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A Review on Guitar Tuners

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Abstract – The guitar is one of the most popular stringed musical instruments and the practical idea of automatically tuning a guitar explores a wide range of technologies and processes. Tuning is the process of altering the frequency of the musical instrument until they create the desired arrangement of tunes. This paper targets to review various types of guitar tuners and various methodology to tune a guitar, which would be helpful for beginner guitar players to assist in tuning an electric guitar to a certain, pre-set tuning preference.

Keywords: Guitar Tuning, Standard Tuning, Various Methods of Tuning

I. INTRODUCTION

Music is scientifically proved to aids in the reduction of pain and anxiety. It also provides an outlet for self-expression. One of the main reasons why individuals want to study a musical instrument, at least once in their lives, is because of this. Guitar is the most popular instrument to learn nowadays. Being a beginner guitar student can be intimidating if one is unfamiliar with the instrument's tuning process. Tuning is the process of altering the frequency of the musical instrument until they create the desired arrangement of tunes. Many inexperienced guitarists make blunders when tuning their instruments. Beginner guitarists' learning progress may be hampered as a result of this. They are providing wrong tunes for their ears by playing an out of tune guitar. To get the most out of each practice session, one must meticulously tune their instrument before each lesson. The tuning process can be somewhat perplexing for a new guitarist. Especially when there are so many different ways to tune a guitar.

II. Various Designs and Types of Tuners

[1] J. Sevilla Salcedo, D. Martinez Gila, I. Ruano Ruano, A. Sanchez Garcıa, E. Estevez Estevez, J. Gomez Ortega y J. Gamez Garcia, "Design and Development of Low-Cost Automatic Stringed Instrument Tuner"

A prototype capable of capturing sound through the shaking of the instrument body is created in this study, primarily employing a microcontroller device and a frequency estimation technique. In comparison to commercial tuners, this prototype development results indicate remarkable accuracy in musical tone diagnosis. The prototype can be used to build new applications and conduct research in quality control, material characterisation, and even non-stringed instrument analysis. The development of a low-cost optimised prototype was critical for the project's progress, demonstrating extremely high precision in musical tone detection, while employing largely commercial items that were not designed for this purpose. The optimization of sound acquisition using the instrument's vibration yielded satisfactory results, with the acquired signal not jeopardising the precision gained. The optimization of sound capture using the instrument's vibration yielded satisfactory results, with the acquired signal not interfering with the precision of the diagnostic. The prototype's mechanical design combines ergonomics and beauty with excellent functionality by integrating all of the hardware. These findings give up new avenues for further investigation into complex regulatory mechanisms. New musical scales could be added to the prototype in order to improve it.

[3] Mary Lourde R., Anjali Kuppayil Saji, "A Digital Guitar Tuner"

The purpose of this study is to learn about the essential characteristics that must be considered when constructing a guitar tuner. The goal of the project is to create an algorithm that can properly detect a plucked guitar string's fundamental frequency from its frequency spectrum. Matlab is used to create a user-friendly graphical interface that allows any user to effortlessly tune his guitar using the produced programme.

This paper explains how to create a digital guitar tuner. Matlab's filtering, measuring, and analysing capabilities were used to create the tuner. The Matlab-based tuner can provide precise instructions, allowing for rapid tuning. A large portion of the project is devoted to determining the fundamental frequency from the frequency spectrum of a guitar sample note. The fundamental frequency of the notes is a significant aspect, and the methods for determining it are explored using Harmonic Product Spectrum. The effects of sampling frequency, sample time, background noise, and the logarithmic nature of signal intervals in musical notes and other examples are addressed in depth. The idea that the harmonic nature of guitar notes may be used to precisely calculate the fundamental frequency aided in the frequency detection algorithm's simplification. According to the publication, this concept may be expanded to incorporate automatic tuning of the guitar strings by employing a motor to turn the tuning pegs at a voltage proportional to the amount of turn required.

