The Frequency Spectrum and Time Frequency Analysis of Different Violins Classification as Tools for Selecting a Good-Sounding Violin

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ABSTRACT

This work evaluates four violins from three distinct manufacturers, notably Eurostring, Stentor, and Suzuki, using a scientific approach. Eurostring1 and Eurostring2 were the names given to the two Eurostring units. The purpose of this study is to identify elements in various violins that could be used as tools for selecting a pleasant-sounding violin by having them classified by a professional violinist. The signal's time varying frequency was evaluated using a frequency spectrum and a time frequency plane, and the combination of frequency spectrum and time frequency domain is utilised. PicoScope oscilloscopes and Adobe Audition version 3 were used to record the acoustic spectra in terms of time and frequency. The time frequency plane is identified, and time frequency analysis (TFA) is produced by Adobe Audition spectrograms. The sound was processed in order to generate Fast Fourier Transform analysis: Fourier spectra (using PicoScope) and spectrograms (using Adobe Audition). Fourier spectra identify the intensity of the fundamental frequency and the harmonic spectra of the overtone frequencies. The highest frequencies that can be read are up to and including the 9th overtone. All violins have a constant harmonic overtone pattern with an uneven acoustic spectrum pattern. Eurostring1 showed inconsistent signal in the string G with 6th and 7th overtone missing, whereas Eurostring2 lack of the 6th overtone. Among the string D, only Eurostring1 display an exponential decay for the overtone. All the string A except for Suzuki showed nice and significant peak of fundamental and overtone. Stentor displays up to the 5th overtone. Among the string E, Suzuki showed inconsistent harmonic peak intensity. TFA revealed that the fundamental frequency of string E for Eurostring1 was lower than the first overtone. Only Eurostring1 has an uneven decay for the overtone frequency, whereas Eurostring2 exhibits a large exponential decay for the overtone frequency.

Keywords: *acoustic spectra, frequency spectrum, harmonic overtone, time frequency analysis, violin instrument classification*

INTRODUCTION

Any periodic sound wave should be heard as a sum of sinusoidal components or partial with their corresponding pitches. A complex tone is the sum of sinusoidal components or partial which are harmonics (Plomp 1976). In general, a typical musical tone consists of a large number of harmonics with frequency ratios 1:2:3:4:5 etcetera. The sound of music instrument results in the sensation of a single note with a single definite pitch equal to the pitch of the fundamental and a specific timbre depending upon the relative amplitude of the harmonics. Hence, the sound intensity of the instruments is different between violins. In this paper, we investigate the comparison between frequency of four violins using PicoScope Oscilloscope and Adobe Audition version 3. The physical parameters of the tone that were analysed are the sound pressure level and frequency. The sensation of tone measured by the PicoScope is only the pitch, while the loudness and timbre are detected by the Adobe Audition. The relationship between time and frequency has been well-established, which include the study of the sound that coincides with the Fourier analysis. Fourier analysis yields the frequency content and associated time frequency analysis (TFA) to understand the sound. The purpose of this work is to study the pure tone signal and TFA in four violins sound. Fast Fourier Transform (FFT) performs a TFA of an input signal by bowing the violin string. The time frequency content of the signal is visualised by creating a spectrogram image, which is done by Adobe Audition. This spectrogram is used to identify the pitch of the sound produce by the signal. The output is a time frequency with time varying according to the frequency content of the signal. Understanding the spectra and spectrogram properties gives the pitch based on the equal tempered scale.

Issues or Problem

Since the human ear is not capable of distinguishing the individual harmonics of a complex tone, the identification of the partials may be nearly impossible in listening to tones in a musical context (Plomp 1976). There have been many features offered to represent musical signals which also targeted to reveal the differences of instrument sounds (Herrera-Boyer et al. 2003, 2006; Deng, Simmermacher and Cranefield 2008; Essid, Richard and David 2006; Klapuri and Davy 2006). While the temporal evolution of the signal is characterised by the time-based features, the spectral features are extracted using spectrum based on the FFT. The frequency spectrum is a very popular frequency analysis techniques, and it is widely used for the non-stationary signals in which the statistical properties vary with time (Mallat 2009). The time varying frequency of the signals is observed in a time frequency plane with the continuous wave analysis where the signal is divided into the fundamental and overtone frequency which varies with time. Accordingly, the use of frequency in musical signals may be separated into two cases based on the following representations. In one representation, the emphasis is given to the extraction of instantaneous frequency from the sinusoidal wave. The instantaneous frequency of a signal can be extracted using FFT displayed as amplitude frequency. These characterise the frequency modulation of the signals. The other frequency representation involves with the time frequency plane. The pitch frequency features have been extracted for audio including musical instrument sounds (Lin et al. 2005). As the study is focused on time frequency representations, the comparison is given to the results with different time functions.

Why is This Study Carried Out?

The organisation of the article is as follows: Section 2 reviews the method of obtaining the frequency spectrum signal and time frequency plane. The experimental study was performed for different violin manufacturers. It is accepted that the starting transients are the most important part of the signal for the recognition of musical sounds (Kostek 2005). Therefore, a frame length consisting of 2,048 samples were selected from the attack part of the musical instrument sounds. Finally, the corresponding results using the experiment were compared to the conclusions made by a professional violin player.

What is the Main Focus?

The primary focus of this article is on representing musical signals with time frequency features that are effective due to the nature of musical signals, in which the frequency varies with time. While the frequency spectrum is likely to yield an acceptable recognition rate, it lacks the temporal dimension of timbre, which is critical in distinguishing violins. That explains why, in addition to the frequency spectrum, time varying frequency is used. Although the primary goal is to classify violin instruments, the note of the violin can be determined by comparing the frequency distribution with time to the frequencies in the harmonics.

Why Do We Need to Know about This Topic?

This is an extremely important topic because only professional violinists can determine what constitutes a good sound violin. However, the term “good” is very relative, and the need is evident not only from hearing. A musician’s ear will never be the same as that of an ordinary person who does not recognise proper pitch. In this work, we identify the fundamental and harmonic of each violin, as well as the regularity of each.

Who Will Benefit as a Result, and Why?

The mentioned tool will be useful to parents, novices, and violin instructors. Precision manufacturing has evolved as a cost-effective means of making handcrafted instruments due to their high cost. Knowing how to select a violin, on the other hand, can assist them and the learner grow.

