Wireless monitoring of the internal hygro-thermal variations in a historical violin during playing - Device design and first results

Markus Krüger,
MPA Universität Stuttgart (Hrsg.)

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TABLE OF CONTENTS

WIRELESS MONITORING OF THE INTERNAL HYGRO-THERMAL VARIATIONS IN A HISTORICAL VIOLIN DURING PLAYING - DEVICE DESIGN AND FIRST RESULTS

G. Goli[1], M. Fioravanti[2], L. Busoni[3], A. Giordano[4]

ABSTRACT

In the framework of a research dealing with the conservation of the historical violin "Guarneri del Gesu'" 1743 known as the "Cannone" a set of studies were performed in order to understand the hygro-thermal stress the violin is subjected when played in a concert. These stresses mainly depend on two factors: 1. the difference between the internal display case conditions and the environmental conditions when the instrument is taken out for being played, 2. the interaction between the player and the instrument. In order to understand the hygro-thermal effects produced by a concert on the violin, a monitoring system and method was implemented by measuring the following parameters: (a) the violin mass before and after the concert, (b) the relative humidity and temperature the violin was subjected in the display case before the concert, (c) the environmental conditions outside the display case and the relative humidity and temperature inside the violin body during the whole time spent outside the display case. For the mass measurement precision balance was used, the RH and T inside and outside the display case were monitored by means of environmental probes connected to appropriate data-loggers. In order to measure hygro-thermal variations inside the violin body a special wireless system was developed in order to be acceptable by the musician and not limit his freedom. A first version was realised with two Moteiv "Tmote sky" wireless modules (receiver and transmitter) and by means of a Sensirion SHT75 relative humidity and temperature micro sensor. The wireless receiver was directly plugged into a computer, the transmitter was integrated in a plastic box to be kept in a musician's pocket and the sensor connected via a telephone cable. The sensor was introduced inside the violin through the bore of an empty end button. A second version of the device was implemented by integrating the transmitter inside a "chinrest" in order to be invisible and to be held directly by the violin. In this paper the wireless devices are presented as well as some first results of the performed monitoring.

Keywords

Violin, Guarneri 'del Gesù'; Cannone; Niccolò Paganini, wireless sensors, relative humidity, temperature

1. Introduction

Historic musical instruments are objects with a great value because of several reasons: because the wood they are made is old and a lot of importance is given to this fact by the players, because of the manufacturer, because of the players that have owned and played the violin, because of their sound. Several instruments during their history were largely modified in order to adapt their sound to new trends. These changes (one typical operation was the adaptation of the neck by sawing the old-one and by the insertion of a new-one) were performed because a special value was ascribed to old violins (in terms of old wood and distinctive sound). These instruments, considered by the players and makers as musical instruments instead of a cultural heritage work, in a large number were completely re-adapted. This is not the case of the "Cannone" violin, made in 1743 by Giuseppe Bartolomeo Guarneri "del Gesù" and owned by the great violin player Niccolò Paganini. After Paganini's death the violin, according by his will, was left to the city of Genova, where he was born. This was an important fact for the violin conservation because after Paganini's death the instrument has maintained its own integrity. In the year 2004 an important restoration for the accessories and the set-up was undertaken by the violinmaker and restorer in charge of the violin conservation Bruce Carlson assisted by his colleagues Alberto Giordano and Pio Montanari (AA.VV., 2004). This operation would allow for recovery of the historical image of the "Cannone" as it was when it was bequeathed to the City of Genoa in 1851. Nowadays the "Cannone" is on display in the Paganiniana Collection in

[1] DEISTAF / University of Florence, 50145 Italy, giacomo.goli@poste.it

[2] DEISTAF / University of Florence, 50145 Italy, marco.fioravanti@unifi.it

[3] LBT AdOpt Group, Osservatorio Astrofisico di Arcetri, 50125 Italy, lbusoni@arcetri.astro.it

