Piano Key Identification using LabVIEW

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***Abstract* — The aim of this paper is to present overview of famous musical instrument the piano, and how the sound created by it is depicted in a mathematical relationship. Using that relationship, a simulation was designed to identify the piano key being pressed in the surroundings with the help of Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW). In LabVIEW a virtual instrument (VI) was developed in which the sound of piano was acquired with the help of simple microphones, and with the help of added frequency filters in the VI file piano key being pressed by the user was identified successfully.**

***Keywords* – National instruments, LabVIEW, piano key identification.**

1. Introduction

The piano is one of the most widely used instruments in the western music. It has a very characteristic sound and a wide dynamic range. Its playing range is more than seven octaves. The piano is usually used as a solo instrument, but often it is used to accompany other solo instruments or singing as well. Its popularity probably arises from its versatility and the fact that it is capable of producing both powerful and sensitive sounds [1].

DOI: 10.18421/TEM91-13
https://doi.org/10.18421/TEM91-13

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Received: 03 October 2019.
Revised: 03 February 2020.
Accepted: 09 February 2020.
Published: 28 February 2020.

A particular musical instrument sounds the way it does because of the harmonic content of the sounds it creates, and the variety of sounds that can be generated from a single instrument are directly related to the harmonic content of different generated sounds. It is apparent that there are many distinct frequency components accompanying the fundamental note [2].

On the basis this distinct frequency phenomenon we designed a Virtual Instrument (VI) in simulation software known as Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW), which can help us to identify the key being pressed on the keyboard of the piano [3].

In this paper we have discussed the basic overview of LabVIEW, how piano generates the sound physically, and in the end there is detail of our implemented project.

2. LabVIEW Background

LabVIEW is a graphical programming language developed by National Instruments in 1986. It was developed to simulate, test and create controlling systems. In LabVIEW in contrary to other programming languages code is not written rather it is built graphically in the similar manner of a flow chart.

Initially it was a simple program which was capable of sending, receiving and integrating data to and from simple electronic devices. Those electronic devices had to be having the General Purpose Interface Bus (GPIB). Later on, it became the application which is capable of analyzing data both in digital and analog format.

2.1. Creating LabVIEW Program

Every project is saved as a virtual instrument (VI). VI is somehow much similar to the electronic circuit designs in the real world. There are blocks representing real output and input devices such as graphs, switches, LEDs, wires etc.

VI has further three main components, named as

- front panel; it is a display of input and output controls at the simulation time,

- block diagram; where the code is built,
- connector pane; which makes the interface between VI and sub-VI if applicable.

LabVIEW executes code in a parallel manner. It means as soon as the required inputs are provided, code will start working.

Over the passage of time LabVIEW has emerged into a general purpose language which is having a large number of applications now. [4], [5].

3. Piano

Piano can simply be defined as a huge keyboard musical instrument in which sound is produced by pressing the keys which further create the movement of hammers causing them to hit metal strings to create melody.

3.1. Overview

Typical piano keyboard comprises 88 keys in total, out of these keys 52 are white and 36 are black. From a keystroke message is generated, which controls the hammer and it hits the string. Due to this collision vibration is produced and sound is generated.

Piano strings generate very complicated sound. The built of sound is very rapid as compared to the decay of sound, which makes it unique as compared to other musical instruments.

Beside this rate of decay for partials is different from one another. Some will take dozens of seconds while the others will be decayed with in few seconds. General mechanical structure of piano is given in Figure 1.

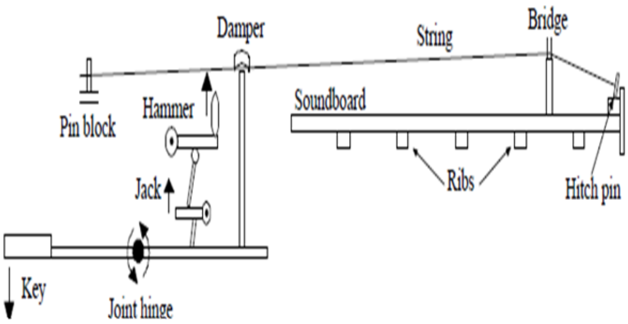

Figure 1. General Structure of Piano [6]

3.2. Historical Background

Pythagoras of Samos was a Greek philosopher. According to him all the relations can be deduced in the form of mathematical equations. This theory was mainly dependent on the observations being done in music, mathematics and astronomy.