The Purpose of This Study

The goal of this study is to collect experimental data utilising Adobe Audition and analyse the frequency that results in TFA as part and partial of the tools. Classify violin instruments for the purpose of selecting a good violin sound. Since musical signals are inherently non-stationary, the properties of the frequency spectrum are typically exploited to generate representative features. For the classification of instruments, features characterising musical instrument sounds based on frequency spectrum are common. The frequency spectrum only shows the frequency information that is available in the feature signal. A representation of violin signals representing their time varying frequency components, mostly constituted of fundamental and harmonic frequencies, is produced using time varying frequency. The capability of the time frequency base feature is evaluated in different violin classification with the different harmonics. This has proven to demonstrate successful classification rates for audio and musical instrument (Deng, Simmermacher and Cranefield 2008; Essid, Richard and David 2006; Lin et al. 2005; Wieczorkowska and Kubera 2009). The purpose of adding time variable frequency in addition to the frequency spectrum is to emphasise the temporal dimension of timbre, which is important in identifying violins. While the frequency spectrum is likely to yield a sufficient recognition rate, the temporal dimension of timbre is lost.

METHODOLOGY

This approach was chosen because most sound analysis and re-synthesis are investigating tone systems. The data from some of the measurements helps in understanding the structure of the sound. The frequency of violin has been measured using oscilloscope, whereas the time frequency has been measured using Adobe Audition. All the work mentions above measured the fundamental frequency and the overtone frequency. In this work, the fundamental and overtone frequency which is also called timbre is measured. Fourier transformation determines fundamentals, harmonics and subharmonics. Different intensity and harmonics or subharmonics (overtones) distinguish each instrument characteristics. Most important, this work showed all the range of available frequencies at a specific time.

The frequencies that are present in the signal are easily identified, but no information about time localisation is available. In our work, the dominant frequency, i.e. time localised frequency content for each tone at a specific time can be identified. The TFA over time with the black and grey part explains its intensity at the frequency range on the vertical axis. The vertical scale is a frequency scale (in Hz), and the horizontal scale is a timescale (in second). TFA provides a description of the sound in the time frequency plane. TFA showed distinct peaks at the fundamental and overtone frequencies. The larger values of these spectra are displayed darker. The grey regions represent values that are near zero in magnitude. The spectra for the individual frequency are clearly separated in the y-axis and clearly divided into line segments, lying above each frequency and corresponding to the fundamentals and overtones in each note. The experimental set up is shown in Figure 1.

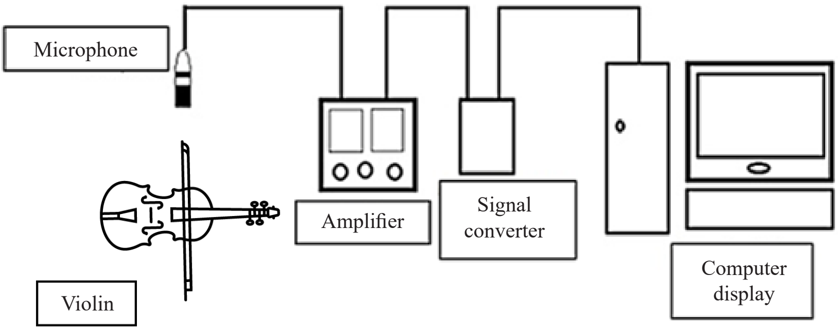

Figure 1 Schematic diagram of the experimental setup.

The frequency was measured at the studio hall of Universiti Malaysia Sarawak (UNIMAS). The acoustic spectra of the violin were captured using PicoScope oscilloscopes to investigate the fundamental and the overtone frequencies. Excitation was done by bowing by an expert player. The microphone was held above the top surface along the axis of symmetry at a distance of 20 cm. In this study, the audio signal derived from the bowing by an expert player is recorded. The audio signal is recorded in mono, at 24-bit resolution and 48 kHz sampling rate. The audio signal is recorded with the aid of a digital audio interface in a.wav format. To ensure the recorded audio signal is at the optimum level, audio signal calibration of the recording system is carried out. A test tone of 1 kHz sine wave is used in calibrating the recording system. Here the "unity" calibration level is at +4 dBu or −10 dBV and is read by the recording device at 0 VU. In this regard, the European Broadcasting Union (EBU) recommended the digital equivalent of 0 VU is that the test tone generated to the recording device of the experimentation is recorded at −18 dBFS (digital) or +4 dBu (analogue) which is equivalent to 0 VU. In this thorough procedure of calibration, no devices are unknowingly boosting or attenuating its amplitude in the signal chain at the time of the recording is carried out. The recording apparatus was the Steinberg UR22mkII audio interface, Audio-Technica AT4050 microphone, XLR cable (balance), with microphone position on axis (<20 cm), and microphone setting with low cut (flat) 0 dB.

The PicoScope computer software (Pico Technology, 3000 series, Eaton Socon, UK) was used to view and analyse the time signals from PicoScope oscilloscopes (Pico Technology, 3000 series, Eaton Socon, UK) and data loggers for real time signal acquisition. PicoScope software enables analysis using FFT, a spectrum analyser, voltage-based triggers, and the ability to save/load waveforms to a disc. Figure 1 shows the schematic diagram of the experimental setup. The violin was placed to where the sound could be captured with minimum interference. The amplifier (Behringer Powerplay Pro XL, Behringer, China) ensured the sound capture was loud enough to be detected by the signal converter.

The uniqueness of our research is visualising the sound sonically through PicoScope oscilloscopes and Melda analyser. The sound spectra of all violins are obtained from PicoScope measurements. After the data sound was captured and recorded, the FFT was also analysed using Melda analyser to obtain dominant frequency for each tone at specific time. In this work, we measure the fundamental and overtone frequency, which is also called the timbre. Fourier transformation determines fundamentals, harmonics, and subharmonics. Different intensity and harmonics or subharmonics (overtones) distinguish each instrument characteristics. In this sense, the difference is necessary to describe the different types of violins by the different manufacturer taking four violin sets.

How were the instruments/strings and the number of instruments was selected?