[4] Violin maker and restaurer, 16123 Italy , info@giordanoviolins.com

Palazzo Tursi, part of the Museums of Strada Nuova located in Genova (IT). As regards more generally wood conservation and especially violins conservation one of the main problems can be considered the physical ageing (Hunt & Gril, 1996) of the material. Physical ageing could be determined by the effects of both moisture variation and mechanical stress, as well as the coupling effects determined by their interaction over time. In order to better understand the hygro-thermal stress the violin is subjected when played in a concert, an experimental campaign was undertaken. The performed measurements were the relative humidity (*RH*) and the temperature (*T*) inside the display case before and after concerts, *RH* and *T* inside the violin and in the environment during concerts and finally the mass of the violin before and after a concert.

2. Material and Methods

2.1 T and RH Monitoring Inside the Display Case

In order to monitor *T* and *RH* inside the display case two Rotronic Hygroclip probes (accuracy ±1%RH, ±0.3°C) were used. For the acquisition a Measurement Computing 12 bits USB board type PMD USB-1208LS set to work between ±1 V in differential mode connected to a PC driven with National Instruments LabVIEW. One sample was collected every 5 minutes.

2.2 Environmental Conditions During Concerts

In order to acquire the environmental conditions a logger type Hobo U10-003 was used presenting the following specifications: T accuracy ± 0.54°C; T resolution 0.1°C at 25°C: RH accuracy: ± 3.5% and RH resolution: 0.07% at 25°C and 30% RH. The acquisition rate was set to 5 seconds.

2.3 T and RH Monitoring Inside the Violin During Concerts

The internal *RH* and *T* of the violin were measured by the means of a purposely implemented device. The reasons to implement this device were: (a) be perceptible as little as possible both for comfort of the player and for safety reasons, (b) adapt a miniaturized *RH* and *T* sensor in order to be introduced inside the violin body without being visible. A wireless approach was then chosen in order to allow: the completion of all the preliminary operations to be performed on the violin (bridge replacement, tuning, etc.) with the sensor inside the instrument without disturbing the player during concerts (classical musician are not used to play with cables around), assure the complete mobility of the player in order to avoid any accident to the violin. In order to assure these requirements a micro sensor and a wireless board were chosen. The measurement sensor was a Sensirion SHT75 (see *Figure 1*) with a resolution of 0.05 % *RH* and 0.01 °C, with an accuracy of ±1.8 % *RH* and ±0.3 °C. The sensor was as little as needed in order to be introduced inside the violin body through the bore of an empty end button (see *Figure 1*).

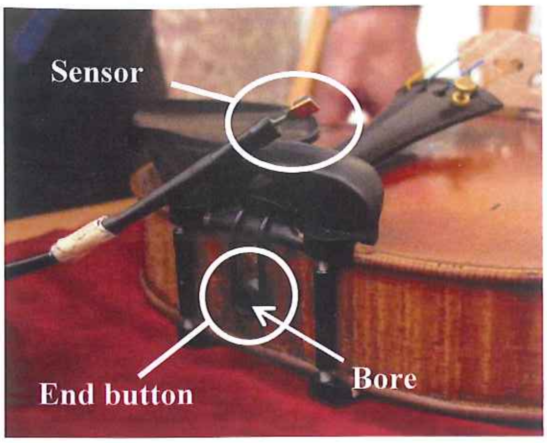

Figure 1 Sensor used for the measurements and end-button bore used to insert the sensor inside the violin

The sensor was acquired and the data transmitted over radio frequency to a PC via two Moteiv Tmote sky radio modules set as transmitter and receiver. Tmote sky radio modules were (actually they are not produced anymore) ultra low power IEEE 802.15.4 compliant wireless sensors modules. The hardware was programmed with TinyOS facilities. The sender module was programmed to acquire and send an averaged set of data every 5 seconds while the base connected to the PC to listen the data that finally were written in an ASCII type file. The program was running on a PC with installed Windows XP pro and emulating a Xubuntu operating system.