[4] Patrik Šarga, Daniel Demečko "Design and Realization of the Guitar Tuner Using MyRIO"

The digital tuner in this paper turns the microphone's continuous analogue audio stream into a sampled digital discrete signal. The nearest tone is calculated once the digital signal is translated to frequency using the functions. After sampling the analogue input, many digital tuners filter out noise and permit sound up to a particular volume level. The output device, which might be an LED indication, a display, or a monitor, displays the result. A PC, tablet, or smartphone can all benefit from a digital tuner. The purpose of this paper is to show how myRIO may be used with the LabVIEW development environment. The example of making a digital tuner exemplifies this. The analogue signal is converted to a digital signal by the software. The digital signal then adjusts to user-friendly information displayed in the program's graphical interface. A well-designed digital tuner can be used to tune a variety of musical instruments. According to this research, the answer might be applied to a variety of problems.

[5] Alexandr PATRAŞCO, ""ITUNE" – Guitar Tuner Application for Android Driven Mobile Devices"

The goal of the iTune programme in this article is to make the process of guitar tuning easier. This programme allows the user to tune their guitar in conventional pitch. It has a user interface that is easy to learn. The design of this application is simple and pleasing to the eye. It is compatible with any current Android operating system version. An IDE (Integrated Development Environment) for Java programming language and Android SDK (Software Development Kit), as well as a bundle of handy tools for Android developers, are utilised to construct an Android application.

[6] Bishnu Deo Kumar, Apoorv Kushwaha, Amit Kumar, Ashutosh Agarwal, "Design & Implementation of Digital Guitar Tuner Using MATLAB"

The major goal of this project is to determine the key characteristics that must be considered while designing guitar tuners. The goal of the design is to develop a logic that can detect the fundamental frequency of a plucked guitar string from its frequency spectrum. A note is played, and the programme determines if the pitch needs to go up, down, or is correct. The FFT expertise, windowing, filterers, identification of pitches and their relationship to basic frequency, MATLAB and Simulink are all used in the algorithm. It can only be adjusted to a restricted number of notes, only six in total (E2, A2, D3, G3, B3, E4). These sounds on any other instrument, on the other hand, can be tuned.

[10] Arvind Kumar, Sumit Srivastava, Mahesh Chandra, G. Sahoo, "Guitar tuner using cepstral analysis and fuzzy controller on arduino board"

An automatic guitar tuner is designed using Cepstral analysis and a fuzzy controller on an Arduino microcontroller in this research. An acoustic guitar's signals are routed into a MATLAB-based system. Cepstral analysis is used to determine the fundamental frequency of the played note, which is then compared to the desired set point. The difference in frequency between the calculated and set frequencies is fed into a fuzzy logic controller, which provides a corresponding output according to the rules. The Fuzzy controller's output is utilised to generate a PWM signal with a variable duty cycle. The PWM signal's output is supplied to a motor driver circuit, which amplifies it and turns the motor in the desired direction at a variable speed. This changes the string's tension, resulting in a shift in frequency, bringing the string to the appropriate pitch. The system was tested and verified for the 'A' note, with minimal offset yielding successful results. This paper also discusses how to create an automatic guitar tuner using cepstral analysis and an Arduino board. Although cepstral analysis for pitch recognition is more prominent in the speech processing sector, an attempt was made to adapt the technique for musical sound and good results were discovered.

[11] Zach Fraser, "Laser Tuner: A Novel Approach to Pitch Detection on a Drumhead"

The goal of this project is to develop a gadget that addresses these issues in a user-friendly manner. The vibrations of the drum head will be measured using a reflected laser. When utilised around the drum, it will be simple to maintain balance at each tuning position. A visible signal was produced when the gadget was built and connected to the computer, and the laser was reflected back onto the photoresistor from a big tom drum. A series of simple tests were carried out to ensure that the electronics were functioning properly. The goal of this experiment was to show that measuring sound using lasers can be a useful tool for tuning drums. This prototype not only captured the frequencies produced at a precise spot on the drumhead, but it is also the only device developed specifically to tune drums with such precision. Comprehensive data gathering and analysis can be undertaken to quantify the precision and accuracy of this device once the software has been further designed and enhanced. This study proposes a solution to a frequent problem that is compact, simple to implement, and uses low-cost components that are far more reliable than current methods.