The instruments/strings and the number of instruments were selected based on the available instruments in the laboratory in UNIMAS Music Department. The method was constructed based on the by PicoScope oscilloscopes and Adobe Audition version 3 available in UNIMAS Music Department laboratory. The frequency of string was measured using PicoScope Oscilloscope. PicoScope Oscilloscope record the real voltage-time signal and the amplitude frequency spectrogram. The frequency of every peak starting from the fundamental up to the 9th overtone is read manually from the spectrogram. The fundamental up to the 9th overtone frequency for each sting for all violins are plotted in a histogram for comparison purposes. The histograms were computed from the pitch at different frequency for music information. The Adobe Audition analyse the TFA for string E. The duration for the fundamental and the overtone are read directly from the TFA. The description of sound in the TFA was based on the magnitudes of the intensity. The distinct intensity differentiates the strength of the overtone frequencies.

RESULT AND DISCUSSION

The frequency spectrum of the individual string G, D, A, and E from four different violins are shown in Figure 2. The pitches of the individual harmonic of string G, D, A, and E from four different violins are shown in Table 1. Figure 3 displays the pitches of the individual harmonic of string G, D, A, and E from four different violins.

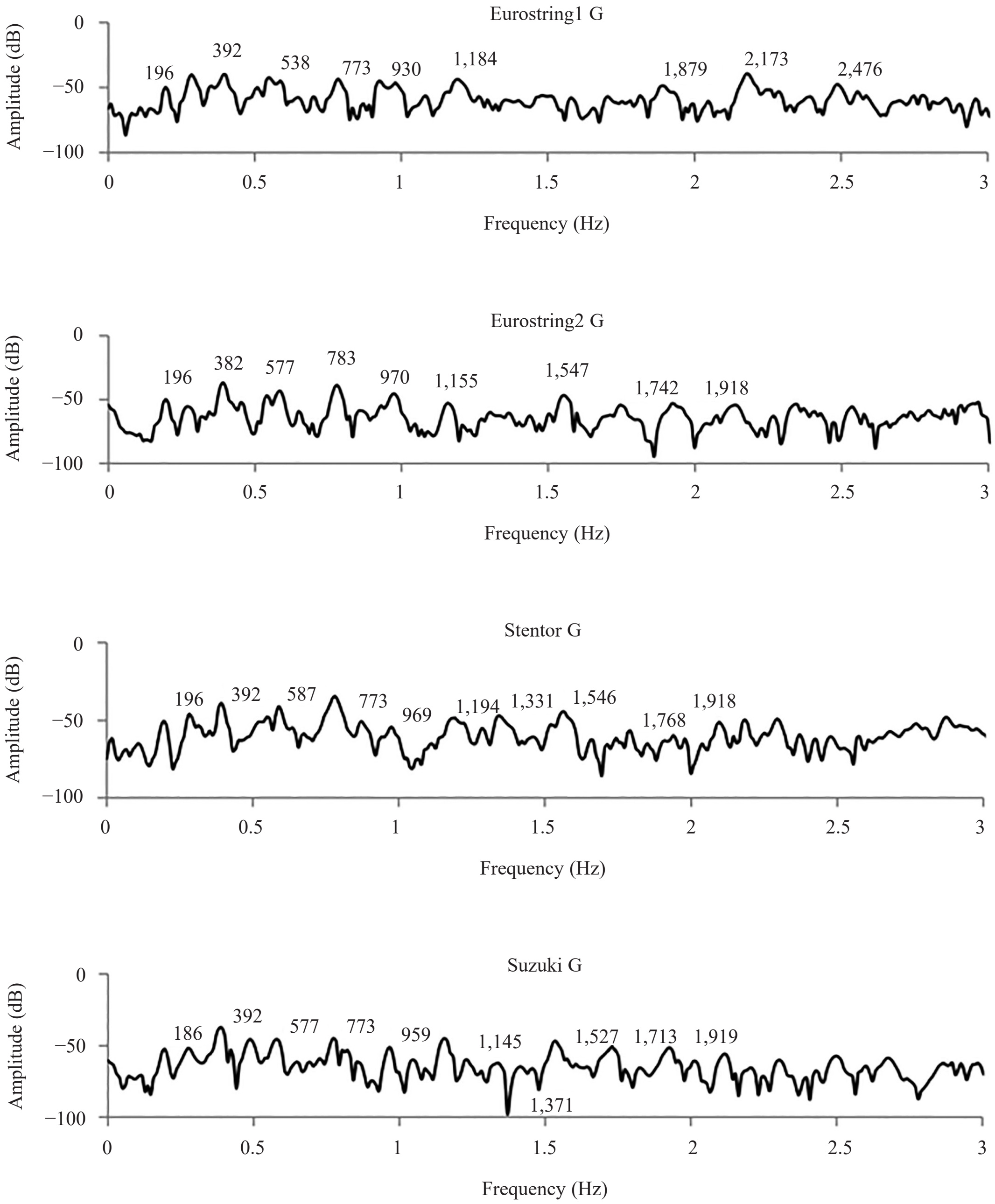

Figure 2a Frequency spectrum of string G from four different violins.