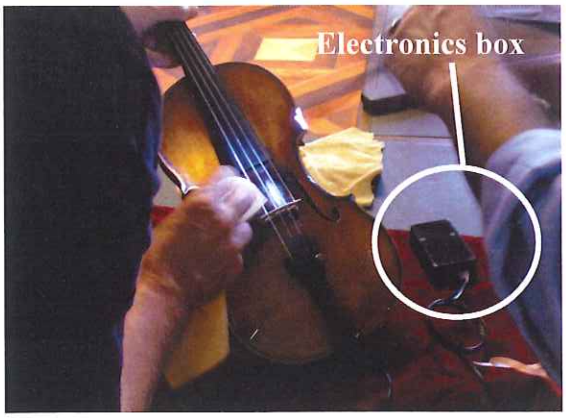

Figure 2 Monitoring during violin cleaning; the plastic box containing the wireless board is visible

The transmitter module was developed in two versions: a first prototype (a) in order to verify the functioning of the whole system with the transmitter adapted to a plastic box (see *Figure 2*), and a final version (b) where the transmitter was integrated inside a chinrest (see *Figure 3* and *Figure 4*). The first prototype was functioning well but within certain limits since the plastic box needed to be fixed to the player and this solution was felt by the player as invasive.

After this first experience the system was customized in order to be inserted into a chinrest and in order to be completely transparent to the player activity. The new chinrest was designed by Mr. Alberto Giordano and produced by the facilities of Bogaro & Clemente. The chinrest was adapted by routing a pocket in order to contain the wireless board and a bore was drilled as well as a cover realized in order to contain a 1/3N 3.0 V Lithium battery. The sensor, connected to the board by a telephone cable, entered inside the violin end button bore of about 50 mm and stayed suspended in the violin centre because of its own stiffness.

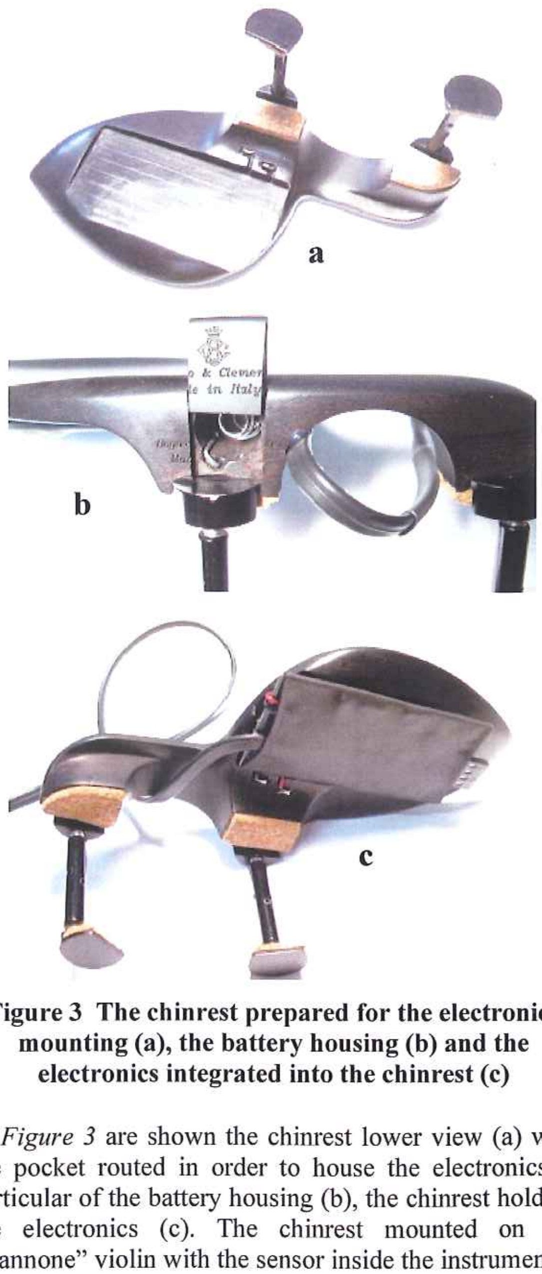

Figure 3 The chinrest prepared for the electronics mounting (a), the battery housing (b) and the electronics integrated into the chinrest (c)

