WoodMusICK

FPS COST Action FP1302

Multidisciplinary approach to wooden musical instrument identification

Cremona, September 30 – October 1

in collaboration with

Museo del Violino

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Tuesday September 30

9:00	Welcome
9:15	**Karel Moens**, *Limits of empirical research on ancient musical instruments. An epistemological approach.*
9:45	**Carlo Chiesa, Bruce Carlson**, *Violin expertise*
10:15-10:45	break
10:45	***Session 1: Wood identification*** • **Catherine Lavier**, Xavier Guerland, Ulrich Leisinger, *The study of the sounding board of a Jacob Stainer's violin: what kind of contribution can we hope from a dendrometrical approach?* • **Peter L. Ratcliff**, *Dendrochronology, an invaluable tool in the classification of instruments of the violin family.* • **Marco Fioravanti**, Giuseppina Di Giulio, Giovanni Signorini, *Non-invasive approach to wood species identification in historical musical instruments.* • **Maria-Cristina Popescu, Carmen-Mihaela Popescu**, *Near infrared spectroscopy and chemometric methods for wood specie identification.*
12:10-1:00	**Flash talk** : Poster Session – STSM reports
1:00-2:30	lunch
2:30-4:00	***Session 2: Varnish characterization*** • Iaria Bonaduce, Susanna Bracci, Maria Perla Colombini, **Francesca Di Girolamo**, Anna Lluveras Tenorio, **Marianne Odlyha**, *A new multi-faceted analytical approach for improved characterization of varnishes in wooden musical instruments.* • **Jean-Philippe Echard**, *Which method should I use to characterize varnishes on wooden instruments? Which goal am I aiming at?* • **Balthazar Soulier**, *Varnishes characterization for the identification of stringed instruments? Possibilities and limits.* • **Carmen-Mihaela Popescu, Maria-Cristina Popescu**, *Identification of structural differences of some natural resins used as varnishs for wooden instruments.*
4:00-4:30	break
4:30-6:00	***Session 3: Vibro-acoustic characterisation*** • **Jan Tro**, *Tap the wood and define the quality;aspects of measuring techniques of sound radiation from wood and wooden instruments.* • **Jean-Loïc Le Carrou, Sandie Le Conte**, *18th and 19th French harp classification using vibratory analysis.* • **E. Guaus**, T. Ofuk, **M.A. Pérez**, *Playing the unplayable: building the dataset.* • **Claudia Fritz**, Joseph Curtin, Jacques Poitevineau, *Why violins are not authenticated by means of playing tests.*
7:30 9:00	Diner Concert

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Wednesday October 1

9:00-10:30	***Session 4: internal identification*** • **Marco Fioravanti, Gabriele Rossi Rognoni**, P. Gallerini, S. Biagiotti, R. Ricci, I. Menchi, *The application of x-ray ct scanner to the documentation of early musical instruments.* • **Nicola Sodini**, Franco Zanini, Diego Dreossi, Josef Kaiser, Alberto Giordano, *Comparison of different experimental approaches in the tomographic analysis of ancient violins.* • **Robert Howe**, Sina Shahbazmohamadi, Richard Bass, *The use of micro-computed tomography to study the internal architecture of wooden musical instruments*. • **Jan Van den Bulcke**, Denis Van Loo, Manuel Dierick, Matthieu Boone, Bert Masschaele, Kristof Haneca, Koen Deforce, Luc Van Hoorebeke, Joris Van Acker, *Multi-resolution x-ray tomography for research on wooden musical instruments.*
10:30-11:00	break
11:00-11:30	**Eiichi Obataya**, *The ageings of wood*
11:30-1:00	**Session 5: Case study** • **Emanuele Marconi**, *An example of the traditional approach in musical instruments identification as starting point:the case of the Nonemacher's mandolin.* • **Fausto Cacciatori, Marco D'Agostino, Marco Malagodi**, *Study and characterization of Antonio Stradivari's handwritings* • Simon Egan, **Manu Frederickx**, Livine Huart, **Pascale Vandervellen**, *Comparative study of Ruckers instruments*. • **James R. Westbrook**, *Investigative methods for the study of historical guitars:Antonio de Torres, a case study*. • **Daniel Gil de Avalle**, *A missed link in the history of the Spanish guitar B. Campo Guitar 1840 and Dionisio Aguado's tripodium.*
1:00-1:15	Closing
1:15-3:00	lunch
3:00-5:00	MC meeting

Posters:

D. Konopka, M. Kaliske	*Numerical simulation of historical wooden music instruments under mechanical and hygrical loading*
J. V. T. Pölkki	*Local traditional woods and common European luthiery woods for various kantele instruments*
M.Odlyha, C.J. Bergsten, I. Bonaduce, M.P.Colombini, E. Lopez-Fontal, L. Bozec	*Correlation of mechanical behavior with advanced chemical analysis of varnished wood and items used in musical instruments*
M. Sedighi Gilani, T. Kuenniger, D. Mannes, E. Lehmann, F. Schwarze	*From microstructure to micromechanics of varnished wood*
P. Sklavos, S. Andreou, N. B., Dionysios T. G. Katerelos	*Revisiting a unique guitar*
P. Gjerdrum	*Tones and instruments from the forest – cultural and commercial aspect from a Nordic forester's view*
L. Tronchin	*Acoustic analysis on the violin since its conception*
H.Tahvanainen	*Acoustical measurement of a string instrument called kantele with different string terminations*
F. Ablitzer, E. Brasseur, R. Caussé, M. Curtit, F. Cayré, J.P. Dalmont, B. David, N. Desmarais, V. Doutaut, B.Elie, P.Evenno, R. Feron, J.M. Fouilleul, V. Fréour, F. Gautier, J. Gilbert, A. Le Duff	*Innovation and instrument-making: a collaborative approach between workshops and research laboratories*
S. R. Zopf	*The 'Amati inch' -a new approach to the historical design of violin*
M. Zauer, R. Sproßmann, H. Stonjek, A. Wagenführ	*Determination of acoustic properties of electrical bass guitars: development of the neck material*
J. A. Torres	*Introducing modal analysis to luthiers through an experiment without analyzer or transducers*
F. Piasentini, A. Scanavini	*Micro computed x-ray tomography applied to bowed stringed instruments*
A. Nouili, R. Moutou Pitti, T. Delaunay, H. Riahi, E- Fournely, E. Le Clezio	*An identification technique for mechanical characteristics of wood in room temperature*
D. Ridley-Ellis, C.-M. Popescu	*PotenTial for estimating the age of instruments by characterisation of wood properties VIA acoustics*
P. Borysiuk, L. Ciach, A. Jankowska, P. Kozakiewicz, A. Kurowska	*Identification issues of wood in folk and professional music instruments*

STSM Reports:

D. Konopka	*Experimental analysis and numerical simulation of the hygro-mechanical behaviour of historical wooden objects*
M. Frederickx	*Research on Ruckers keyboard instruments at Cité de la Musique Paris*
N. Warneke	*Non-destructive and multidisciplinary methods for the identification of African xylophones in Portuguese collections*
C. Gauvin	*Hygromechanical behaviour of a wooden painted artefact*
S. Doganis	*Evaluating the effect of restoration on wooden recorders by acoustic impedance*

LIMITS OF EMPIRICAL RESEARCH ON ANCIENT MUSICAL INSTRUMENTS.

AN EPISTEMOLOGICAL APPROACH.

Karel Moens, Museum Vleeshuis I Sound of the City, Antwerp, Belgium.

Epistemology is the branch of philosophy concerned with the nature and scope of knowledge. It questions what knowledge is and how it can be acquired.

What do we really know about old musical instruments? What can we know anyway? How much of our "knowledge" is only tradition? What do we only believe? How reliable are our sources?

For some types of musical instruments, those questions are not really problematic.

Among the European instruments, most problems appear on old keyboard instruments and stringed instruments, bowed instruments in particular. The larger the market value of an instrument, the greater the problems relating to attributions.

Often an opinion is clouded by numerous, mostly undocumented interventions in the past, false information as to acquisition and the lack of a reliable frame of reference.