He later proved that if there are two strings under the same physical circumstances, then the string half in length generates the pitch of frequency exactly double than the pitch produced by the full length cable. This relationship was given the name of being one octave higher.

Later a German scientist Hermann Helmholtz added further relationships to this theory. According to Pythagoras and Helmholtz frequency ratios provided in Table 1 were derived.

Table 1. Standard Frequency Ratios [7]

Ratio	Name
1:1	Unison
1:2	Octave
1:3	Twelfth
2:3	Fifth
3:4	Fourth
4:5	Major third
3:5	Major Sixth
5:6	Minor Third
5:8	Minor Sixth

These ratios are applicable on fundamental frequency and their over tones along with the separate keys relationship also. [7]

3.3. Keyboard Frequency Relationship

In full piano keyboard we have seven octaves in total in the series of notes given the name from A-G. The distance from a note to the next time that note is repeated is known as an octave. Frequency of any key can be calculated with the provided equation.

$$f(n) = 440\,(\sqrt[12]{2}\,)^{n-49} \tag{1}$$

Whereas n= number of key.

With the help of reverse mathematics if frequency of the pitch is known key number can be calculated with the given relationship [8], [9], [10].

$$n = 12\,log_2\left({}^{f}\!/_{440} \right) + 49 \tag{2}$$

Full piano keyboard with frequencies is given in figure 2.

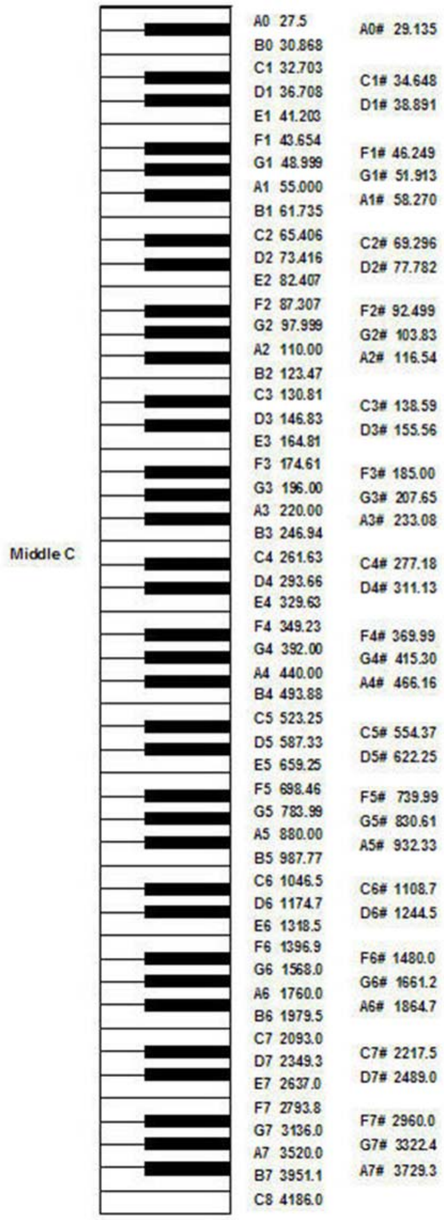

Figure 2. Frequencies of Piano Keyboard [10]

4. Experiment

4.1. Problem Statement

We were required to identify the key of piano being pressed. At the time given a group of seven keys can be selected out, one of which we had to identify a certain pressed key. It can be stated as following:

- Acquire sound from a piano/digital piano after each 0.5 seconds, only seven specified keys of the piano can be pressed.
- Filter the sound to keep wanted frequencies and remove unnecessary noise.
- Detect the keys that were pressed to produce the sound

4.2. Solution

The problem was simple enough as we knew the group of keys which can be pressed. Due to the knowledge of keys fundamental frequency was also known. From the literature review we know that all the overtones are basically multiples of their fundamental frequency. Depending on these facts we developed a flowchart which is provided in Figure 3, and with the help of that we managed to develop the VI to identify the pressed key.