In *Figure 3* are shown the chinrest lower view (a) with the pocket routed in order to house the electronics, a particular of the battery housing (b), the chinrest holding the electronics (c). The chinrest mounted on the "Cannone" violin with the sensor inside the instrument is shown in *Figure 4*.

Figure 4 The chinrest mounted on the violin with the sensor inside the body

3. Results

3.1 Mass variations during concerts

The mass variations during concerts are reported in *Table 1* as well as the average T and RH inside the display case. An average RH of 53,68 % (CV 3,8 %) and an average T of 21,6°C (CV 13,5 %) was measured in the period of the concerts. As it can be observed by the low Coefficient of Variation the dispersion of data around the mean is very limited than an average of the whole period can be reasonably be taken as reference. As it can be noticed the violin mass variations resulting because of a concert are very limited. This is among other reasons mainly connected to the fact that the periods spent by the violin outside the display case were limited (the longer period the violin spent out of the display case was 4 hours as can be observed by the "Time over case" parameter in *Table 1*). One first thing to notice is how the violin mass increases when the *RH* outside the conservation case is higher then inside and decreases when the *RH* outside the conservation case is lower then inside. This could seem obvious but in reality shows that possibly the influence of the player is not very relevant because the general behaviour is very close to the behaviour expected without the player. Apart from this the internal *RH* and *T* measurements could give more details on the role of the player on these phenomena.

If we compare these mass variations that in the worse case are lower than 0.5 g with the whole violin mass being measured 433.18 g, we would notice that these variations are very narrow. If we suppose, according to (Simpson, 1998), the violin to be equilibrated at a 9.4 % EMC, a dry mass of 395.96 g can be computed that corresponds to a variation of moisture content over the dry mass of 0.13 % in a 4 hours period. Even considering one half of the violin dry mass as non exchanging water, because very thick and protected by varnishes, we obtain a variation of moisture content over ½ dry mass of 0.26 % that is still very limited.

3.2 T and RH behaviour during concerts

A total number of 5 concerts were monitored and the internal and external *T* and *RH* recorded. The typical diagram resulting from a concert is reported in *Figure 5*. As it can be observed at the initial phase, when the violin it is not held or played, the *T* and *RH* values inside and outside the violin are very close. As soon as the player gets in contact with the instrument two effects are visible:

- the temperature progressively rise;
- the internal *RH* values get different from the environmental.

Iit is obvious that the temperature increase is due to the contact between the player body and the violin. As it can be observed in *Figure 5* in fact, as the concert starts the temperature begins to rise, possibly with a logarithmic increment, and when the player stops playing and take the violin far from his body for a time period sufficiently long, the temperature decreases.

As regards *RH*, it can be observed that the internal *RH* (as already noticed in *§3.1*) stays between the external *RH* and the *RH* the violin is equilibrated too. This could be because of two main reasons:

- the formation of a particular microclimate;
- the role of the player that insert humidity in the system.

As it can be observed in *Figure 5*, on the internal *RH* line, the moments the player stops playing are very clear. At these moments the internal *RH* drops down. This is possibly because of two main reasons: when the player stops the violin is moved, making easier the air circulation with the exterior where a lower *RH* is measured, because after the player stops playing, consequently he stops to put in humidity and, with a higher T, relative humidity drops down.