We will define the issue with three cases: An early keyboard instrument, an early viola da gamba and an early violin. Almost everything I discuss in this lecture about these three instruments has already been published earlier by other scholars and by myself. What matters is what we can deduce from those findings, regarding our knowledge of ancient instruments.

The "Geigenwerck“

The first case is the "Geigenwerck“ (MIM, Brussels) attributed to Raymundo Truchado, 1625. Is a unique instrument of its kind. So there is no possibility to compare it with other similar instruments.

There were already doubts about the authenticity shortly after the acquisition by the museum in 1902. Dendrochronology offers no solution, because the original soundboard did not survive. Fifteen years ago, there was a new discussion about the authenticity, after examining the paintings. More than a century after the acquisition, we still don’t have conclusive answers about the authenticity of this instrument.

Viol attributed to Heinrich Ebert

The second case is a small viol attributed to Heinrich Ebert, Venice ca. 1560-70. (MIM Brussels). Dendrochronological analysis argues that the instrument can have been built from 1585 on.

We investigate step by step what elements may contribute to a scientifically founded attribution. In this investigation, we come across so many problems that we are sure about anything, not even that this was originally a viola da gamba.

We encounter similar questions on almost all viola da gambas attributed to makers of the 16th century. These problems are so huge, that we will never get a correct view on the 16th century viola da gamba, unless a systematic and critical verification of all the instruments as historical sources is carried out.

Violin, attributed to Andrea Amati

The third case is a violin, attributed to Andrea Amati, Cremona 1564, in the Ashmolean Museum, Oxford. It should be part of an ensemble of 38 string instruments built for King Charles IX of France.

Until today, no source has been found that would confirm this story. Moreover, there are numerous reasons why we can describe this assertion as extremely unlikely.

The paintings with the arms of Charles IX and the label differ in many ways from those on other instruments that should belong to the same group. For those reasons, the paintings and the label can not be used as an argument to link the instruments to the so-called royal order, or attribute them to Andrea Amati.

Many details point out that the belly probably came from an other instrument. That means that dendrochronology doesn’t offer a solution.

Stylistic characteristics such as the outline, the soundholes, the scrol, the varnish, can not be used as criteria for the attribution of this violin to Andrea Amati, because of the major differences within the group of instruments attributed to Andrea Amati and because of the alterations.

The ultimate question is: do we have in this case the necessary knowledge to conclude that this instrument was built by Andrea Amati? The issue of this violin is exemplary, not only for instruments attributed to Andrea Amati, but for lots of old violins, especially violins attributed to Italian makers.

Conclusion

There is a great need for multidisciplinary research on ancient musical instruments, in particular on old string instruments, in order to create a reliable frame of reference. Without this framework, it is impossible to obtain science-based identifications of ancient musical instruments.

VIOLIN EXPERTISE

Carlo Chiesa, Bruce Carlson

1. Violinmaker, historian, Italy; 2. Violinmaker, restorer, Italy

The goal of violin expertise is to correctly identify the author of any specific musical instrument under examination. Sometimes it is imperfect, and the expert can only suggest the whereabouts and date in which an instrument was most probably made. To say the least, it is a responsibility that is horribly complex and full of pitfalls. In a world where expert knowledge, in any field, is becoming more and more specialized, violin expertise is no exception. It requires substantial training in differentiating between details of form, three dimensional shapes, varnish and wood preparation, and to recognize different construction techniques. A knowledge of materials, their origins and how they can be worked is also indispensable, as well as a knowledge of the historical context within any given school of making developed its characteristic mannerisms.

Expertise must necessarily be based on knowledge of surviving instruments from the past that have come down to our day relatively undisturbed and with a correct label. Obviously, the investigation is greatly simplified when a maker is prolific; when several to many examples can be compared for common features.

In reality, most instruments are no longer in an ideal or original condition and it is necessary for the student of antique instruments to sift through and read beyond the camouflage of modifications, improvements or modernizations that the instrument may have undergone since its construction. In order to do this, a full knowledge of repair and restoration is extremely important. New pieces of wood grafted onto the edges and elsewhere, varnish retouch which conceals damage or complete revarnishing, new ribs, re-cut soundholes are only some of the alterations to watch out for. The out-size instruments have sometimes been cut down or built up accordingly to “standardize” their dimensions to taste of the period or even to individual whim. The redimensioning of the body of an instrument for example, deprives us of a principal characteristic of identification where the outline the instrument is altered.

No matter what the instrument is, the expert must always apply his honest judgment at his or her best. The examination of an instrument must follow a procedure; one is taught to start looking at the back, and only later to continue with the rest. One is taught a method because there is also a logical way to go about the examination of an instrument and to have a qualified mentor or teacher is invaluable. A method also facilitates the memorization of detail instead of randomly perusing an instrument with no fixed system. The back can reveal quite a bit of information, enough at times to be able to arrive at the proper identification of the instrument. Basic features are the outline, wood choice, arching shape, purfling materials and proportions and edgework, corner shapes, tool marks and construction features, varnish appearance and wood treatment.

Another area of prime importance is a knowledge of paper, printing techniques, ink and handwriting which make up the labels we may find inside any given instrument. The label can either confirm or deny what we have already seen upon examining the instrument, but as a rule cannot be taken for granted to identify the author of an item. Nevertheless, at least one instrument per maker ought to exist and ideally, at least two from different sources, or there will usually be no possibility to identify the work of that particular maker.

Obviously, another essential aspect is access or exposure to a large number of fine and characteristic instruments in order to develop and train the eye and the mind. Photographs in a book or an album can help but this is rather an aid to recalling what has already been seen and examined in person.

A JACOB STAINER'S VIOLIN: CONTRIBUTION OF THE STUDY OF THE SOUNDING BOARD

Catherine Lavier (1), Xavier Guerland (2), Ulrich Leisinger (3)

1. LAMS, UMR8220: CNRS-UPMC-University Paris 6, France; 2. Collector, France; 3. International Mozarteum Salzburg Foundation, Research Department, Austria

Introduction

Jacob Stainer (c.1617-1683) was a very famous Austrian “luthier” and an non-Italian one to so known in this artistic craft. His preserved violins seem to be rather rare. His production concerns a little more than 300 musical instruments, always made by himself; and can be divided in three periods (before 1650, until 1667 and until his death). The most famous soloists of XVIIIth c. were in possession of a "Stainer’s". We propose to present a study of one of his violin to appreciate his work.

Methods

This study will be led through tree rings of the sounding board by dendrometrical analysis and by explaining all the specific process form the data taking up to statistical calculations.

Results

The study of visible and preserved tree rings indicate the use of two boards stemming from the same tree. The growth direction is opposite towards the center. The dendrochronological profile is replaced in the third part of the XVIIth century and the biogeographical origin is similar to Tyrolean forests such as Obergurgl sectors. Similarities are observed with other productions as those of Sellas’.

Discussion

This is a current study so the next step will be to interpret these information: results will be done for the symposium, in particular concerning the period of its making, and replacing this violin in the Stainer’s production, in its time and in comparison with Stainer’s contemporaries.

DENDROCHRONOLOGY, AN INVALUABLE TOOL IN THE CLASSIFICATION OF INSTRUMENTS OF THE VIOLIN FAMILY

Peter L.Ratcliff

Dendrochronological Laboratory for Musical Instruments, Hove, United Kingdom

Introduction

One of the aims of the WOODMUSICK project is to investigate the tangible added value element that systematic scientific approach can bring to the world of traditional visual expertise. In the world of instruments from the violin family, a few dealers/experts have, what is often regarded as the final say on the authenticity of an instrument. However, dendrochronological testing is gradually becoming a pre-requisite to many positive authentications. Countless tests have been carried out, on behalf of Musical Instrument auction houses, experts, dealers, players and institutions in order to corroborate or negate authentications. A favourable outcome often becomes an integral part of the instrument's accompanying literature, whereas an adverse result often remains undisclosed, although it cannot be ignored and is always taken into consideration when describing the instrument. Analyses often reveal far more than a date, offering targeted anecdotal information of remarkable worth, suggesting likely wood provenance, but more importantly, confirming relationships with wood from other instruments (Ratcliff 2012, Topham 2000, Beuting 2009) and discovering new ones.

