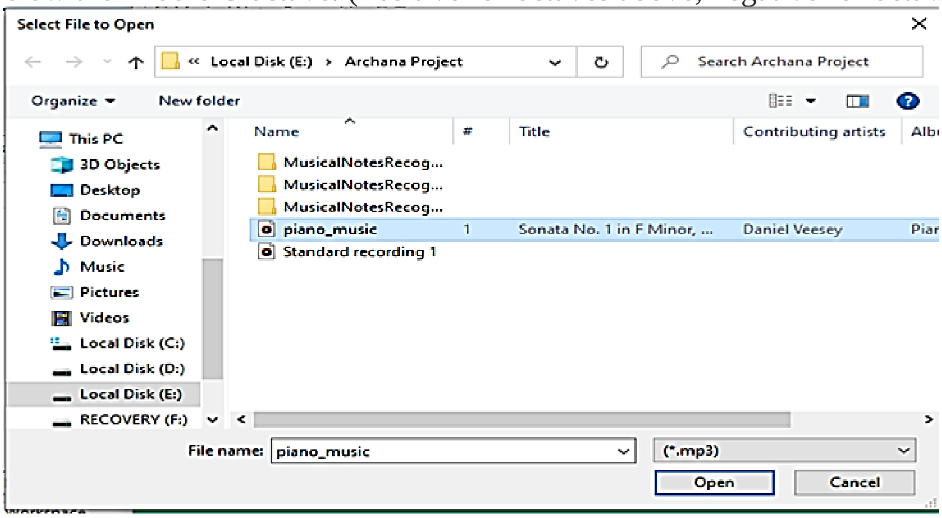

Figure 2. Selection of file

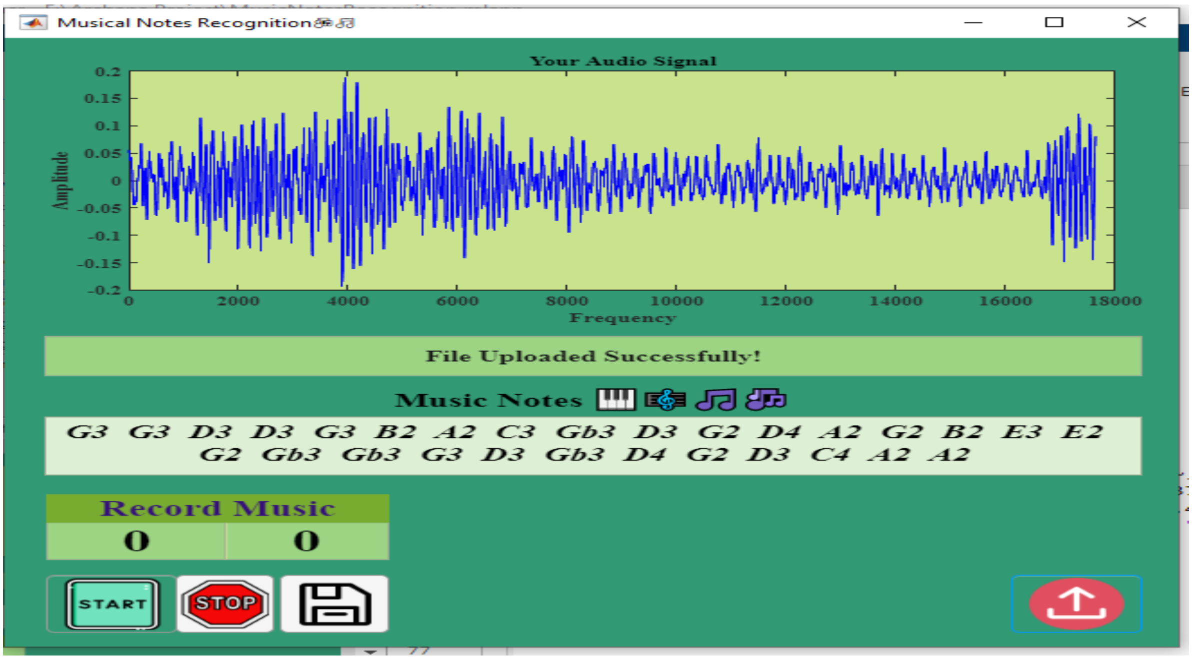

Figure 3. Musical notes recognition

IV. CONCLUSION

We have successfully designed and implemented an effective and user-friendly application of frequency estimation system with Fourier analysis. In this paper, the frequencies of a piano song is detected, corresponding notes are identified with duration. The method used here for note identification is more optimized than previously used methods. By varying the parameters like threshold values and width, we can get the desired results with time duration of each note.

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Applications

1. It is useful for the beginners to learn music.
2. And also useful for the professionals

Advantages

1. . User –friendly interface
2. Can be used for audio matching
3. Reduces effort in identifying notes

4. Mostly used for beginners of music
5. Reduces effort in identifying notes.
6. Easily identifies musical Notes for piano
7. Decode the musical note type for any unknown audio signal.
8. Beginners can learn music in simple way by referring musical notes.
9. Pitching of voice can also be known using graph feature in this interface.
10. It's useful for composers because it allows them to write down their ideas for songs, concertos, or symphonies

Limitations

1. Limitation in our system is that it can only recognize one note at a time. It can't distinguish notes played simultaneously, like chords or perhaps two instruments playing at the same time.
2. It is limited for only piano music.

Future Scope

Advanced Note Detection: There are lot of ways we to improve and customize note detection. Most of them use variations in intensity, which is not the right way because strictly speaking a note is said to change when the frequency of the signal changes. It is not easy to keep track of change in frequency because the change is gradual and hence it is an existing challenge. Moreover, the frequency estimation for calculating note detection requires note detection in a crude sense which is paves way for development in this area.

Multiple Notes at a time: Our paper assumes that only a single note is played at a time. But that is not it. We can develop it further by using Fourier Analysis again. There are existing algorithms which can isolate multiple notes. After splitting the audio sample into individual notes we can apply our own techniques to find the frequency.

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