[14] Zhen J. Wang, Cesar Ortega-Sanchez, "Electronic Assisting Violin Tuner"

The Electronic Assisting Violin Tuner's design concept, implementation, and verification procedure are presented in this work (EA VT). The frequency information was extracted from the violin sound using a Goertzel filter that was optimised and integrated in a microcontroller. The frequency information obtained is utilised to tune the violin by controlling actuators. Safety concerns were also taken into account, and necessary measures were adopted to prevent the chance of inadvertent string breaks, which could injure the violinist. The purpose of this research was to create a gadget that would assist in tuning each violin string.

The violin tuner described in this paper is capable of tuning all four strings to an IHz precision. The tuner obtained the desired frequency 90% of the time during continuous testing. Before amplification, a 4th order Inverse Chebyshev low pass filter was added to improve tuning reliability. While the ultimate goal has been met, many other aspects of the findings could be improved, such as speed (make tuning faster), robustness (make the tuner more durable), size (make it smaller), weight (make it lighter), and reliability (make it more accurate every time). There is also the possibility of additional future work to increase the EVAT's performance. Future work could include the ability to tune all four strings at the same time (polyphonic tuning), which would drastically reduce the amount of time required to tune the instrument. Another idea for the future is to use the YIN algorithm to compare performance to the Goertzel.

[15] Peeyush Garg, Anshuman Kamboj, Ajay shankar, Abhishek Kumar, "Mechanization of G, C and D Chord playing system using servomotors for Acoustic Guitar"

The proposed technique in this research provides exact control of the G, C, and D chords. The system consists of an Arduino-based control unit and a servo-motor-based actuation system that allows for accurate string pressing on the fretboard as well as time-coordinated plucking or strumming actions at the acoustic guitar's neck and hole areas. The scheduling system is in charge of creating a specific musical melody. Existing audio processing methods were used to verify the chords played. The servomotors are used to pluck and strumming the specific strings, while the static rack arrangement of servomotors is used to press the right frets on the fretboard, which were visually checked and also verified by software utilising analysis of the resulting chord sound. Striking and pressing on strings with a motor reduces human effort while also ensuring proper music chord creation over time. The designed system is capable of playing the chords C, G, and D on the guitar in a consistent manner.

[16] Rodrigo Melo, Rodrigo de Paula Monteiro, José Paulo G. de Oliveira, Bruno Jeronimo, Carmelo J. A. Bastos-Filho, Anna Priscilla de Albuquerque, Judith Kelner, "Guitar Tuner and Song Performance Evaluation Using a NAO robot"

The NAO robot is proposed as an alternate purpose in this paper: music teaching. By combining robot traits with signal processing techniques, it was able to achieve this goal. To help children learn and improve their acoustic guitar talents, a NAO robot was used to implement the Guitar Tuner and Song Performance Evaluation. Despite the fact that no trial with children was carried out, the writers put the app to the test. As a result, the NAO robot could process in a timely manner. The tuning application is in good working order. Even when tested in a noisy area, the programme provided accurate feedback on the tuning process. The evaluation procedure, on the other hand, has some trouble distinguishing specific notes with a harmonic in the 680 Hz region. In addition, the evaluation procedure was not put to the test in a noisy environment. Despite this, the robot was able to keep up with the beat (metronome) and record the performance of the song. The next stage for future development is to conduct user experience tests, particularly with young music students. These tests will determine what improvements/modifications should be made to the student-robot interaction process. Another issue that needs to be investigated is how to disable the bumpers' detection in the NAO's feet, because when contact is sensed in them, the algorithm stops functioning.