Methods

Over the last 13 years, tree-ring data from thousands of instruments have been accumulated, both from microscopically measured rings, and more recently from high quality digital images. Instruments from all available sources have been analysed, irrespective of attributed maker, country of origin or period, some made as early as the fifteenth century, and as late as the twenty-first, with the aim of compiling as comprehensive a database as possible. This expanding collection of data, increases the likelihood of replicating identical cross-dating results, hence increasing the probability of finding a true match. Statistics are used for the initial cross-matching. One ot the formulae used, based on Baillie and Pilcher's algorithm (Baillie & Pilcher 1793), identifies the level of significance of a correlation between data. Software using B&P's formulae is widely used in dendrochronological laboratories throughout the world, as one of the reliable indicators for true cross matching. Other parameters, including the GLK, or *Gleichläufigkeit*, are also taken into consideration. Comparing matching data graphically should consolidate the statistical results, and confirm a true temporal relationship.

Results

Examining overall results of multiple analyses on instruments, many have been found to fit existing tree-ring patterns from other instruments. The tests have exposed a myriad of inter-correlations between their wood, often proving more significant when their manufacturing location is supposedly related. To summarise overall results of the tests, data can be grouped and categorised based on the level of significance of the cross-correlation. The assumed regional origin of an instrument is not, a priori, a contributing aspect to the classification, but it often proves to fit dendrochronologically with instruments of similar origin and comparable period. According to our data and those of other specialist practitioners, many "groups" can been identified. These often coincide with particular periods of manufacturing within specific schools. Although distinct, they often merge on their periphery. Some cover distinct periods, originating within a fairly short time span, and disappearing equally as fast. This can sometimes be explained within the context of history, economics and regional conflicts. The main categories identified so far have proved to contain, on the whole, instruments from specific areas are:

1) The Cremonese, Venetian, Neapolitan and Roman makers of the 18th century.
2) The French makers of the 18th century.
3) The early English and Dutch makers between about 1650 and 1720 (same category).
4) A variety of European instruments from Germany, Bohemia, England France and Italy made in the nineteenth and 20th century.
5) French instruments, mostly from Mirecourt, from about 1900.

To each of the above clusters of instruments, can be attributed separate general growing locations. Their precise settings are, however not currently known, or been strictly identified with dendrochronological analysis. Whilst accurate wood provenance is mostly still speculative, the clustering of instruments from individual locations resulting from statistical cross-dating is not. A large proportion of the spruce, or other conifers was originally sourced in the Alps. Regional reference chronologies suggest locations towards the east, in Switzerland, right across to the west of Austria. The Jura mountains, along the northern borders of Switzerland, today supplies tonewood, and certainly has done so since about 1900 (Group 5), but no instrument in our database, made much before then reveals any relationship with the wood from that area. Equally, no dendrochronological evidence is currently available, categorically linking specific Italian Alpine forests with the Classical Italian makers. Other identifiable wood sources span across mountainous region of the Czec republic, whilst the Italian Apennines have shown to have been the source of tonewood in the past (Bernabei et al, 2011). More broad-spectrum groups have also been identified, in which woods from instruments from separate countries often appear to share nearby growing location. Such is the case for English, German, Mittenwald instruments as well as some Italians, between about 1720 until the mid 19th century. From then on, a further group becomes predominant (Group 4) linking instruments from many parts of Europe and weakening the clues pointing to possible instrument origin. Wood fitting this cluster, was used extensively in Germany and Bohemia, but evidently exported to other European countries.

Discussion

Instruments attributed to makers from separate schools of making, on the whole, should fit the category they purport to belong to. Whilst they may not necessarily do so, it would have to be regarded as anomalous, in view of extensive current dendrochronological results, were they found to fit a totally separate group to the one they ought to belong to. The desirability of Italian instruments has, over the last 3 centuries, led to countless attempts at faking, re-labelling, and alterations. Many instruments, ascribed to Italian makers, whilst fitting perfectly well within their attributed period of manufacture, have in fact shown strong dendrochronological associations to the exclusive French 18th century category (cat.2). Equally restrictive, the 3rd group, typically encompassing Early Dutch and English makers, often re-establishes the true origins of an instrument. Historians can offer further insight into local business practices, sometimes linked to strict imposed regulations, and weigh out the likelihood, or not, of such wood reaching other places. In most cases, the findings will engender a more critical approach to the stylistic and other details of the instrument, often tipping the balance. One aspect that cannot be altered or copied is the tree-ring pattern, although some violins are now produced using wood old enough to fit with the style of the instrument copied, which may indeed cause problems. Extensive research on instruments by Antonio Stradivari, has revealed that many of his instruments were made using wood from a single log. So far, 16 violins, made between 1695 and 1705, fit the pattern. Many of his other instruments find twins amongst contemporary production. Equally, comprehensive research of the extant production of Andrea Amati, found that 5 out of 13 instruments were made with wood from a single log (Ratcliff 2012). Several other case studies, some contentious, have often brought a conclusion to age old disputes thanks to dendrochronological analysis. Although powerful, the indications provided by dendrochronological results must not be exaggerated, nor misinterpreted. A “same tree match”, whilst exciting must not be extrapolated and does not ever necessarily signify “same maker”. Our database contains data from 3 violin bellies originating within the same tree, one made in Cremona in 1742, one in Venice contemporaneously, the last one in Madrid, about 25 years later (Ratcliff, 2014). That particular case, involving a foreign violin is however, so far, unique.

Conclusion

As more instruments are tested, the specificity of the categories identified above becomes increasingly apparent, especially in the case of instruments of the 17th and 18th centuries. In the minefield that is musical instrument identification, dendrochronology offers a unique and revealing scientific tool, helping experts towards a true and unbiased assessment.

Acknowledgements

Thanks are particularly extended to John Topham and Micha Beuting, both esteemed colleagues, with whom ongoing discussions further our mutual knowledge and understanding of Dendrochronological findings.

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NON-INVASIVE APPROACH TO WOOD SPECIES IDENTIFICATION IN HISTORICAL MUSICAL INSTRUMENTS

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Introduction

Historical musical instruments represent one of the highest expression of processes in which the technological knowledge are constructed through the tangible and intangible production sorted out and selected during the time in same social and cultural reality.
This view bring to consider the technological skills acquired by the Old masters as a body of knowledge, that have been maintained by local communities through complex interaction with the natural environment, and that represents the results of a processes where the technological solution adopted were continuously assessed and revisited before to be transmitted to the future.
Wooden musical instruments can be also see as a repository of these information that need to be re-interpret through a technological observation. In these studies crucial steps are represented by the observation of object's structural assembling, by the assessment of working techniques and working tolls used, and in particular by the identification of the wood specie that represents either an important source of knowledge on the technological development in ancient or more recent past, either an useful support to the identification of the old instruments.

Materials and methods

A group of 133 historical musical instruments of European origin have been studied with the aim of identifying the wood species employed.

The group represents part of the collection of the "Luigi Cherubini" Conservatory of Florence, preserved at the Galleria dell'Accademia museum.

The identification has been carried out for every visible part of the instruments. They have been selected inside the three categories of bowed stringed instruments, plucked string instruments and keyboard instruments. Some piano mechanics have also been studied.
Because of the high historical and cultural value of the artefacts, the wood has not been analysed using invasive methods of identification, nevertheless a simple macroscopic identification of wood through naked eye or lens has resulted unsuitable, for the difficulty of studying the wood through varnishes, paint and patina and for the very small amount of anatomical features visible at this level.

Bowed stringed (91)	***Plucked string (23)***	***Keyboard (11)***	***Piano mechanics (8)***
Violin (29)	Guitar (6)	Spinet (4)	Models (7)
Bow (21)	Cymbalon (4)	Hurdy gurdy (3)	Real
Viola (17)	Mandola (3)	Harpsichord (2)	
Violoncello (9)	Mandolin (3)	Piano (2)	
Tenor violin (6)	Cittern (3)		
Double bass (5)	Chitarrone (2)		
Rebec (2)	Bass mandolin		
Kit violin	Lyre guitar		
Marine trumpet			

Table 1: Historical musical instruments object of this study.

