AUTOMATED LASER-BASED INTERFEROMETER MEASUREMENTS ON MUSICAL INSTRUMENTS

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Abstract: Laser-based interferometer measurement on musical instruments allows us to track and analyze vibrations of single point on the instrument surface without physical contact. To analyze the instrument more precisely, we need to gather the vibrations from more surface points. To make this procedure more feasible, we have designed a set of both hardware and software tools. The hardware part consists of three motor-driven carriage travels, which allows moving the laser within all three axes. The software part contains the control and logic to set up the measurement and gather the results. The complete system allows automated scanning of the instrument surface vibrations using chessboard-like net of measuring points, with adjustable boundaries and steps. Within this paper, we will present such a system and we will also give a comparison with other measurement tools and methods such as ESPI laser interferometer or VIAS.

1. Introduction

2-dimensional measurements of instrument vibrations allows us to identify possible problems in instrument mass and/or to examine the interconnection between instrument vibratons and the quality of instrument's sound. Our department is equipped with three different devices which allow us to perform such a complex measurements. One of them is ESPI laser interferometer, which allows to take snapshot of vibrations of complete 2-D plane and imediatelly shows the result in a form of image. The ESPI system is delivered as complete solution by the Dantec-ettemeyer company [1]. The second one is beam laser interferometer, which allows to measure only one point at time. Therefore we have developed a specialised construction with carriage travels, which alow to move the laser beam. These carriage travels are controlled by a specialised piece of softare, which allows us to scan the instrument surface in matrix-like manner. The third one is VIAS system, which measures vibrations in one point using needle-like measuring sensor.

2. ESPI laser interferometer Q-600

The ESPI Q-600 is a product of Dantec-Etemeyer company [1]. It takes an advantage of a diffraction of coherent light (laser) on non-polished surfaces. This diffraction is very sensitive to the changes of the difractor shape - in our case this change of shape is caused by vibrations of an instrument. The ESPI system produces two short flashes immediatelly after each other, records these diffractions by a CCD camera and then compares (substracts) both images. The resulting image corresponds to the vibrations of the instrument surface. How the output looks is shown on the following picture (Fig. 1). The principle of the system is explained on figure 2.

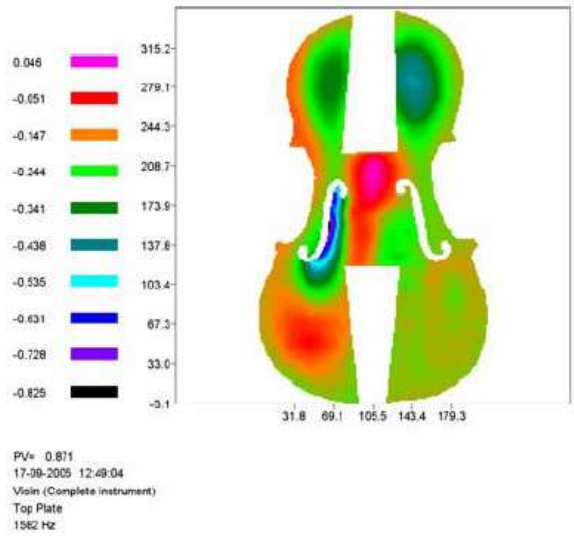

Figure 1. Output of the ESPI system

The main advantage of ESPI system is, that it can provide information about vibrations of huge area nearly immediatelly. It is also non-contact, so it cannot harm the instrument in any way (in the contrary to the VIAS system when using it improperly).

The disadvantage is that the system is very huge and heavy, and therefore cannot be moved out of

the laboratory. A photograph of whole system is figure 3. Also it is worth to mention, that the system sometimes gives different results for the same frequency, which is caused by the fact, that we snapshot these vibrations at different position of the period.