[17] Kourosh Rahnamai, Brian Cox, Kevin Gorman, "Fuzzy Automatic Guitar Tuner"

A fuzzy logic controller was used to construct and create an automatic guitar tuner in this paper. Simulink and the XPC real-time kernel were used to create the guitar tuner. The technology takes the signal from an electric guitar and feeds it into an XPC-enabled target PC. The system calculates the fundamental and harmonics of the played notes and compares them to the intended pattern using Fast Fourier Transforms (FFT). The frequency difference is fed into a fuzzy logic controller, which adjusts the tension of the desired string automatically. The oscilloscope and auto tuner, both types of hardware testing, have revealed that the tone is slightly flat. The note, on the other hand, sounded in tune when listened to by ear. The tuner has a margin of error for the frequency of the note that will consider the note "in-tune" because he can't determine if it's slightly flat. This is significant since it facilitates system development and enables for an acceptable limited range of frequency variances to be termed "in-tune."

[18] Pin Zhuo, "Optimization of Intelligent Tuning System for Stringed Instruments Based on Wireless Sensor Network"

This paper covers the current state of tuning tools for stringed instruments, analyses the existing challenges with tuning tools for popular stringed instruments, and proposes an automatic tuning system based on wireless sensor networks in the field of wireless sensor networks. Audio acquisition module, tuning control module driver circuit design, voice broadcast module, and network communication module selection analysis are all part of the hardware design of an intelligent tuning system based on a wireless sensor network. Embedded software design and mobile software design are both included in the software design of an intelligent tuning system based on a wireless sensor network. System flow design and automatic tuning function design are two of the most important aspects of embedded software design. The paper adopts the improved short-time average amplitude endpoint detection method, which improves the accuracy of chord signal endpoint detection to a certain extent, in response to the problem that the traditional endpoint detection algorithm is susceptible to random noise and causes false detection, based on the characteristics of chord signal. The harmonic peak approach is used to address the problem that a single pitch detection method cannot match the tuning precision requirement over the whole frequency band. The tuning system's functionality and performance are evaluated. The tuning system has a good human-machine interaction, and it has automatic tuning, winding, voice broadcasting, wireless control and display, and metronome functions. Instruments like guitars and ukuleles are currently supported by tuning systems.

[19] Narongsak Tirasuntarakul, Arbtip Dheeravongkit, "An Automatic Multi-String Musical Instrument Tuner using One-to-Many Micro Actuating Mechanism"

The one-to-many micro actuation mechanism is devised and implemented as part of an automatic string tuning system on a multi-string musical instrument in this study. On the three topmost treble strings of a Thai hammered dulcimer, the tuning technique was evaluated. When a string is hit, a pickup sensor is placed beneath it to identify and measure the signal amplitude. The starting frequency of the strings is calculated using the Goertzel algorithm. Each string's tuning time is calculated in advance. For the projected tuning time period, the micro actuation modules adjust the tension of the strings to the target frequency. The cycle is repeated until the desired frequency is achieved. The experimental results reveal that the suggested micro actuation modules can tune three strings of different initial frequencies to the same goal frequency concurrently and independently utilising a single motor drive.

The pickup sensor is designed to simultaneously measure the signals of all strings without being distracted by external noise. Furthermore, due to its small size, the sensor can distinguish between impulses from strings that are only 3mm apart. All strings' fundamental frequencies can be determined using the Goertzel algorithm and two-step search algorithms. The tuning time predictor reduced the amount of user intervention required to tap the strings repeatedly throughout the tuning process by calculating the tuning time for each string in advance.

[20] Primoz Podrzaj, Matej Zerjav, "Arduino Based Automatic Guitar Tuning System"

An automatic guitar tuning mechanism is given in this study. It's built on top of the Arduino platform. It records the sound with a microphone, calculates its frequency, and then utilises a stepper motor to turn the tuning pegs on the guitar head to get the desired frequency. This paper's main goal is to show another possible mechatronic application for Arduino-based systems. The described automatic guitar tuning system provides players with an intriguing initial step into the fields of engineering and electronics. Of course, the system's applicability is limited in its current configuration. Because we used components from previous projects, many of them aren't optimised. For example, the battery is far too huge. The system would also be of practical benefit if optimizations were made, particularly in the case of battery and stepper motor fixing, as some of the guitar players we asked to test the system have highlighted.