The *in situ* observation was carried out by means of two portable digital microscopes with different magnifying levels, one of which is equipped with polarized light which facilitates the observation of the wood structure when it is covered with transparent paint. The portable microscopes were used basing on the necessity to study the wood tissue (lower magnification), or the anatomic features of wood (higher magnification with polarized light). These two instruments were the most used in this study, due to their versatility and their ability to capture images and store them in the computer.

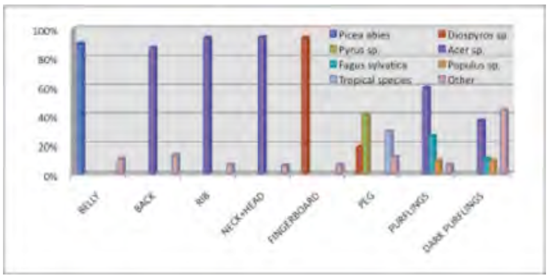
Another instrument that has been used is the microtomography in phase contrast mood from syncrotrone light, applied to eight bows.

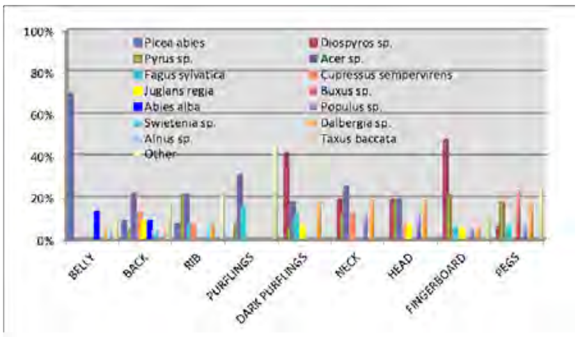
Results and discussion

The identification was done for every single visible part of the musical instruments. For the identification of the wood species macroscopic features such as veining and colour were used at first, whereas anatomical characters observable at the magnification levels allowed by the instruments used or by the quality of the surfaces were used subsequently. In transverse sections arrangement of vessels and parenchyma, size of rays, resin canals and fake growth rings were visible. In longitudinal sections rays cellular composition, width and height of rays, storied structures, prismatic crystals, arrangement of large intervessel pits, kind of perforation plates, helical thickenings, tyloses and deposits in vessels, axial and radial resin canals, bordered pits and axial parenchyma cells with coloured deposits were visible.

In almost 6000 observations, 8% gave no results. This happened due to the presence of dyes that alter the natural colour of the wood and of thick layers of varnish that make it practically impossible to see the structure of the underlying wood. Moreover, we must add that some parts of the instruments were not accessible or difficult to observe.

The study has given the following results: Spruce (*Picea abies* Karst.) mainly in belly. Cypress (*Cupressus sempervirens* L.) in the soundboard and case of most keyboard instruments and in the back of some plucked string instruments. Maple (*Acer* sp.) in back, ribs, neck, head, light and dark purflings mainly on bowed stringed instruments. Pear (*Pyrus* sp.) in pegs, keys and jacks. European boxwood (*Buxus sempervirens* L.) in pegs and keys. Jujube (*Ziziphus jujuba* Mill.) in pegs and in a Harpsichord lid. European beech (*Fagus sylvatica* L.) in purflings. Ebony (*Diospyros* sp.) in pegs, fingerboards and black keys. Rosewood (*Dalbergia* sp.) in pegs, neck and head of some plucked string instruments (See figures below).





Alongside these species, which can be considered the most typical in making of musical instruments, there were some exceptions worth citing. For example, in a Viola the belly was of Douglas fir (*Pseudotsuga menziesii* Franco) and in two rebecs it was made of Poplar wood (*Populus* sp.). In the first case the reason for the use of such species is due to the experimental character of the instrument, that had also the back made of Pear wood. In the second case, the reason of the choice of the wood was that the instruments were not built to be played, but just as an aesthetical object. Other particular wood species found in the instruments were: Yew (*Taxus baccata* L.) for the back of two plucked string instruments. Kingwood (*Dalbergia cearensis* Ducke) and Andira rosso (*Andira coriacea* Poulle), two variegated species, were instead used as marquetry on the case of an harpsichord.

The bows of the collection deserve particular attention: these artefacts consist of a stick obtained generally from the wood of certain exotic species coming from South America chosen for their physical features. The identification of these objects posed some problems because these species are best identified through examination of their cross section, in fact, the arragement of parenchyma and vessels is crucial. Through 3D post processing of Microtomographic slices there was the possibility to analyze clearly the three sections and, moreover, due to their higher density, crystals become clearly visible inside the wood matrix. The micro-tomographic study gave the following identification results: four sticks were made of Massaranduba (*Manilkara bidentata* (A. DC.) A. Chev.), three were made of Snakewood (*Brosimum guianense* (Aubl.) Huber) and one of Brazilwood (*Caesalpinia echinata* Lam.).

Referces

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NEAR INFRARED SPECTROSCOPY AND CHEMOMETRIC METHODS FOR WOOD SPECIE IDENTIFICATION

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Introduction

Wood is a natural composite material which has found over time application in varios domains, from fuel to construction or decorative objects. As a constitutive material of musical instruments, this plays an important role in their design and contributes to their behaviour and cultural identity. There are many types of wood used to make musical instruments. In this field, an esential aspect is represented by the acustic response, but also mechanical response, physical stability, visual aesthetics and/or tactile propetries are important properties which are required. Due to the very different sound qualities of each type, different kinds of instruments can be made for different kind of wood.

The knowledge of the wood structure in this context is very important in identification of materials used for musical instruments construction.

Near infrared (NIR) spectroscopy, because of its low cost instrumentation and little or no sample preparation is applicable to process monitoring and quality control evaluations. Changes in chemical composition, morphology or physico-chemical properties of materials such as wood will therefore cause spectral changes in diffusely reflected near infrared radiation. Multiple chemical absorptions considerably affect the shape of NIR spectra and lead to effects such as shifts and baseline offset. NIR spectroscopy has been shown to be versatile in the non-destructive evaluation of various wood species stiffness [Meder, 2002] and structural changes during thermal treatment [Schwanninger, 2004; Popescu, 2013] and/or biodegradation [Ferraz, 2004].

In the present study, eight wood species were investigated by NIR spectroscopy and chemometric methods in order to evidence the structural/morphological differences between them.

Materials and methods

Blocs of eight wood species – fir, hornbeam, cherry, beech, walnut, maple, poplar and oak - were selected for characterisation.

NIR spectra were recorded by means of a PHAZIR Handheld Near-Infrared Analyzer (Thermo Fisher Scientific – Portable Optical Analysis) in the spectral range 1100–2600 nm by diffuse reflectance method. Processing of the spectra was performed using the Grams 9.1 program (Thermo Fisher Scientific).

Principal component analysis (PCA) is a multivariate statistical technique used for extraction and interpretation of the systematic variance in a data set. The underlying idea in PCA modeling is to replace a complex multi-dimensional data set (e.g. spectroscopic data) by a simplified version involving fewer dimensions (principal components (PCs) or factors), but still fitting the original data closely enough to be regarded as a good approximation [Seyferth, 1994]. One of the many outputs from PCA analysis is represented by the "loadings plot". These are calculated per PC and indicate which variables (wavelength) contribute to the variance explained by that particular PC.

Results and discusions

The physical, mechanical and chemical properties of wood are strongly influenced by the arangement and amount of constitutive components (cellulose, lignin, hemicelluloses) in the wood structure.

In the NIR region, due to the broad and highly-overlapped bands, the correlation between the spectra and structure is more difficult to establish than in the mid-IR region. However, this method presents a combination of advantages like speed, simplicity of sample preparation, easy usage, non-destructiveness and good reproducibility. NIR spectral bands are assigned to first and second vibrational overtones of different chemical bonds.

In order to evaluate the spectral diferences usualy the second derivative of these spectra are used. In Figure 1 the second derivative of the NIR spectra of wood samples are presented.