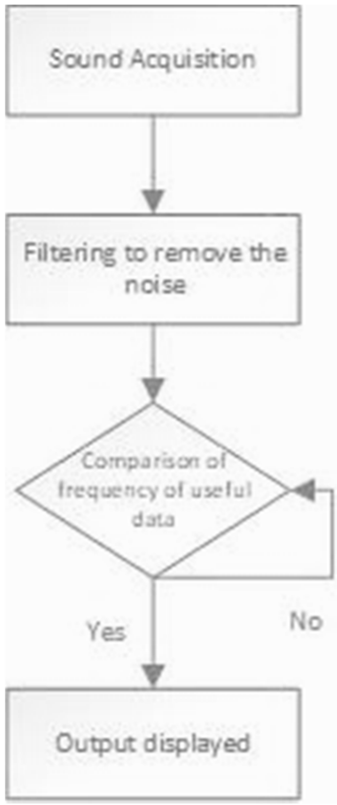

Figure 3. Flowchart of Solution

4.3. Simulation Design

Following steps were taken to implement the task:

- Acquisition of Sound: Sound is acquired using the "Acquire Sound Express VI". The input and output parameters of the VI were selected as per our requirement. When one runs the project VI the acquired sound express VI, and one will acquire sound through the microphone of the computer after each time period that is set to acquire the sound. For this project we kept it to 0.5 as was assigned to us. The sound can be played from a real piano or a digital piano within the computer.
- Filtering: Only seven specified keys on the piano can be pressed, so we used seven filters to filter the sound and acquire clearly the sound of our interest if it was played. Filter express VI is used for this purpose it gives a lot of options to choose.

We choose band pass filter of order five for each required frequency.

- Identification of Keys Played: To detect the keys of the piano that are pressed to produce the sound "Tone Measurement Express VI" is used to detect the magnitude of each frequency. If some magnitude (above a threshold, required to be adjusted according to the environment, i.e. the quality of sound) of any of the seven key frequencies is detected this is an indication that the said key was pressed. To compare this magnitude to a threshold value a "Greater or Equal Function" is used, which returns TRUE if **x** is greater than or equal to **y**. Otherwise, this function returns FALSE. The output is fed to Boolean true/false indicator which glows to indicate true state.

Front panel and block diagram of VI are given in Figure 4 and Figure 5 respectively.