III. DIGITAL SIGNAL PROCESSING TECHNIQUES

[2] Arnie Gedanken Branta, Emanuel Marques Martins, Verônica Isabela Quandt, Solivan Arantes Valente, "Development of a triple input musical instrument tuner using Yin algorithm"

This study describes the creation of a low-cost optimal pitch detection system that runs on an Android smartphone and can detect and process sound signals issued by various instruments with frequencies ranging from 27.5 Hz to 4186 Hz. It also describes the development of a device that aims to combine the various methods of capturing acoustic signals emitted by instruments of various categories into a single device, allowing musical groups to tune their instruments with a single tuner rather than using specific tuners for each type of instrument, resulting in lower investment and greater portability. It discussed the creation of a universal tuner. The reported results demonstrate capability, which is comparable to commercial solutions. It provides more information than the other gadgets tested in various ways. The use of an internal battery system is recommended as a future upgrade.

[7] Urja Kulkarni, Shrishti Kaushik, Lanita Lobo, Reena Sonkusare, "Comparative Study of Digital Signal Processing Techniques for Tuning an Acoustic Guitar"

The results of a comparative examination of alternative tuning procedures for an acoustic guitar are presented in this publication. The sounds of guitar strings are recorded and saved as WAV files in this study, which are then used as input to a tuning algorithm written in Python and MATLAB. The two techniques that have been compared are the Fast Fourier Transform and Spectral Density Estimation. Both systems' tuning processes have been described in detail, and the outcomes of both approaches have been published in a tabular style so that the accuracy of each method may be compared. The method that produces findings that are closest to the true values of the fundamental frequency is considered to be the superior method. Five different fundamental frequencies were estimated using both methods, and the accuracy of the calculated fundamental frequencies was compared. The findings acquired by the Power spectral density technique were more accurate and faster than the results obtained by the Fast Fourier Transform algorithm, as shown in the graphs and table.

[8] Joseph Reagan, Sedig Agili, Aldo Morales, "Real Time Implementation of a Tuning Device Using a Digital Signal Processor"

The use of a digital signal processing (DSP) board for educational purposes and project realisation is demonstrated in this paper. The project will be implemented by designing a guitar tuner on a digital signal processor (DSP) architecture. The design's purpose is to improve the DSP process so that the guitar tuner gets the best results possible. This entails choosing the right DSP parameters and employing DSP techniques to achieve correct guitar tuning, such as frequency resolution and sample rates. The programme was developed using the TMS320C5402 DSP Starter Kit as a target hardware device (DSK). The guitar tuner application is written in the C programming language and takes use of Texas Instruments' DSP assembly routines. The guitar tuner software may be executed in the Code Composer Studio (CCS) Integrated Development Environment (IDE) and can accurately tune a guitar in a variety of tunings.

[9] Miroslav Stanek, Tomas Smatana, "Comparison of fundamental frequency detection methods and introducing simple self-repairing algorithm for musical applications"