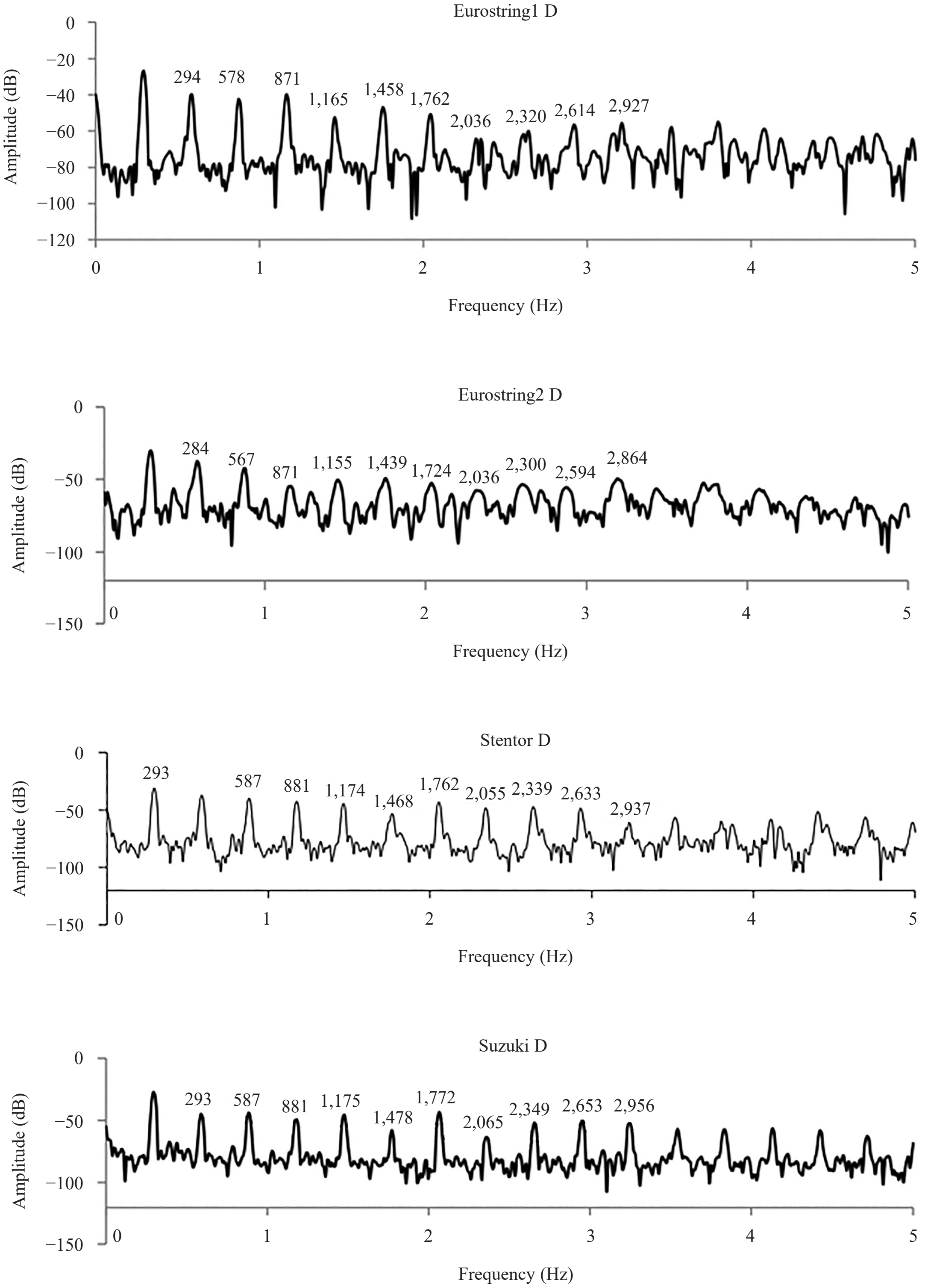

Figure 2b Frequency spectrum of string D from four different violin instruments.

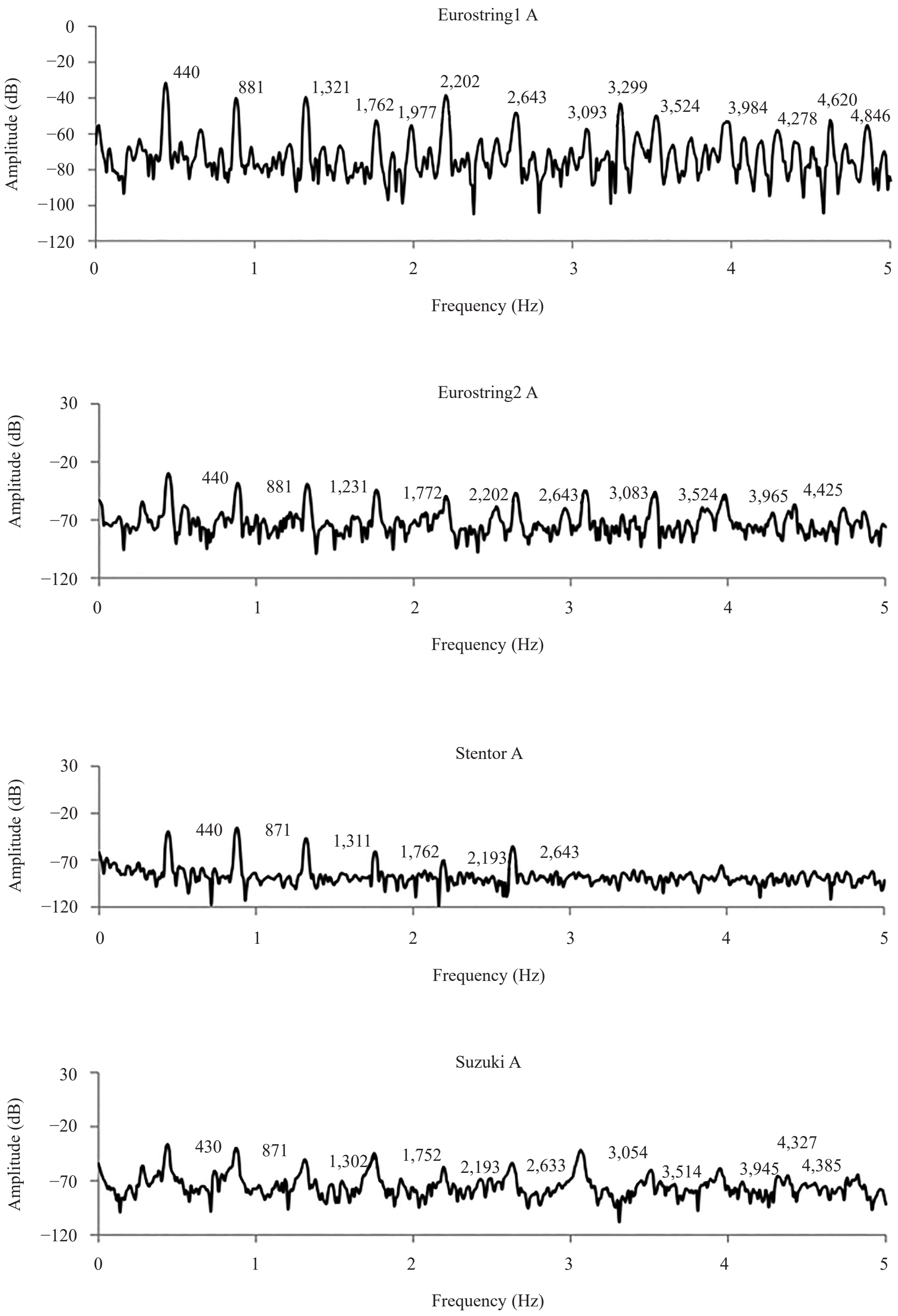

Figure 2c Frequency spectrum of string A from four different violins.