Spectral diferences are in good agrement with lignin, hemicellulose and cellulose content of wood species. Therefore, the bands located at 1170 nm assigned to 2^{nd} overtone of assimetric stretching of C-H and HC=CH groups, 1677 nm assigned to 1^{st} overtone of stretching vibration of C_{ar}-H groups, 1720 nm assigned to 1^{st} ovetrone of stretching vibration of C-H groups, 2134 nm assigned to stretching vibration of C_{ar}-H and C=C bond and 2267 nm assigned to stretching vibration of O-H and C-O bonds from lignin decrease in order: fir, poplar, maple, hornbeam, beech, walnut, cherry and oak. The lignin contents for these wood species are in the interval of 25-17 % [Popescu, 2011].

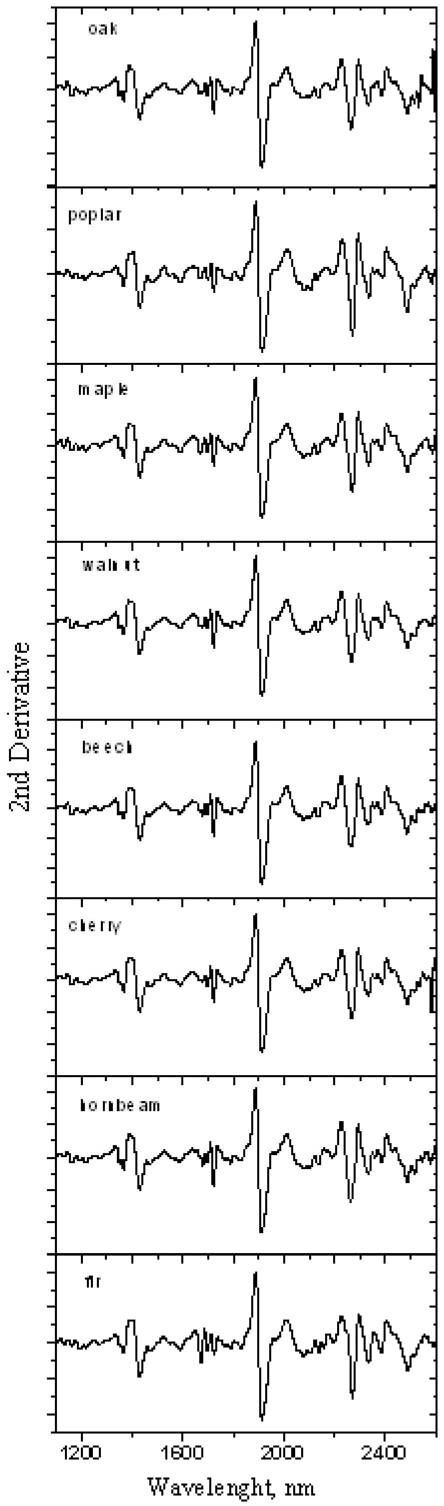

Figure 1: 2nd derivative of NIR spectra of diferent wood species

The bands at 1350 nm assigned to 1st overtone of stretching and deformation vibration of C-H bonds from CH_3 groups in acetyl ester groups in hemicelluloses, 1665 nm assigned to 1st overone of stretching vibration of C-H bond from CH_3 groups, 1710 nm assigned to 1st overtone of stretching vibration of C-H groups from furanose or pyranose due to hemicelluloses and 2332 nm assigned to stretching and deformation vibration of C-H groups from hemicelluloses and xylan vary also in acordance with the content of these components in wood structure in the order: poplar, oak, beech, maple, hornbeam, cherry and fir [Popescu, 2011].

In order to classify the wood species after the chemical composition, PCA analysis was used.

The principal component analysis (PCA) is a well-established technique in statistics and chemometrics, which gives a precise mathematical estimation of changes along the object and variable vectors. PCA is the data mining method which reduces data dimensionality by redefining the axes, so that they correspond with the directions of most variances, where these new axes or principal components (PCs) correspond with the eigenvectors of the original data's covariance matrix. By converting the data into the dimensionally reduced PCA space, the input data set is decomposed into two matrices of interest: scores and loadings. The loadings matrix defines the new axes of the dimensionally reduced data set, while the scores matrix describes the samples in the PC space. The use of a multivariate analysis with polymer systems has been limited. With PCA, the most important features of the NIR spectra can be identified, and the peak shifts and non-symmetries in the peaks between the samples can be quickly determined.

The PC1 (principal component factor 1) describes 93% and PC2 (principal component factor 2) 4% of data variance of PCA scores plot of the wood samples based on the NIR spectra.

PC1 is the most informative latent variable for the description of the structural deferences between wood samples. Therefore, the wood with higher content of lignin have negative scores on PC1 and those with lower lignin content have pozitive score on PC1.

The spectra are separated also on PC2. The spectra of wood species with low degree of crystalinity show negative PC2 score, while those with high degree of crystalinity have positive PC2 score.

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A NEW MULTI-FACETED ANALYTICAL APPROACH FOR IMPROVED CHARACTERIZATION OF VARNISHES IN WOODEN MUSICAL INSTRUMENTS

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Introduction

Due to the multi- material, multi-layered nature of the varnish layers applied wooden musical instruments, a multi-analytical and multi-methodological approach is needed in order to achieve a detailed knowledge on the materials and techniques used to varnish the instrument. The protocols to be applied should involve the identification of the physicochemical state of the varnish and the origins of the materials used in its preparation. A multi-analytical approach for the identification of the organic and inorganic compounds that form these layers has been already successfully proposed and applied in the literature [Echard, 2007, Echard, 2008; Echard, 2010].

Discussion

To solve essential issues about the manufacture of a musical instrument, including its attribution to a specific workshop, requires the collection of a wide body of data on varnishes from musical wooden instruments produced by known workshops, and defined geographical areas and periods. To this aim we propose as a useful approach the combination of the acquisition and subsequent comparison of data at two different levels.

The first level involves the micro destructive analysis of varnish fragments for the unequivocal identification of the materials present. In particular organic materials are the most challenging ones, given the fact that several organic materials can be present in a varnish layer and these are degraded by human processing first and ageing afterwards. A GC-MS procedure is applied to the same micro-sample to determine glycerolipids, natural waxes, terpenoid resins, proteinaceous and polysaccharide materials, overcoming interferences from inorganic media simultaneously present [Lluveras 2010].

For the identification of organic colorants, such as anthraquinones or dragon's blood, protocols have been optimized for the extraction of the organic colorants from the sample matrix to be analysed by LC-MS-MS [Degano, 2009].

As far as several layers are applied with different functions to the wood, imaging techniques should be added to the array of analyses to be performed in order to determine the distribution of the materials identified by destructive techniques in the sample build-up. The emergence of innovative micro-analytical imaging constantly expanding techniques, sets the conservation science in a key moment for their exploitation and consequent widening of the knowledge obtained until now. The use of Synchrotron Radiation (SR) based techniques allows the resolution necessary to map the different materials. Principally, the use of UV multispectral luminescence microimaging together with the FTIR will allow to establish the distribution of organic materials while micro XRF and micro XRD would allow identifying and determining the distribution of the inorganic materials and their function in the sample layers. The use of micro tomography can also be explored. Preliminary analyses on samples from instruments have already demonstrated the capabilities of SR based techniques to determine the structure and function of the materials in the varnishes build-up [Thoury, 2011; Bertrand, 2011].

Preliminary investigations have also demonstrated that imaging using atomic force microscopy (AFM) can be performed in situ on varnished wood surfaces [Modugn, 2011]. The small portable system that was used (Nanosurf EasyScan 2 AFM) allowed in situ imaging. The state of the varnish may clearly affect the sound properties and it is proposed to investigate this aspect. In addition, where possible, measurements of localized glass transition temperatures can be made using nanothermal analysis. This operates in a similar way to AFM but uses a heated tip which allows measurements of the glass transition temperature (Tg) of the varnish. The value of Tg will provide an indication of the physicochemical state of the varnish. The extent of crosslinking of the varnish, would have the capacity of making the wood tighter and harder, and improve the sound quality [Nagyvary, 2005]. At this stage non-invasive measurements have been performed on model varnish samples prepared in the MEMORI (Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets) project where the effect of volatile organic acids on the Tg of the varish films has been investigated [Dahlin, 2013].