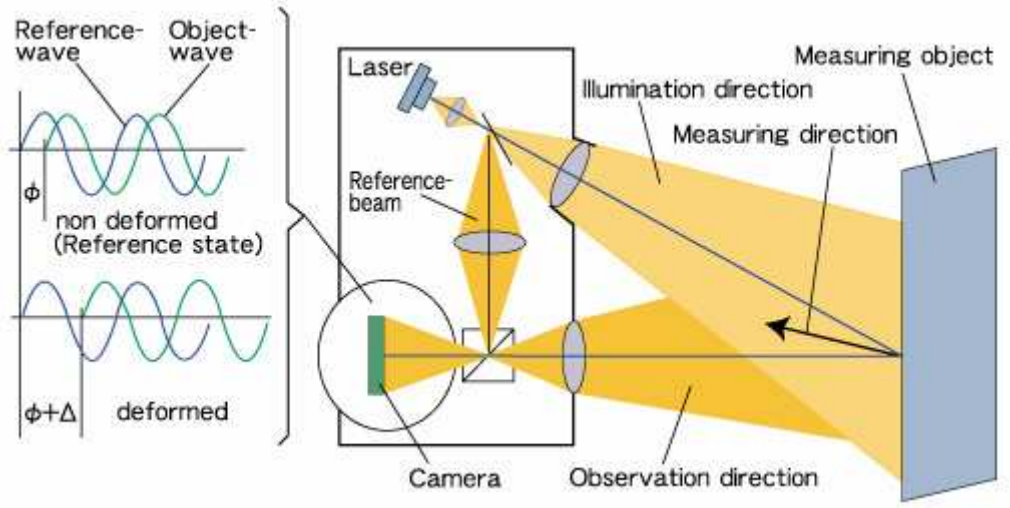

Figure 2. The basic principle of ESPI Q600

Figure 3. ESPI Q-600 measuring system

3. VIAS

Although VIAS is dedicated to explore violins, it can be used for any string instrument or vibrating object. It was developed in Institute für Wiener Klangstil [2].

It is based on measuring of the instrument impedance at the point where the sensor (needle) touches the surface. In other words, the needle excites the instrument at the touch-point and measures the resistence of the surface. The needle-like sensor is on the following picture (Fig. 5). The accompanying softyware displays harmonics as several lines (Figure 4.).

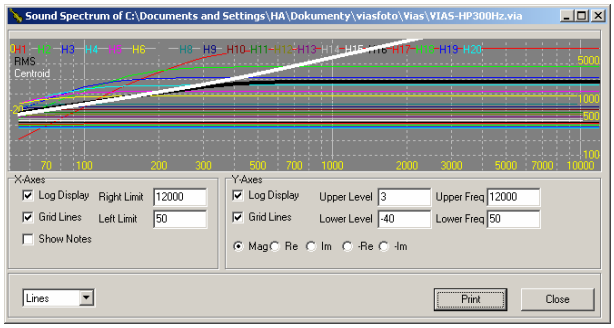

Figure 4. VIAS application screenshot

The VIAS software generates a sine wave sweep between two corner frequencies with adjustable duration. A logarithmic sweep with a length of 120sec is sufficiently slow to excite even subtle resonances of violins.

The disadvantage of VIAS system is, that the measuring needle and it's mounting is not sufficiently rigid (see fig 5), and therefore the results are not accurate. But for informative measurements is it completelly acceptable.

The main advantage of the VIAS system is that the whole system is portable, so it can be carried to the place where the violin are kept (rare and/or valuable instruments).

Also, the placement of the needle have to be made very gently, which disables the use of automated carriages.

Figure 5. Detail of VIAS measuring sensor

4. Automated laser scanner

The main advantage of a single - beam laser interferometer is (compared to VIAS), that it is a non-contact method. Therefore we have designed a motor-driven carriage system, which can move the laser at any position. The system consist of three step-motors controlled by M1486 processor [4].

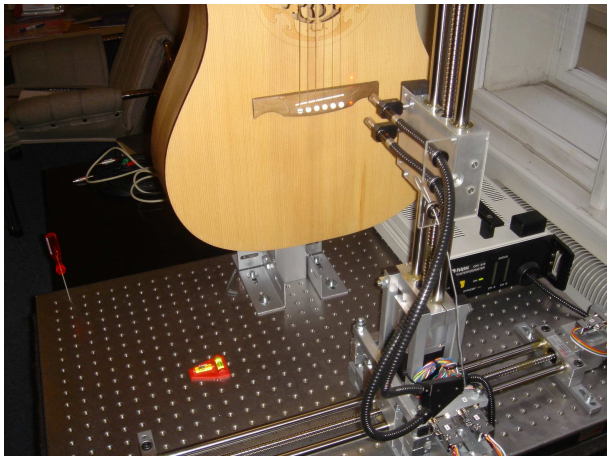

Figure 6. Automated carriage system

To scan a bigger area automatically, we have developed a unique piece of software called iFero, which can do all the measurements in three mouse clicks. The user just selects top-left and bottom-right points, which defines the area of interest which will be scanned. Optionally, the span between two measured points can be set-up, as well as the audio wav file used to excite the instrument during measurement. During the scan procedure, the system displays allready measured points in the color acording to the volume level. A snapshot of the main program window on fig. 7 describes it more clearly. The program was written in Borland C++ Builder [3] and works under MS Windows.