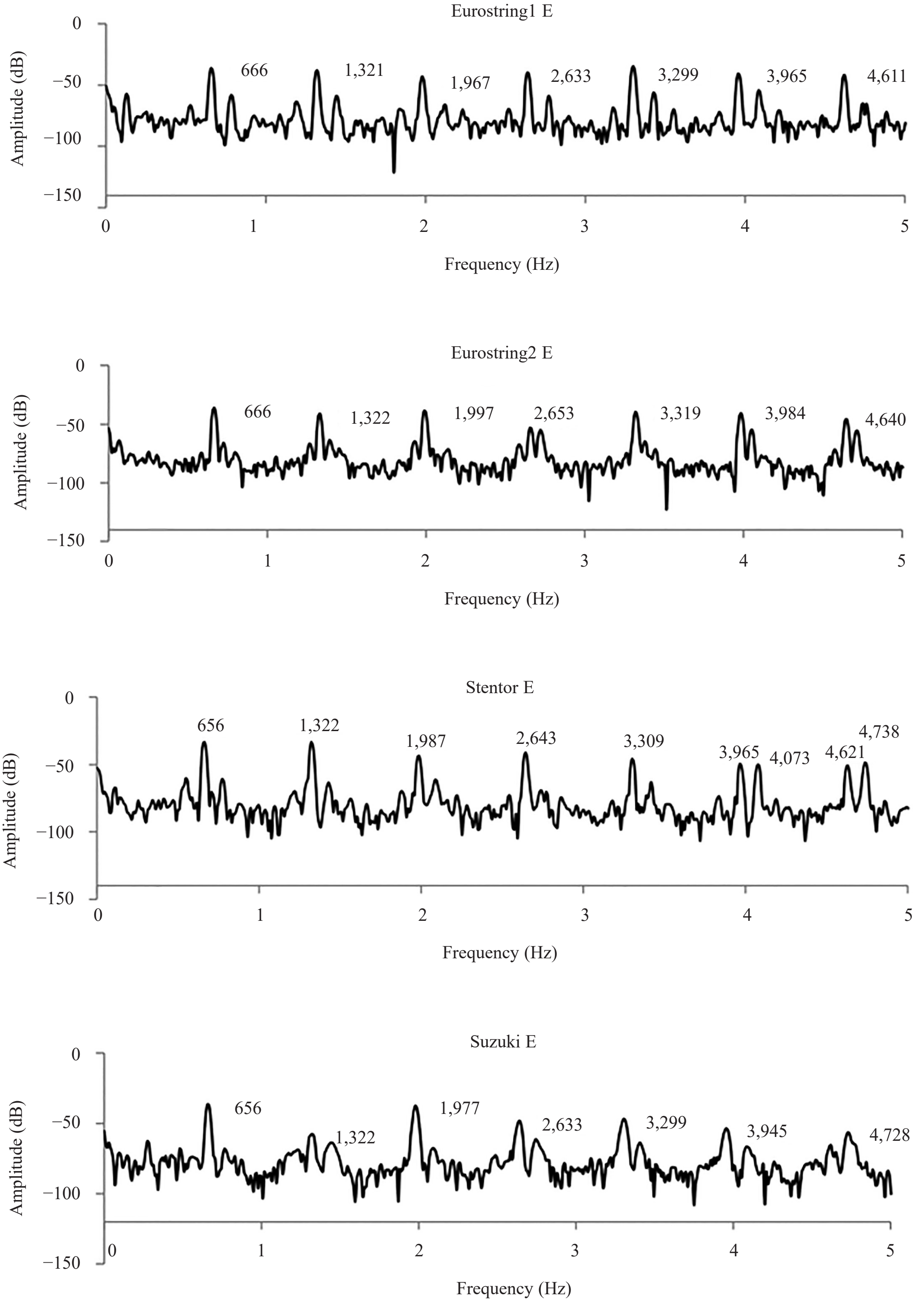

Figure 2d Frequency spectrum of string E from four different violins

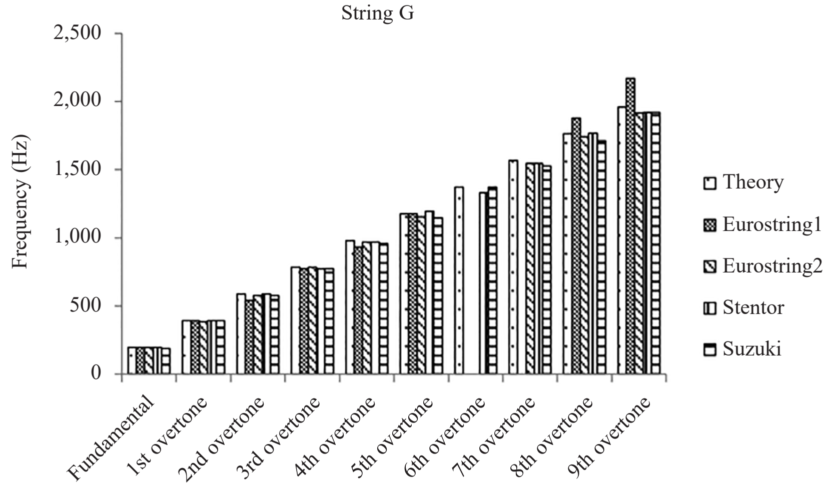

Figure 3a The pitches of the individual harmonic of string G from four different violins.

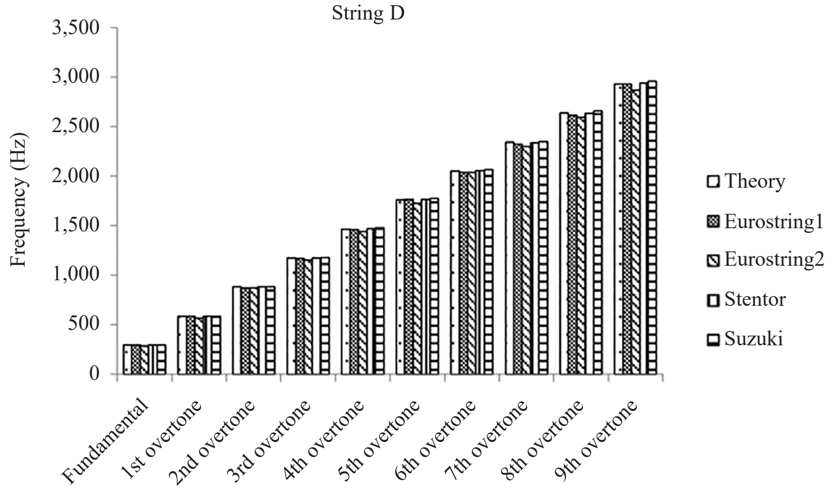

Figure 3b The pitches of the individual harmonic of string D from four different violins.