The second level of analyses to be performed on varnishes of wooden musical instruments involves the use of non destructive portable techniques [ICVBCmobile-http://nuovo.icvbc.cnr.it/mobile/] . This includes imaging techniques (such as visible light photography, IR photography, IR false color, UV fluorescence, light induced luminescence, IR thermography, 3D take-over, Portable Digital Microscope) and single spot techniques (such as Colorimetry, X-ray fluorescence (XRF), TR FTIR reflectance infrared spectroscopy, Raman spectroscopy, Fiber Optic Reflectance spectroscopy FORS). These techniques, although alone can give less detailed information on the complete organic and inorganic composition of a varnish of a wooden musical instrument, could be combined with the invasive techniques for the charaterisation of varnishes from musical wooden instruments produced by known workshops, and defined geographical areas and periods. This approach would allow us to build a huge database rich of information which could be of great help in the understanding the manufacture of varnished wooden musical instruments. A statistical treatment of the data obtained by this way could highlight similarities between manufacturers and differences between workshops as well as allow relating the material evolution with time.

This two-step multi-analytical combined approach can be used to establish the materials used in the production of varnished wood instruments as well as their use and application and, thanks to the portable instrumentation, to extrapolate the data to a large number of instruments. The final goal would be to highlight and provide evidence of differences between workshops, areas and eras as well as to relate them to the technical treatises and the physical properties of the instruments for a complete understanding of the art of instrument making.

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WHICH METHODS SHOULD I USE TO CHARACTERIZE VARNISHES ON WOODEN INSTRUMENTS? WHICH GOAL AM I AIMING AT?

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Introduction

For the last 150 years, the composition of varnishes of historical musical instruments –uttermostly of Cremonese violins– have been analyzed using various methods. Bruce Tai and I had independently reviewed in 2007 the various approaches and methods used until then [Tai, 2007 ; Echard et al, 2008]. The goals of the present paper are (a) to review the quite numerous and important works that have been published since, some of them relying on major technological breakthroughs in terms of analytical methods available ; (b) to present and discuss the goals that the researchers are aiming at, when performing such analyses.

Review of methods recently used

Conventional separative methods, such as Gas Chromatography coupled to Mass Spectrometry (GC-MS), or with pyrolyser interface (Py/GC-MS), still represent the key methods for the identification of individual molecules and molecular fingerprints from minute samples [Bertrand et al, 2011 ; Echard et al, 2010a ; Soulier et al, 2012 ; Caruso et al, 2014]. However, such methods are still mostly used in a qualitative way. Recent work in our group have studied the drying/curing of modern "binary" mixtures of linseed oil and *Pinaceae* resin in different and known proportions using Py/GC-MS [Lattuati-Derieux et al, 2014]. This study seems to indicate that the oil/resin ratio has a strong influence on the relative evolution of fatty acids and diterpenoids signals at same ageing time, in the same conditions. It gives clear indications on the ability of the method to retrieve the oil/resin ratio of aged historical samples, and to compare it to historical written sources [Echard et al, 2014 in press].

X-Ray Fluorescence Spectrometry (XRF), that had been initiated on micro samples [von Bohlen, 1997] and, later, in situ on violins using mobile spectrometers [Echard, 2004], was more frequently used, benefiting from the development of handheld equipments [Caruso et al, 2012]. Contrary to what is now done on easel paintings, the spatial distribution of elements on the coating of a musical instrument has not –but once– been imaged using raster-scanning XRF [Muller et al, 2008].

The century-old observation and photography of UV-induced visible fluorescence is still frequently used [Brandmair et al. 2010, Malagodi et al. 2012]. Even if it allows to distinguish some binding media and retouches, this method still suffers from several limitations, the main of which being the lack of standardized and spectrally-calibrated methods. This prevents this approach to allow for efficient inter-instruments comparisons of the observations and images obtained by different research groups.

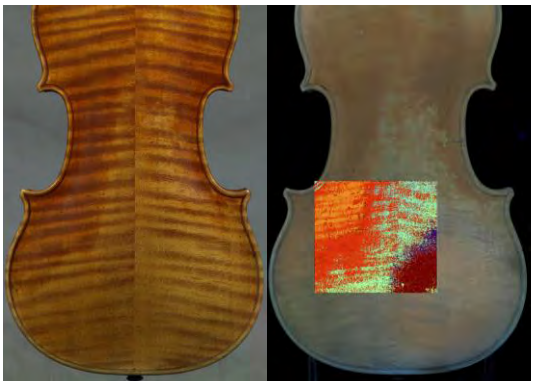

Figure 1: The 'Provigny' violin (A. Stradivari, 1716, coll. Musée de la musique, *E.1730) under visible (left) and UV-rich (right) light. The false-color insert on the right is the result of a segmentation algorithm of luminescence multispectral imaging data, towards an improved discrimination of some retouch materials, barely noticeable in the UV photograph.*

A major breakthrough for our field was the implementation of in situ spot spectroscopies and 2D spectral imaging (multispectral and hyperspectral) to cultural heritage artifacts. Following-up several advances of his partners [Daher et al, 2010 ; Thoury et al, 2011a], and preliminary works in the *Musée*'s laboratory (Fig. 1) on these subjects, the *Musée de la musique* is currently leading an on-going French PNRCC research program on in situ characterisation of organic coatings of historical violins. The complementary investigated methods include, among others, in situ reflectance mid-IR spectroscopy and reflectance and luminescence multispectral imaging. For the latter, a dedicated acquisition set-up and post-treatment algorithms were developed [Simon-Chane et al, 2014 submitted].

At the micro-scale, a complete Stradivari varnish cross section was analyzed using luminescence multispectral imaging, where the excitation light was obtained from a highly-monochromatic tunable synchrotron source [Thoury et al, 2011b]. More recent developments using this method allowed obtaining chemical imaging of varnish cross sections at a submicrometer scale, providing an alternative method to determine the compound class of each varnish stratum [Echard et al, 2014 in preparation]. More conventional, but not frequently used, is mid-IR microspectroscopy [Echard et al, 2010a]. It is frequently difficult to retrieve from mid-IR spectra the individual ingredients of the varnish, especially in oil-based varnishes, or containing several resins [Daher et al, 2010]. In raster-scanning or imaging modes, on carefully prepared cross sections (microtomed or polished), this method allows to localize and characterize both organic and inorganic compounds in a single acquisition on one cross section sample [Bertrand et al, 2011 ; Soulier et al, 2012]. Finally, we have recently investigated the potentials of 3D non-linear microscopy methods that are today developed for biomedical applications. The first results obtained on model multi-layers coatings on wood are promising: 3D mapping of lake pigments, binder, fillers, as well as lignin and crystalline cellulose in the wood [Latour et al, 2012].

How relevant the approach?

The aim frequently invoked for analytical works on musical instruments varnishes is the search for the ingredients used by the “Old Masters”. However – and whatever the quality of the analytical method– the representativity of the analyzed material often seems neglected or forgotten. These centuries-old instruments have been maintained, restored and retouched several times, and experts/organologists should definitely be included in the research team to help selecting, on historically-relevant and well documented instruments, analysis spot or sampling areas that have been as little modified as possible since the first varnishing of the instrument [Echard et al, 2010b]. Also, the characterization of the ingredients represents only a small fraction of the information contained in historical varnishes: using a dedicated multi-analytical sequence, it is quite easy to access the number and thickness of strata, the finishing state of the wood before varnishing, the penetration of the first layer into the wood pores, the nature of mineral particles, etc [Echard et al, 2010a]. This approach allowed the study of several tens of European 16^{th}-18^{th}-c. varnishes of instruments of the *Musée de la musique* collection, which led to first indications of regional practices, in particular on the nature of the ground layer [Echard, 2010].

Conclusion

First applications of 2D and 3D chemical imaging methods –developed in the last decade– should pave the way for promising and exciting new technical ways to better characterize historical varnishes in musical instruments: better spatial resolution, better spectral/chemical contrasting and identifications, better knowledge on preparation (purification, boiling temperature, use of solvent, rheology) and ageing conditions of these varnishes. However, any of such analyses ought to be performed in order to be useful to meet the expectations of the various communities interested in the results.