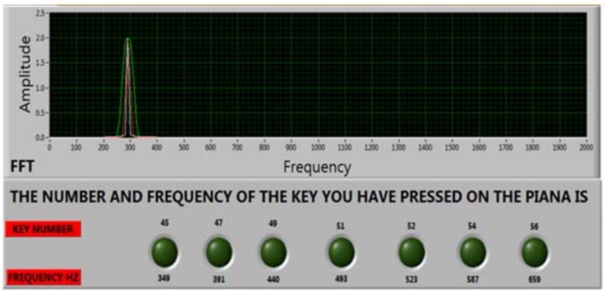

Figure 4. Front Panel

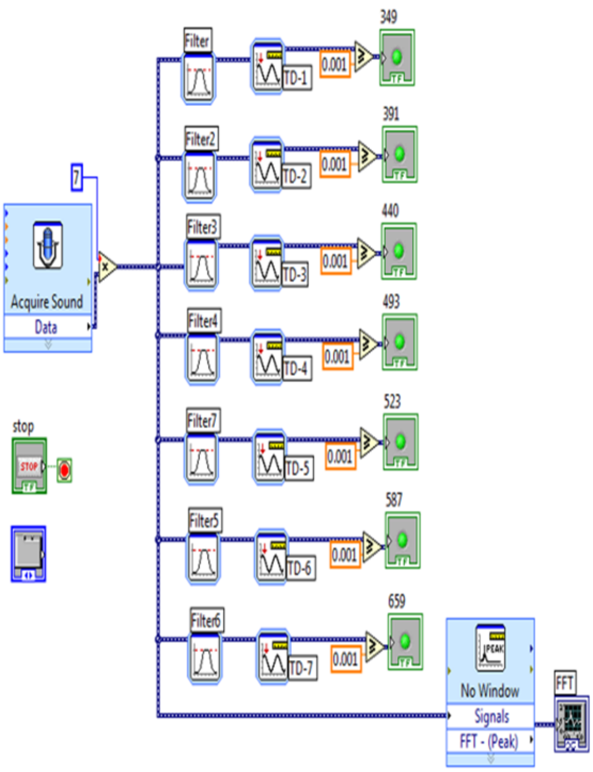

Figure 5. Block Diagram of VI

4.4. Data

Two set of seven piano tones are selected for this project. The first set is selected from electronic piano, which can be played on laptop. Second set of seven tones are individual mp3 tones that can be played individually using mp3 player. For these two sets two separate VIs have been built. The lists are given below:

Table 2. Selected Piano Tones First Set

Fundamental Frequency (Hz)	Key Number on Standard Piano	Keyboard Key of Laptop
349.228	45	Q
391.955	47	W
440	49	E
493.883	51	R
523.251	52	T
587.330	54	Y
659.255	56	U

Table 3. Selected Piano Tones Second Set

Fundamental Frequency (Hz)	Key Number on Standard Piano
329.628	44
369.994	46
440	49
466.164	50
493.883	51
554.365	53
587.330	54

4.5. Results

Results were obtained by a very simple interface between user and device.

Run the VI and the VI will start acquiring the sound when any electronic piano is played around the computing device or within the computer. After acquiring the data, the indicator light will go on according the key pressed or frequency generated.

For the reference few results are attached in figure 6,7 and 8. These results are being generated by playing piano on the mobile phone and running VI on the laptop.

In Figure 6 and 7 keys are identified, but for figure 8 multiple keys were pressed at the same time and only the waveforms are being displayed. No keys were being identified due to overlapping of tones. In the result figures waveform signals are visibly shown in the graph portion and they match with the frequency chosen.

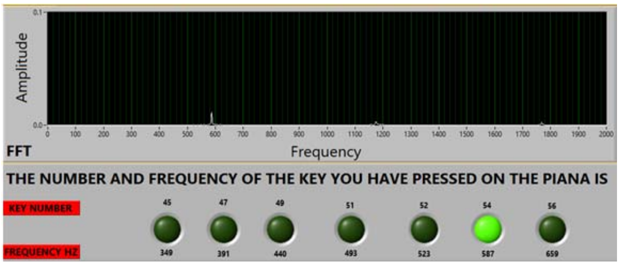

Figure 6. Key-54 Identified

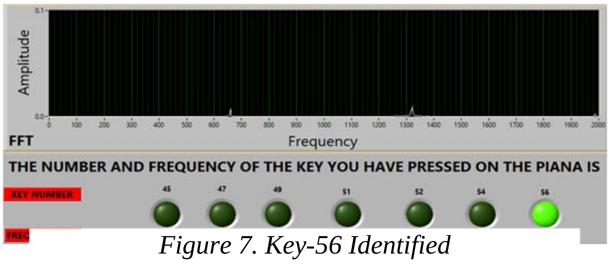

Figure 7. Key-56 Identified

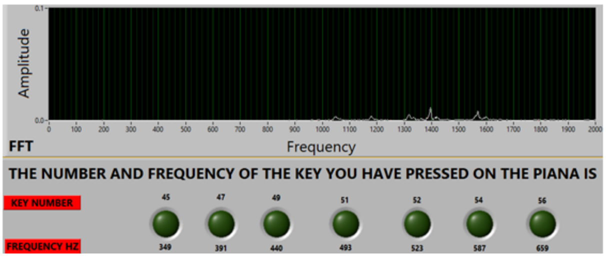

Figure 8. No Key Identified

5. Conclusion & Future work

LabVIEW is a user friendly graphical environment which is generally considered to be useful for taking measurements from various laboratory instruments, but it can also be used to perform various mathematical and logical functions. It can be used to create virtual instruments to apply and test various functions provided in LabVIEW.

The tones of the virtual piano created for this paper were identified using frequency filters and the results were displayed after doing some mathematical operations.

The work is important to encourage readers to understand the capabilities for similar tasks using any other virtual and real instruments. Further on, this project can be improved by taking more samples at the given time.

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