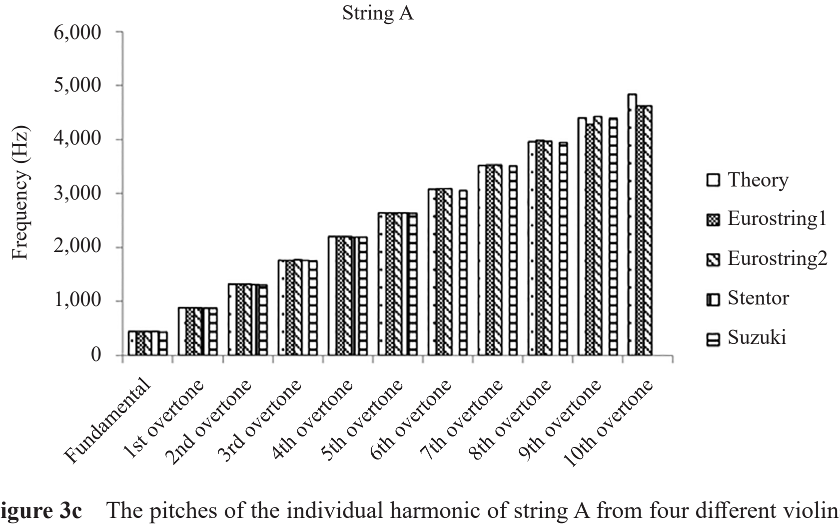

Figure 3c The pitches of the individual harmonic of string A from four different violins.

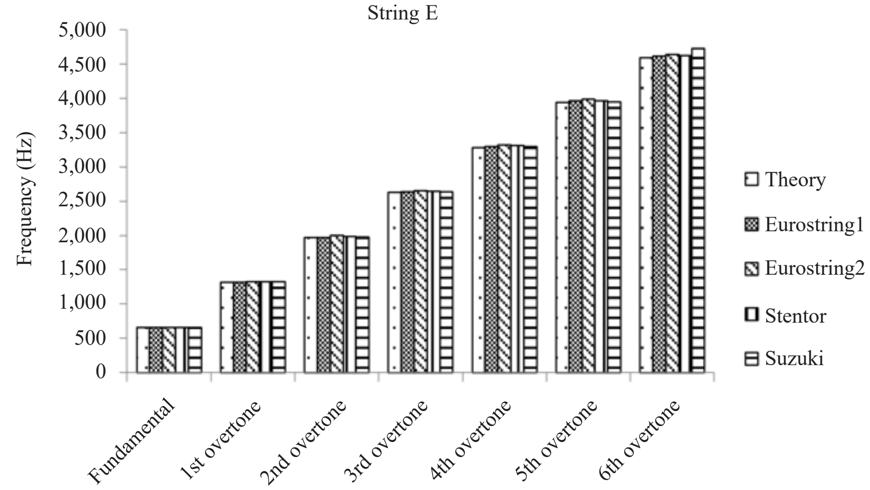

Figure 3d The pitches of the individual harmonic of string E from four different violins.

Table 1a The pitches of the individual harmonic of string G from four different violins.

String G for all violins					
Frequency	**Theory**	**Eurostring1**	**Eurostring2**	**Stentor**	**Suzuki**
Fundamental	196	196	196	196	186
1st overtone	392	392	382	392	392
2nd overtone	588	538	577	587	577
3rd overtone	784	773	783	773	773
4th overtone	980	930	970	969	959
5th overtone	1,176	1,184	1,155	1,194	1,145
6th overtone	1,372	–	–	1,331	1,371
7th overtone	1,568	–	1,547	1,546	1,527
8th overtone	1,764	1,879	1,742	1,768	1,713
9th overtone	1,960	2,173	1,918	1,919	1,919

Table 1b The pitches of the individual harmonic of string D from four different violins.

String D for all violins					
Frequency	**Theory**	**Eurostring1**	**Eurostring2**	**Stentor**	**Suzuki**
Fundamental	293	294	284	293	293
1st overtone	586	587	567	587	587
2nd overtone	879	871	871	881	881
3rd overtone	1,172	1,165	1,155	1,174	1,175
4th overtone	1,465	1,458	1,439	1,468	1,478
5th overtone	1,758	1,762	1,724	1,762	1,772
6th overtone	2,051	2,036	2,036	2,055	2,065
7th overtone	2,344	2,320	2,300	2,339	2,348
8th overtone	2,637	2,614	2,594	2,633	2,658
9th overtone	2,930	2,927	2,864	2,937	2,956

Table 1c The pitches of the individual harmonic of string A from four different violins.

String A for all violins					
Frequency	**Theory**	**Eurostring1**	**Eurostring2**	**Stentor**	**Suzuki**
Fundamental	440	440	440	440	430
1st overtone	880	881	881	871	871
2nd overtone	1,320	1,321	1,321	1,311	1,302
3rd overtone	1,760	1,762	1,772	1,762	1,752
4th overtone	2,200	2,202	2,202	2,193	2,193
5th overtone	2,640	2,643	2,643	2,643	2,633
6th overtone	3,080	3,093	3,093	0	3,054
7th overtone	3,520	3,524	3,524	0	3,514
8th overtone	3,960	3,984	3,965	0	3,945
9th overtone	4,400	4,278	4,425	0	4,385
10th overtone	4,840	4,620	4,620	0	0

Table 1d The pitches of the individual harmonic of string E from four different violins.