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VARNISHES CHARACTERISATION FOR THE IDENTIFICATION OF STRINGED INSTRUMENTS? POSSIBILITIES AND LIMITS

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As early as the 17th century, lute and violin varnishes were (unlike varnishes on furniture and paintings) regarded as an integral part of the original instruments, hence worthy of preservation. As a result, most old violins retain at least part of their original varnish.

In recent years multidisciplinary scientific investigations on a large group of instruments have obtained significant new findings. A complementary array of analytical tools (such as light microscopy, infrared spectroscopy as well as gas and liquidchromatography) was applied to determine the structure and the chemical composition of the coats. The results provide new information on the materials that were used by the Masters, with a detailed characterization of the stratigraphy of the coatings. These natural scientific findings allow recognition of distinctive varnishes from diverse lutherie centre.

A two-layer system has been generally established: a ground layer that fills the upper wood cells, and the actual varnish. Italian instruments, from 16th-century lutes to Stradivari violins, reveal an oil-resin-based ground. Instruments from north of the Alps generally show a glue-based ground. Mineral particles have been largely ruled out as main constituents of the ground layer. The actual varnish consists, before the mid-18th century, fundamentally of mixtures of drying oil and resins of the pine family. From a chemical perspective, the main differences among historical instrument varnishes (except the ground layer) reside in the colouring system. While Italian Renaissance lute makers and early luthiers from the north of the Alps coloured their red varnishes with soluble colourants or highly heated resins, Cremonese and Venetians luthiers of the 17th and 18th centuries used very fine crimson lake pigments mixed with inorganic red pigments.

The possibilities and limits of the scientific characterization of varnishes for the identification of historical stringed instruments will be discussed.

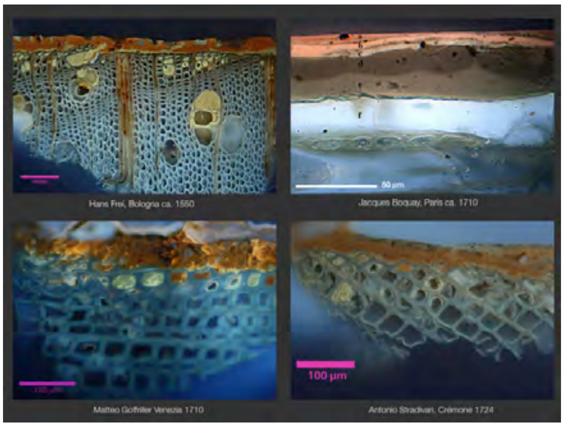

Figure 1: Cross sections of historical varnishes under UV-illumination.

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IDENTIFICATION OF STUCTURAL DIFFERENCES OF SOME NATURAL RESINS USED AS VARNISHES FOR WOODEN INSTRUMENTS

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Introduction

Generally, wooden musical instruments are coated by a varnish, a transparent layer which represents a sensitive interface between wooden material and environment and acts mostly as a protective layer, but also as a modifying agent of the visual aspect. It is usually composed by several successive layers with a very complex structure, consisting mainly in organic compounds, sometimes mixed with inorganic matter [Echard, 2008; Bertrand, 2011]. The study of these "structures" is important from the point of view of restoration and preservation of historic instruments, but also provides unique information on the original technique and further degradation of the original materials.

If in the case of the paintings, sometimes the degraded and very old varnish can be removed and renewed if necessary, the varnish from the instruments is considered as an original part of it and cannot be removed or changed. In order to preserve and to understand the original materials used as varnishes, it is necessary to study and evaluate the chemical composition of them. The organic part of the varnishes was mostly composed by natural products such as: tree resins and gums, insect resins, oils, dyes, proteins or/and polysaccharides used alone or mixed between them. The instrument-makers distinguish three classes of varnishes: oil varnishes (different resins mixed with siccative oils); essential oil varnishes (different resins mixed with volatile oils) and spirit varnishes (different resins mixed in alcohols). The siccative oils more often used were linseed and walnut oils, volatile oils were turpentine and spike oils, while the resins or gums used presented a large variety including: colophony, sandarac, copal, mastic, elemi, dammar – diterpenic and triterpenic tree resins and shellac – insect resin, etc. [Echard, 2008]. Difference in their chemical composition may be obvious (through the presence of one or more specific compound) or fine (only the amount of the compounds vary). At the same time drying and ageing of the varnish induce important changes in the composition, particularly through oxidation processes, and generally tend to make the positive identification of a specific resin more difficult.

In both cases the identification of the chemical composition of varnishes is carried out using different analytical methods [Domenech-Carbo, 1996; Burgio, 2001; Colombini, 2000; Osete-Cortina, 2005; Nevin, 2009].

In order to understand the historic structures of different resins and the modifications which took place during time, the aim of this study is to evaluate the non-degraded resins by infrared spectroscopy.

Materials and methods

Different natural resins such as: arabic gum (acacia gum), dammar, mastic, colophony, sandarac and shellac resins provided from Kremer Pigmente (Germany) were analysed without further purification.

Infrared spectra were recorded on solid samples in KBr pellets by means of FT-IR DIGILAB Scimitar Series Spectrometer (U.S.A.) with a resolution of 4 cm^{-1}. The concentration of the sample was of 5 mg/500 mg KBr. Five recordings were performed for each sample after successive milling and the evaluations were made on the average spectrum obtained from these five recordings. Processing of the spectra was performed using the Grams 9.1 program (Thermo Fisher Scientific).

Results and discussion

According to literature [Azémard, 2014; Osman, 1993; Gören, 2010; Romero-Noguera, 2014], arabic gum is a complex and variable mixture of arabinogalactan oligosaccharides, polysaccharides and glycoproteins, mastic and dammar consist in a mixture of diterpenic and triterpenic compounds, colophony mostly diterpenic acids, sandarac contains a considerable amount of free acids, notably pimaric acid, and yields a small quantity of an essential oil containing dextropinene and a diterpene.

The infrared spectra of the studied natural resins are presented in Figure 1. As can be observed there are two important regions namely: the 4000-2500 cm^{-1} assigned to hydroxyl and methyl, methylene groups stretching vibrations and the 2000-800 cm^{-1}, so called "fingerprint region", assigned to different groups from the resins structure stretching and deformation vibrations.

In the first region (4000-2500 cm^{-1}) there are differences in respect to hydroxyl group's vibrations, being observed a higher amount of these groups in arabic gum and shellac, while colophony and sandarac presents the lowest amount of these groups in their structure. At the same time, comparing the bands at around 2930 and 2860 cm^{-1} assigned to methyl and methylene stretching vibrations, one can observe that dammar and mastic resins present the higher amount of these groups, followed by colophony, sandarac and shellac resins.

According to the spectra from Figure 1, similarities in the structure of the dammar and mastic resins and also between colophony and sandarac resins can be seen.

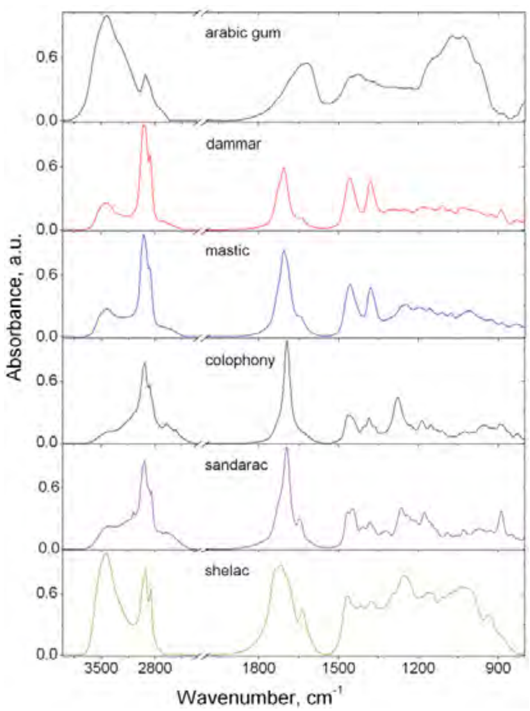

Figure 1: Infrared spectra of the studied natural resins

In the second region (2000 – 800 cm^{-1}) the spectra are more complex. Here, different concentrations according to bands intensities of the carbonyl groups at around 1700 cm^{-1} can be observed. The higher content of these groups is observed in colophony resin structure, but also in sandarac, shellac and to some extent in mastic and dammar.

