Master's Thesis Engineering Technolgy

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UTILIZATION AND OPTIMIZATION OF MICROPHONES FOR VIBRATIONAL AND ACOUSTIC MEASUREMENTS IN A COST-EFFECTIVE DEVICE TO ENHANCE VIOLIN CRAFTSMANSHIP

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SITUATION

This thesis aims to advance the development of a device designed to assist luthiers in assessing the **acoustic properties of violins.** The primary objectives for this device are to ensure it is;

- Accurate - Cost-efficient
- User-friendly - Non-invasive

The experimental **setup** shown in Figure 1 is designed for test with violins, allowing the violin to vibrate with **minimal damping** thanks to the rubber band support.

Figure 1 : Experimental setup

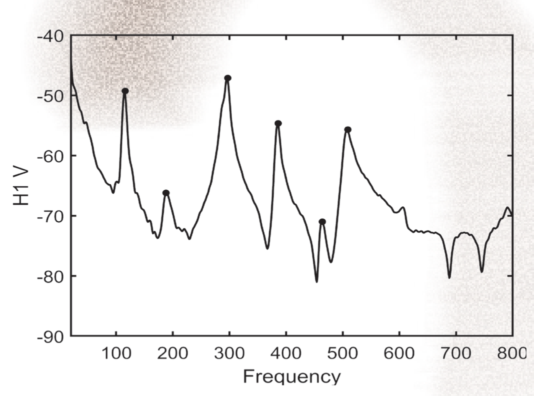

Figure 2 : FRF from left below corner of a violin's backplate

FRF

A **frequency response function (FRF)** is used to identify the **modal frequencies, damping,** and **mode shapes.** The FRF is created by exiting the violin with known frequencies and force [1]. It is a plot in the frequency domain of the responsive motion of the instrument divided by the input force.

In this research, FRF will be used to **evaluate** the device and the **sensors.** Figure 2 displays a FRF generated by the device, where the peaks indicate the mode frequencies.

IMPLEMENTING MICROPHONES

The first prototype of the device used **accelerometers**, attached to the surface of the violin, to measure vibrations. This thesis explores the possibility of using a **microphone** in a **contactless** manner, to cause less damage to the instrument. By examining the characteristics of microphones, including **sensitivity, SNR, frequency response,** and **directivity,** [2] the goal is to determine their suitability for accurately capturing the acoustic properties of the violin. Based on these the **AUM-4537L-HD-R** microphone was selected.

When **inserting** the microphone into the violin during FRF computation a sensitivity higher than **-37dBV**, as the AUM-4537L-HD-R, in a 0-3,3V range can cause **clipping**. For **external uses**, this sensitivity proves to have advantages over less sensitive models and equal performance as the accelerometer in terms of **coherence** and **quality factor**. However, the accelerometer remains less susceptible to **external influences**.

ROOM IMPULSE RESPONSE

When measuring sound in any testing environment, the room will inevitably **influence** the measurements. In addition to capturing the original sound, the microphone also registers its **reflections** from nearby surfaces. This influence is called the **room impulse response** (RIR) [3]. **Dividing** the outcome of the microphone by the RIR in the **time domain** compensates for the influence. To compute the RIR for any given environment a practical test is developed based on the **sine sweep** method using an esp-32 microprocessor. With this fast and user-friendly test, it will be possible to calculate the impact of the room up to **3000 Hz**, sufficient for the FRF calculations.

Figure 3 displays the RIR calculated for a rectangular room measuring 5.5m x 3.4m x 3.3m. The room's influence on the signal fades away after 0.1 seconds.

CONCLUSION

The new method for computing the FRF with the microphone shows **promising** results. Despite the effect of the environment and ambient noise, the mode frequencies were accurately located. Compared with the old accelerometer-based testing method, it causes **less damage** and is more **user-friendly** as it does not require to be attached to the instrument. Additionally, the influence of the RIR can be compensated using the proposed technique. Nonetheless, these testing procedures require further refinement to seamlessly integrate with the device.

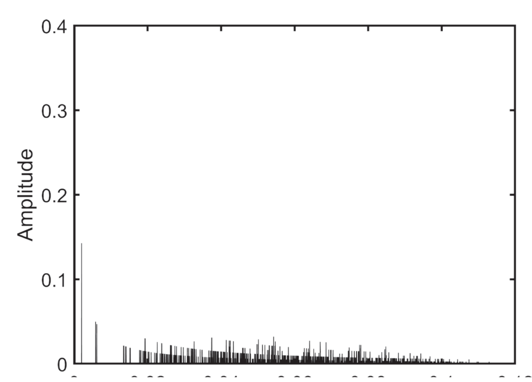

Figure 3 : Room impulse response of a test environment

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[1] Siemens DISW. (2020, Jul 2020). https://community.sw.siemens.com/s/article/what-is-a-frequency-response-function-frf
[2] MIC University. (2020, May 27). Read microphone specifications and understand mic quality.
DPA. https://www.dpamicrophones.com/mic-university/how-to-read-microphone-specifications
[3] R. Stewart. (2007, Sept,10). Statistical measures of early reflections of room impulse responses

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