String E for all violins					
Frequency	**Theory**	**Eurostring1**	**Eurostring2**	**Stentor**	**Suzuki**
Fundamental	659	656	656	656	656
1st overtone	1,318	1,321	1,322	1,322	1,322
2nd overtone	1,968	1,967	1,997	1,987	1,977
3rd overtone	2,624	2,633	2,653	2,643	2,633
4th overtone	3,280	3,299	3,319	3,309	3,299
5th overtone	3,936	3,965	3,984	3,965	3,945
6th overtone	4,592	4,611	4,640	4,624	4,728

For string G, Eurostring1 showed the lowest frequency at the 2nd, 3rd, and 4th harmonic overtone. At 6th and 7th overtone Eurostring1 lost the harmonic overtone totally but appears again at 8th and 9th overtone with the highest values. Eurostring2 only lost the 6th harmonic overtone. Although both Eurostring1 and Eurostring2 violins (from the same manufacturer) showed similar pitches, the peaks of the signals from Eurostring1 are less distinct compared to Eurostring2 (with sharper harmonic overtones). Both the Stentor and Suzuki display a regular pattern signal with the presence of all the nine harmonic overtones.

In most harmonic overtone frequency for string D, Eurostring2 tends to be lower than other violins. From all the violins, only Eurostring1 showed a regular exponential decay of the harmonic overtone up to the 6th harmonics overtones at 2,063 Hz. Compared to Suzuki, Stentor showed a better regular pattern of the harmonic overtones with less ripples of noise frequencies. In general, all violins except Stentor did not display any harmonic overtone at 6th, 7th, 8th, 9th, and 10th for string A. Suzuki also did not display the 10th harmonic overtone for string A. In most harmonic overtone frequency for string A, Eurostring1 showed a distinct harmonic overtone with sharp peaks whereas Stentor showed a distinct exponential decay for the harmonic overtone. Eurostring2 and Suzuki showed a regular pattern with less distinct peaks of the harmonic overtone with many ripples of noise frequencies. All string E overtones are harmonic with the theoretical values, except for 6th overtone from Suzuki. In general, although the overtones are harmonic with the theoretical values for all string E, the signals did not display a regular pattern with a distinct sharp peak of harmonic overtone. The signal also did not display any exponential decay to the harmonic overtone. All signals are mixed with many ripples of noise frequencies.

Since the human ear is not capable of distinguishing the individual harmonics of a complex tone, the identification of the partials may be nearly impossible in listening to tones in a musical context (Plomp 1976). Thus, experimental evidence using Adobe Audition analysing the frequency lead to TFA. In order to determine the frequency intensity, we applied the Adobe Audition version 3 technique. Figure 4 showed the TFA for string E.

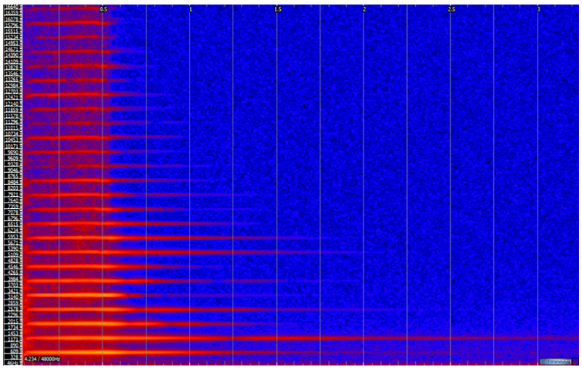

Figure 4a TFA for Eurostring1 E string.

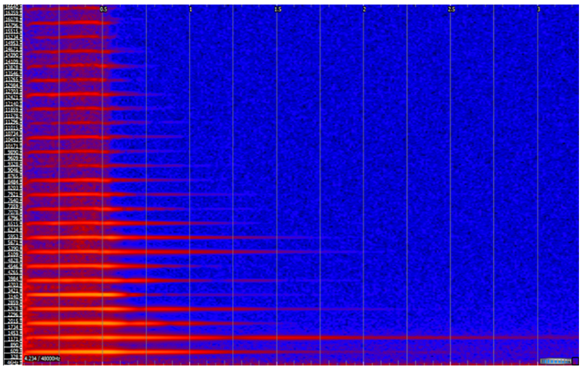

Figure 4b TFA for Eurostring2 E string.

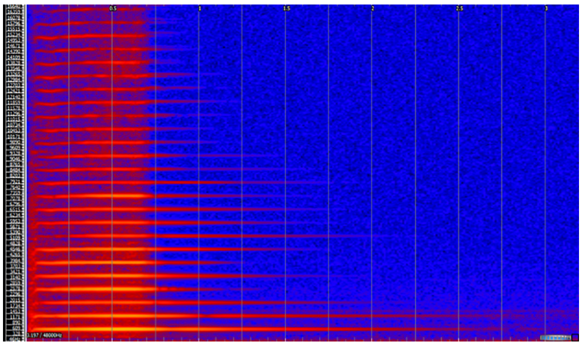

Figure 4c TFA for Stentor E string.

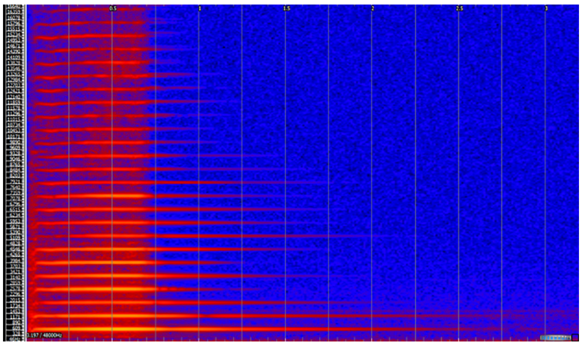

Figure 4d TFA for Suzuki E string.

The background noise is consistent for 0.5 second. Although the 2nd overtone decreased drastically, the 3rd overtone appeared to be higher than the 2nd overtone. The 4th until 10th overtone fluctuates in the intensity. The 3rd, 7th, and 8th overtone sustained their harmonics up to 1.5 seconds. The fundamental frequency sustained for 2.5 seconds, whereas the 1st overtone reaches beyond 3 seconds.

The noise is also maintained for 0.5 second for Eurostring2. Like Eurostring1, the 2nd overtone also decreased drastically, with the 3rd overtone appeared higher than the 2nd overtone. The 4th until 10th overtone fluctuates in the intensity. The 3rd, 7th, and 8th overtone sustained their harmonics up to 1.5 seconds. The fundamental frequency also sustained for 2.5 seconds, whereas the 1st overtone reaches beyond 3 seconds.