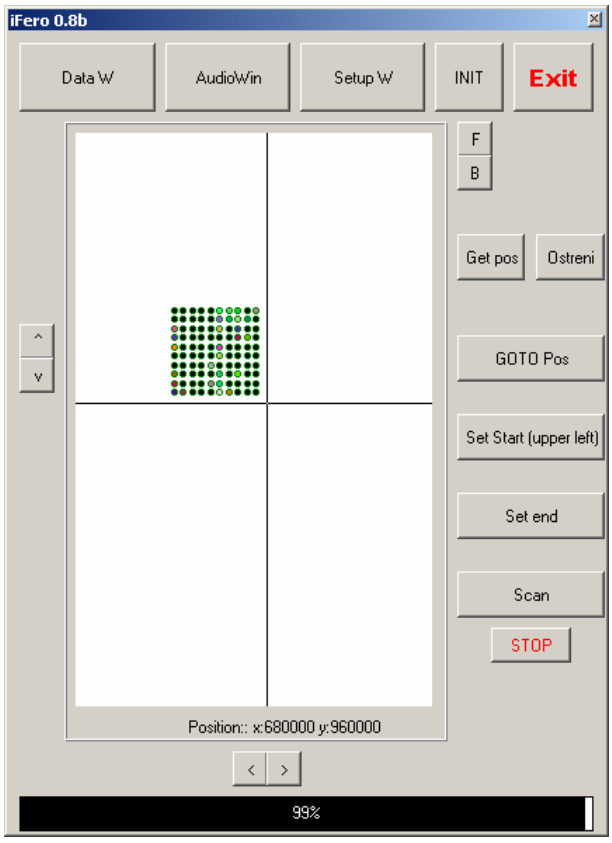

Figure 7. iFero user interface with scanned points

The systems records the responses of all the points into wav files, which are named according to the position of the point (i.e. X700Y500.wav). To analyze such a set of data, we have developed a standalone application, which analyses and displays the measured data set.

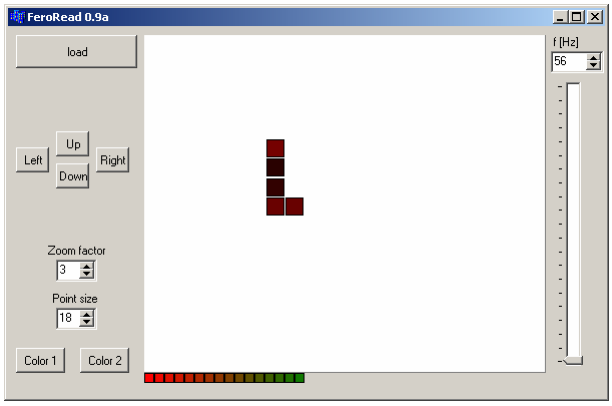

Figure 8. FeroReader - Observing vibrations at 56Hz

First, it decomposes the wav name into the original position, then computes a FFT[1] and display the processed point in a color, which correspons to the amplitude at a certain frequency. The frequency, at which are the points displayed, can be easily changed by the slider on the right side of the window (see figure 8) and allows the scientist to observe the behaviour of the intrument at various frequencies.

The main advantage of our custom-made system is the flexibility. The iFero system allows to choose the sound file to excite the instrument and the responses at each point are saved into wav files, which can be easily read and analysed by numerous third-party software, such as Adobe Audition, MatLab etc. The disadvantage of our system is the same as ESPI system has - it is quite heavy and therefore it is bounded to laboratory.

5. Conclusions

In this paper, we presented a custom-made system to scan the instrument vibrations which was developed at our department. It allows to scan complete 2D plane vibrations and visualise them. Althrough it is not so fast as the ESPI system, it gives the same results and provides more fkexibility.

Besides ESPI, we have compared our system with VIAS with a result that both systems are targetted to other task and research. The advantage of VIAS system is it's mobility, but it does not provide so exact results as the laser interferomerty method.

In near future, we plan to implement more analysis tools, which will work on iFero data sets.

Acknowledgement

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References

[1] Dantec-ettemeyer GmBH homepage, *http://www.dantec-ettemeyer.com/*

[2] VIAS system and IWK (Institutes für Wiener Klangstil) homepage: *http://iwk.mdw.ac.at/*

[3] Borland C++ Builder website. *http://www.borland.com/us/products/cbuilder/index.html*

[4] M1486 step-motor controller. *http://www.microcon.cz/*

[1] Fast Fourier Transformation