Table 1 Environmental (Env.) and violin body internal (Int.) average RH and T measured during some concerts. Δ mass: violin mass variation during concert, Time Over Case (TOC): time spent by the violin out of the display case during the concerts

Date [dd/mm/yy]	Av. Con. T [°C]	Env. T [°C]	Int. T [°C]	Av. Con. RH [%]	Env. RH [%]	Int. RH [%]	Δ mass [g]	TOC [hh:mm]
27/06/2007	21,6	24.2	28.9	53,7	61.1	55.9	+0.38	3:00
22/09/2007	21,6	26.1	29.0	53,7	41.4	45.8	-0.37	2:45
17/10/2007	21,6	24.4	26.8	53,7	42.9	44.2	-0.39	2:00
18/10/2007	21,6	24.4	26.3	53,7	47.4	50.1	-0.25	4:00
23/05/2008	21,6	23.5	26.5	53,7	61.7	54.5	+0.47	3:15

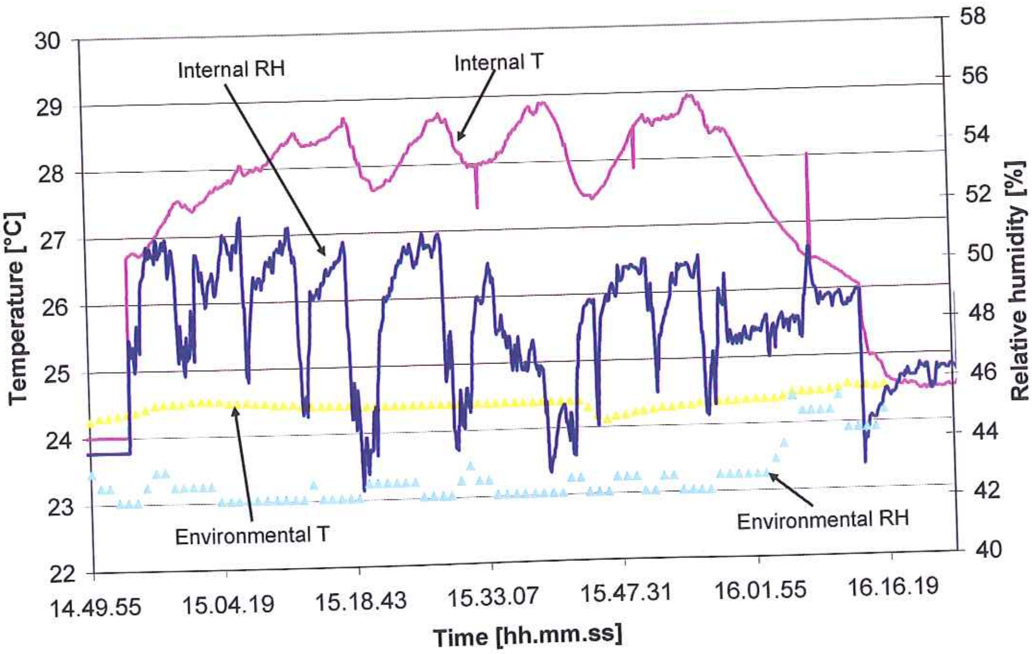

Figure 5 Violin internal and external relative humidity and temperature conditions during concert rehearsal held in Palazzo Tursi in Genova (IT) by Peter Sheppard Skærved on 17 October 2007

3.3 T and RH variations during transport

Another interesting investigation point for violin conservation was the understanding of the impact of moving the violin in different climatic conditions from one place to another inside the transport case. As it can be observed in *Figure 6*, in "*Phase 1*" are shown the values of *RH* and *T* measured by two sensors before one was introduced inside the violin. The *T* and *RH* values in this phase result very close. After the introduction of one sensor inside the violin and of the violin inside the carrying violin case, the internal and external sensors set to different values. In "*Phase 2*" in fact it can be observed how, after having placed the violin inside the carrying case, the violin itself creates its own microclimate very close to the relative humidity it is equilibrated to (about 53,7 %). This condition does not change significantly even during transportation. Finally in "*Phase 4*" it can be observed the opening of the carrying case and how the violin starts again to be influenced by the external conditions.