The fundamental and the 1st overtone sustained the same duration, i.e., 3 seconds for Stentor and Suzuki violins. The 3rd until 7th overtone fluctuates in the intensity. The 4th, 6th, and 7th overtone sustained their harmonics up to 1.5 seconds. Both the fundamental frequency and 1st overtone sustained for 2.5 seconds.

Eurostring1 display weak fundamental but very strong 1st overtone frequency. The intensity of the higher overtone fluctuates with time when 7th overtone increases again. Eurostring2 showed that the intensity decay exponentially, with the fundamental as the highest frequency. In Stentor and Suzuki both the fundamental and the 1st overtone have similar intensity with the higher overtone fluctuates in intensity as well. Although all violins displayed distinct harmonic frequency, they showed a noisy background along with the harmonic peaks. Pico data in Figure 3c for string E display all overtones have similar intensity with the fundamental. TFA provides a description of the sound in the time frequency plane. From TFA, the magnitudes of the intensity are very distinct to differentiate the strength of the overtone frequencies. The violins have been classified by parameterising the spectrum of each string. The observation reveals that the distribution pattern of frequency values within the harmonics is similar for the four violins.

The selection of violins was difficult to describe in terms of good sound in terms of fundamental and harmonics. The data from the measurements only aids in comprehending their fundamental and harmonics. The violin sound lacks an explanation of timbre as an art since it is seen as a process only understood by expert musicians with musical sensibility and experience. In this case, the frequency was measured using an oscilloscope and the vibration frequency of an overtone was analysed.

All of the study mentioned above measured the fundamental frequency and took into account the overtone frequency. These works determine the harmonics and subharmonics, as well as the timbre. The fundamental and overtone frequencies, commonly known as timbre, are measured in this work. The Fourier transformation determines fundamentals, harmonics, and subharmonics. Different intensities and harmonics or subharmonics (overtones) differentiate each instrument's features. The most essential aspect of this work was that it demonstrated the entire spectrum of accessible frequencies at a given time.

In our work, the dominant frequency that is time localised frequency content for each tone at a specific time can be identified. The TFA over time explains its intensity at the frequency range on the vertical axis. The vertical scale is a frequency scale (in Hz), and the horizontal scale is a timescale (in second). TFA provides a description of the sound in the time frequency plane. TFA showed distinct peaks at the fundamental and overtone frequencies. The spectra for the individual frequency are clearly separated in the y-axis and clearly divided into line segments, lying above each frequency and corresponding to the fundamentals and overtones in each note.

The expert violinist's intuitive hearing is typically based on instinct knowledge or comprehending the pitch rather than facts or arguments. Each player has his or her own set of references. This study seeks to extract the intuitive hearing of a professional violinist and examines it using two distinct TFA methodologies.

Fourier spectra (using PicoScope), and spectrograms (using Adobe Audition). PicoScope reading provides the fundamental and several overtone frequencies in the entire signals, while Adobe Audition spectrograms identify the frequency with time.

Adobe Audition provides TFA with the black and grey part that explains its intensity at the frequency range stated on the vertical axis. From this work, it can be concluded that the PicoScope reading are in good agreement with those from Adobe Audition. The PicoScope only display the range of frequency obtained at a set time or duration. Unfortunately, mother's nature creation cannot detect the frequency changes in the interval of 0.5 second as shown by Adobe Audition spectrograms. These yield difficulties in discriminating sound wave by human ear. Individual harmonics are not easily distinguished because the human ear is not capable of distinguishing the individual harmonics of a complex tone, and the identification of the partials may be nearly impossible in listening to tones in a musical context. The identification of the partial may be nearly impossible when listening, but the frequencies that are present in the signal are easily identified, with information about time localisation giving the dominant frequency for each tone at a specific time.

This investigation indicates that one violin's intonation, tone, and feel will always differ from another. This is because the intuitive feeling (professional player's listening experience) does not always match the output from the PicoScope and Adobe Audition. The best violin is chosen solely by the professional based on hearing. Hence, it proved that these the PicoScope and Adobe Audition translate the best sound from the violin set. This primitive hearing was replaced by PicoScope and Adobe Audition, and it proved that the transmission of the sound of the violin set can be shown on the aspect of intonation, tone, and feels. From the PicoScope data, all violins showed complex tone with their fundamental equivalent to equal tempered scale. Although its frequency accuracy is nearly similar, it differs from the aspect of intonation and tone characteristic. One aspect that needs to be considered in this study is the sound characteristic sense. The sense which is derived from the maker himself allow him to craft a specific "signature" through sound characteristic of a particular violin sets.

When a violin is bowed in an ensemble of violins, the sound stands out as other parts make the sound faculty of the violin ensemble unique. This is the peculiarity of violin, it is exclusively handmade produced and constructed through primitive tools and processing hence create an offset overtone and timbre. The violin is the entire instrument. It has a sound that is bound to the aesthetics of a group of musicians (of a community in the past, today of some professionally engaged musicians serving the entire sound of the instrument). In this work, this sound was read with PicoScope analysis and Adobe Audition, and it proved that the transmission of the sound onto the PicoScope can be shown on the aspect of intonation, tone, and timbre.

CONCLUSION

This paper offers frequency spectrum and time frequency plane to show features for representing violin signals. The frequency spectrum has been classified based on parameterising the spectrum of each string. These features have been found efficient, but they lack the time domain information. By displaying the time varying frequency content of the signal, the time frequency plane features were found to have better classification rates than the frequency spectrum features. Although the frequency content was summed in the table in order to make fair comparisons with the harmonics, the extraction of time frequency plane performed at different frequency give the time resolutions. In this paper, we have examined two different approaches to time and frequency analysis: Fourier spectra (using PicoScope) and spectrograms (using Adobe Audition). PicoScope reading produces spectral peaks within entire signals, while Adobe Audition spectrograms identify the frequency with time. The PicoScope provides the fundamental and several overtone frequencies in the entire signal. Adobe Audition provides TFA with the red and amber part that explains its duration at the frequency range stated on the vertical axis. The peaks from PicoScope are harmonic spectra since they are integral multiples of the fundamental. TFA provides a description of the sound in the time frequency plane. From TFA, the magnitudes of the frequency are very distinct to differentiate the strength of the overtone frequencies. The observation reveals that the distribution pattern of frequency values within the harmonics is similar for the four violins. Thus, it seems possible to fuse this information to solve the identification of fundamental and harmonics at the same time, which will be helpful for violin sound classification.

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