This research compares five widely used approaches for detecting fundamental frequencies in speech signals, namely in vocal and melodic instrument signals. The effectiveness of the chosen strategy is tested using a series of musical notes played on the bass clarinet. AutoCorrelation (ACF) and Modified AutoCorrelation (MACF) functions had the maximum efficiency in fundamental frequency detection. This study also includes a description of a self-repairing algorithm, which may be defined as a valuable tool for correcting incorrectly identified fundamental frequencies associated to significant musical notes. The most acceptable segment length for correct pitch identification and self-repairing algorithm function can be chosen as a half value of the smallest known musical note in the processed signal. The combination of ACF, MACF, and a self-repairing algorithm augmented by some fundamental frequency shifting method can be utilised as an excellent almost real-time tool for tuning and other musical applications due to its great efficiency and low computing performance. On the input signal under test, four time-domain detection approaches and one frequency-domain detection method were detected. The ACF method and its variant MACF produced the best results. Both approaches failed to correctly detect fundamental frequency on a single segment, indicating that they might be used in real time. The spectral approach, which is only suitable for heavily sampled input signals, produced the worst results. The described self-repairing technique, which employs found fundamental frequencies on surrounding segments for current segment correction, can lower the error ratio of attained fundamental frequencies. It is required to set the shortest detectable note in the input signal adequately in order for it to perform properly. According to the basic idea of this research, the recently proposed simple self-repairing algorithm's functionality is good, but more accuracy on testing data sets is required for it to be modified in the future. Clearly, combining the ACF or MACF methods with the newly presented self-repairing algorithm results in a powerful instrument for analysing recorded and near-real-time input signals, with promising outcomes in emotion speech analysis, voice and other musical applications.

[12] Rafael George, Amado Jozue, Vieira Filho, "Pitch Detection Algorithms Based on Zero-Cross Rate and Autocorrelation Function for Musical Notes"

The zero-cross rate (ZCR) and autocorrelation function are used in this study to examine two pitch detection algorithms (PDA) for simple audio sources (ACF). It highlights some of the benefits and drawbacks of adopting these methods, as well as some of the enhancements that have been made to improve their performance. To begin, the Zerocrossing Rate (ZCR) algorithm was tested with many musical notes (actual acoustic guitar signals) and the results were compared to reference values. The Autocorrelation function (ACF) algorithm was then tested in the same way as the ZCR, and the results were compared to the same benchmark. The creation of methodologies to improve the performance of traditional procedures was the next step. These procedures were put into practise, and the results were compared to those obtained using traditional methods. In all situations, the modifications greatly reduced the inaccuracies revealed by the traditional methods.

[13] Tomáš Harþarik, Jozef Bocko, Kristína Masláková, "Frequency analysis of acoustic signal using the Fast Fourier Transformation in MATLAB"

The Fast Fourier Transformation is used to analyse the frequency of acoustic signals in this study (FFT). After understanding the normal frequencies of a vibrated system, efforts to decrease vibrations should be performed. One technique to do this is to record sound to a digital file and then transform the data using the Fast Fourier Transform. The study discusses the application of FFT to mechanical vibration analysis. Experiments offer us with a time-dependent series of diverse physical characteristics that we can use to investigate mechanical system properties. When converting a digital signal from the time domain to the frequency domain, FFT analysis is a good option. It illustrates that other data from acoustic sound, such as acceleration, velocity, or displacement collected from sensors, can be transformed as well.

IV.CONCLUSION

Tuning process is vital in learning to play not just a guitar but also any other musical device. The tuning process can be somewhat perplexing task for a new guitarist. Especially when there are so many different ways to tune a guitar. There are many techniques and methods to tune any musical instrument but this paper focuses of tuning of a stringed instrument, particularly guitar, and reviews the various methods and techniques.

REFERENCES

[1] J. Sevilla Salcedo, D. Martinez Gila, I. Ruano Ruano, A. Sanchez Garcıa, E. Estevez Estevez, J. Gomez Ortega y J. Gamez Garcia, "Design And Development of a Low Cost Automatic Stringed Instrument Tuner", XL Jornadas de Automática, August 2019.