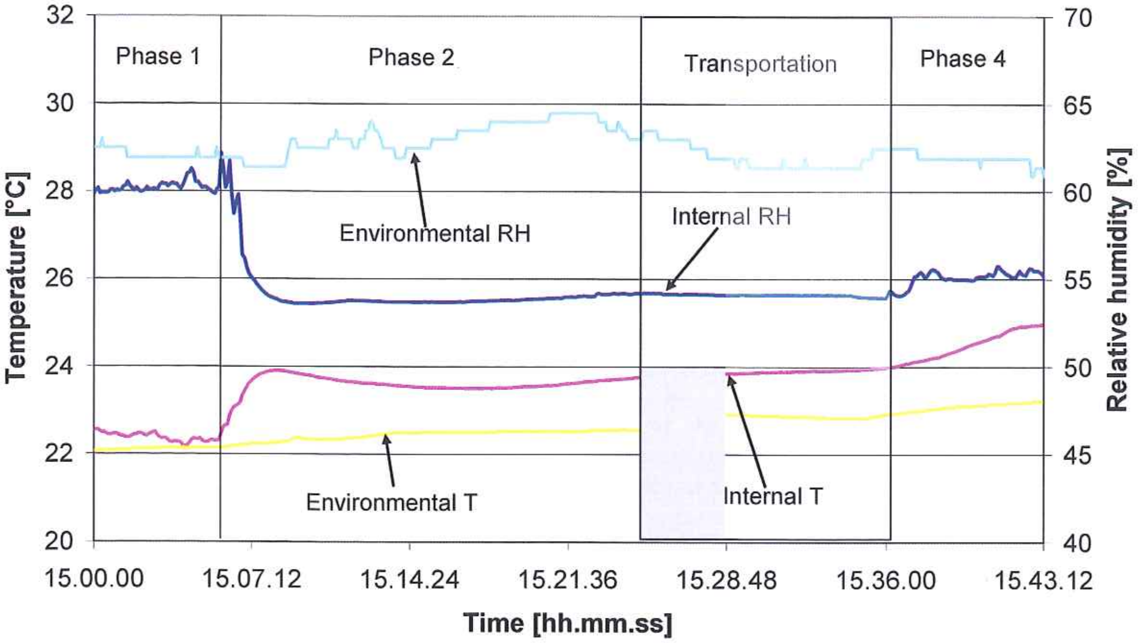

Figure 6 Effect of holding the violin inside the carrying case during transport

4. Conclusions

A complete system for monitoring the hygro-thermal stresses a violin is subjected to, when taken out from the display case and used in a concert, was implemented. In order to develop a system "transparent" to the user a wireless chinrest was developed. The system resulted to be very effective. The violin internal conditions during concerts result to be intermediate between the relative humidity inside the display case and the external environmental conditions during a concert. A thermal effect of the player was highlighted as well as the importance of the input of humidity from the player. The mass variation during concerts resulted to be very limited for a short amount of hours spent by the violin outside the display case. These are the first results that would need to be deeply analysed, in order to better understand if these hygro-thermal variations could result in mechanical stresses, dangerous for the violin conservation.

5. Acknowledgements

We would like to thank the violinmaker and restorer and conservator of the "Cannone" violin Bruce Carlson, the violinmakers and restorers Pio Montanari who assist the conservation of the "Cannone" violin. We would like to thank Dr: Laura Malfatto conservator of the "Cannone", and Dr. Anna Rita Certo both working for Genova Municipality for their cooperation. We would like to thank the violin players Mario Trabucco, Feng Ning, Peter Sheppard Skærved, Salvatore Accardo for having accepted to monitor their performances with the "Cannone" violin. We would like to thank Mr. Danilo Dini for the help in adapting the electronics to the chinrest.

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