[2] Arnie Gedanken Branta, Emanuel Marques Martins, Verônica Isabela Quandt, Solivan Arantes Valente, "Development of a triple input musical instrument tuner using Yin algorithm", International Journal of Advanced Engineering Research and Science (IJAERS), Vol-6, Issue-12, Dec- 2019

[3] Mary Lourde R., Anjali Kuppayil Saji, "A Digital Guitar Tuner", International Journal of Computer Science and Information Security, Vol. 6, No. 2, 2009

[4] Patrik Šarga, Daniel Demečko "Design and Realization of the Guitar Tuner Using MyRIO", Journal of Automation and Control, 2017, Vol. 5, No. 2, 41-45

[5] Alexandr PATRAŞCO, ""ITUNE" – Guitar Tuner Application for Android Driven Mobile Devices.", Technical University of Moldova

[6] Bishnu Deo Kumar, Apoorv Kushwaha, Amit Kumar, Ashutosh Agarwal, "Design & Implementation of Digital Guitar Tuner Using MATLAB", 2021 International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE), March 2021

[7] Urja Kulkarni, Shrishti Kaushik, Lanita Lobo, Reena Sonkusare, "Comparative Study of Digital Signal Processing Techniques for Tuning an Acoustic Guitar" International Conference on Smart Structures and Systems (ICSSS), July 2020.

[8] Joseph Reagan, Sedig Agili, Aldo Morales, "Real Time Implementation of a Tuning Device Using a Digital Signal Processor", Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, 2004.

[9] Miroslav Stanek, Tomas Smatana, "Comparison of fundamental frequency detection methods and introducing simple self-repairing algorithm for musical applications", International Conference Radioelektronika (RADIOELEKTRONIKA), April 2015.

[10] Arvind Kumar, Sumit Srivastava, Mahesh Chandra, G. Sahoo, *"Guitar tuner using cepstral analysis and fuzzy controller on arduino board"*, Microsystem Technologies, December 2017.

[11] Zach Fraser, "Laser Tuner: A Novel Approach to Pitch Detection on a Drumhead", The Canadian Science Fair Journal (CSFJ) Volume 2, Issue 5, 2020.

[12] Rafael George, Amado Jozue, Vieira Filho, "Pitch Detection Algorithms Based on Zero-Cross Rate and Autocorrelation Function for Musical Notes", International Conference Audio, Language and Image Processing ICALIP 2008

[13] Tomáš Harþarik, Jozef Bocko, Kristína Masláková, "Frequency analysis of acoustic signal using the Fast Fourier Transformation in MATLAB", Procedia Engineering 48(2012) 199 – 204.

[14] Zhen J. Wang, Cesar Ortega-Sanchez, "Electronic Assisting Violin Tuner", TENCON 2012 IEEE Region 10 Conference, Nov. 2012.

[15] Peeyush Garg, Anshuman Kamboj, Ajay shankar, Abhishek Kumar, "Mechanization of G, C and D Chord playing system using servomotors for Acoustic Guitar"**,** International conference on Electronics, Communication and Aerospace Technology (ICECA), June 2019

[16] Rodrigo Melo, Rodrigo de Paula Monteiro, José Paulo G. de Oliveira, Bruno Jeronimo, Carmelo J. A. Bastos-Filho, Anna Priscilla de Albuquerque, Judith Kelner, "Guitar Tuner and Song Performance Evaluation Using a NAO robot", Latin American Robotics Symposium (LARS), 2020 Brazilian Symposium on Robotics (SBR) and 2020 Workshop on Robotics in Education (WRE), Nov. 2020

[17] Kourosh Rahnamai, Brian Cox, Kevin Gorman, "Fuzzy Automatic Guitar Tuner", Annual Meeting of the North American Fuzzy Information Processing Society, June 2007.

[18] Pin Zhuo, "Optimization of Intelligent Tuning System for Stringed Instruments Based on Wireless Sensor Network", Journal of Sensors, May 2022.

[19] Narongsak Tirasuntarakul, Arbtip Dheeravongkit, "An Automatic Multi-String Musical Instrument Tuner using One-to-Many Micro Actuating Mechanism" Proceedings of the 2018 International Conference on Machine Learning and Machine IntelligenceSeptember 2018, Pages 64–67.

[20] Primoz Podrzaj, Matej Zerjav, “Arduino Based Automatic Guitar Tuning System” Proceedings of the Third International Conference on Electronics and Software Science (ICESS2017), Takamatsu, Japan, 2017