The bands at 1450 and 1380 cm^{-1} assigned to C–H bending vibration of methyl and methylene groups in the dammar and mastic resins are in accordance with the bands in the other region, proving the higher amount of methyl and methylene groups in the structure of these resins.

Further processing of the infrared spectra, such as second derivative spectra, gives the possibility to indicate more precisely the chemical structure of these resins.

By infrared spectroscopy, the structure evaluation of the old masters resins used for varnishes can be done. Difficulties, because of their similar structure can be encountered when someone need to differentiate the dammar and mastic based varnishes and also to some extent between colophony and sandarac based varnishes.

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TAP THE WOOD AND DEFINE THE QUALITY; ASPECTS OF MEASURING TECHNIQUES OF SOUND RADIATION FROM WOOD AND WOODEN INSTRUMENTS.

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Summary

This paper describes some traditional acoustical measuring techniques, including resonance analyses, intensity vector imaging, average long-time spectra and radiation patterns in order to detect possible new factors for identifying and defining wood and wooden instrument properties. The aim is to simplify measuring procedures.

Introduction

Looking at the violin maker tapping the finger in order to excite the violin top plate we understand this shows a remarkable capacity to listen, analyze and control the different acoustical properties of the vibrating wooden plate and to identify certain wood qualities.
Acoustical measuring methods have always been trying to replace these individual personal skills by technological instrumentation and more or less suitable measuring procedures, but we still don't have the ultimate data based automatic high quality analyzer.
Using one of the very first established one-microphone intensity measuring devices [Tro, 1983] the radiation from a double bass at a certain frequency (*Figure 1*) gave us new insight into both musical instrument sound radiation and new measuring technics of sound radiation.

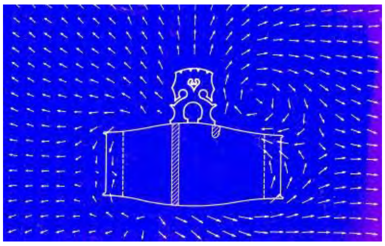

Figure 1: Intensity vectors showing sound radiation from a double bass in the horizontal plane. [Tro, 1983]

Today intensity measuring techniques include both sound radiation intensity vector analyses and 3-D particle velocity measurements mainly dedicated to established acoustical laboratories..

Methods

In cooperation with a local Trondheim violin maker we are measuring a lot of wood specimen and completely finished instruments in order to evaluate different measuring techniques.

The main goal is to simplify techniques for sound analyses in order to achieve the highest confidence of quality by the simplest way to excite and analyse the specimen.

Results and Discussion

In previous projects [Buen, 1994], [Morset, 2001], [Tro, 2013] some measuring methods of violine have been discussed and evaluated.
Figure 2 shows a long-time-average-spectrum as discussed in [Gabrielsson, 1976]. This method

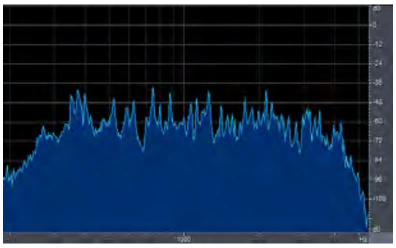

Figure 2: Long Time Average Spectrum of the Hagetrø violin as played in the NTNU anechoic chamber by a professional performer.

has rarely been used even if it makes an easy way to get interesting analysing results based on sound recordings.

The original paper described recordings made in a reverberation chamber. My figure above is based on an anechoic recording and shows the similar possibilities to a definition of resonance peaks of the instrument parts, as the top plate and the resonating inner volume.

The final Cremona presentation will include a detailed analysis of the different measuring techniques and hopefully find some easy way to get fundamental information out of reasonably simple measuring procedures.

Acknowledgements

Thanks to all who have taken part in the many valuable discussions and have contributed to this project. Suggestions, comments and multiple discussions among colleagues P. Svensson and U. Kristiansen have been heavily appreciated.

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18TH AND 19TH FRENCH HARP CLASSIFICATION USING VIBRATORY ANALYSIS

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Introduction

The *Musée de la musique* in Paris preserves 31 pedal harps built in France during the 18th and 19th centuries. This interesting collection is a great opportunity to carry a deep comparative study. Nevertheless, nowadays when a musical instrument enters a museum collection it becomes a cultural heritage object that is loaded with a new cultural value in relation to its connection to history, music and culture. Therefore, this implies changes in the criteria that attributes value and interest to the instrument: its historic role and connections, its rarity, its peculiarity of shape and material may become more relevant than the quality and power of its sound or its usability for concert repertoire. In this context, it became essential to develop a methodology and tools of study which exclude to put those instruments under a mechanical stress such as the string tension (typically more than 450 kgF for a 41 strings-harp) [Firth, 1990], and of course any destructive analysis to gather all information.

This paper describes a methodology based on a non-destructive measurement to evaluate the vibrational behaviour of the instrument and then to classify historical harps. To do so, after an historical description of the instrument, the corpus is presented. The methodology is then described and an example of result is detailed.

Historical context

Two personalities seem to dominate harp making in Paris during the 18th century, with regard to the quality and quantity of constructed harps especially with regard to the inventiveness of these makers: Georges Cousineau (1733-1800) and Sébastien Erard (1752-1831). Both were at the head of workshops and prosperous shops where the public could find harps and other instruments alongside manuscripts and printed music. Due to his apprenticeship with François Lejeune [Milliot, 1970], Georges Cousineau comes from the parisian environment of the stringed-instrument makers, holders of knowledge solidly anchored in a tradition of several centuries. During his career, he invented several systems of mechanics for the harp (system with crutches (béquilles), system with rotating tuning pegs[1]) in order to mitigate the limits of the “hooks” system. Sébastien Erard was not only a harp maker but also a maker of the piano forte and a brilliant inventor. Contrary to Cousineau, he does not come from the luthiers circle but from harpsichords makers, having been trained in drawing and geometry, which was appreciably different from the average parisian craftsmen of the time. He finalized a system of mechanics known under the name of “forks system” for the harp which quickly made all the pre-existing systems obsolete.

From an organological point of view, the instruments made by Cousineau and Erard at the same time present similarities and striking differences, bearing in mind that Cousineau was the elder of Erard by about twenty years.

Corpus comparison

The vibrating lengths of the instruments are nevertheless comparable on the observed models, on the other hand the number of strings is higher with Erard (from 41 to 47) than with Cousineau (from 35 to 39). The design of the soundboards is particularly comparable regarding the arrangement of the wood fibres which are perpendicular to the axis. In the same way, the barring of the soundboards is comparable with fine longitudinal bars stuck inside on both sides of the bridge. We also note the presence of nuts made of brass, wood or ivory, inlayed in the bridge at the edge of the string holes to prevent the cutting of the wood by strings. On the other hand, we notice a great disparity in the thickness of soundboards; Cousineau' soundboards are always thinner than Erard’s. Another difference in the instrument construction is on the soundbox. Cousineau builds soundboxes by assembling seven thin wood ribs (generally made of maple) whereas Erard introduces plywood backs with the first numbered

1 Beautiful examples of this type of harp, patented in 1799 by Jacques-Georges Cousineau (1760-1836), son and successor of Georges, are on display at the Musée de la musique in Paris and at the Musée de la Malmaison where one can see a harp having belonged to empress Joséphine of Beauharnais.

harps (c.1798-99). This evolution modifies the vibrational behaviour of the instrument.

Vibratory analysis of the soundbox

A way to study the evolution in the harp's corpus, without playing the instrument is to analyse the vibratory behaviour of the soundboard as well as the soundbox. For that, the mobility of the soundboard and of the soundbox were measured. The mobility characterizes the capability of the soundboard or the soundbox to vibrate under an excitation imposed on the soundboard. To measure the mobility of the instrument, the impact testing method was used. This method is well adapted to our corpus because it is non-intrusive. The experimental set-up si shown in figure 1.

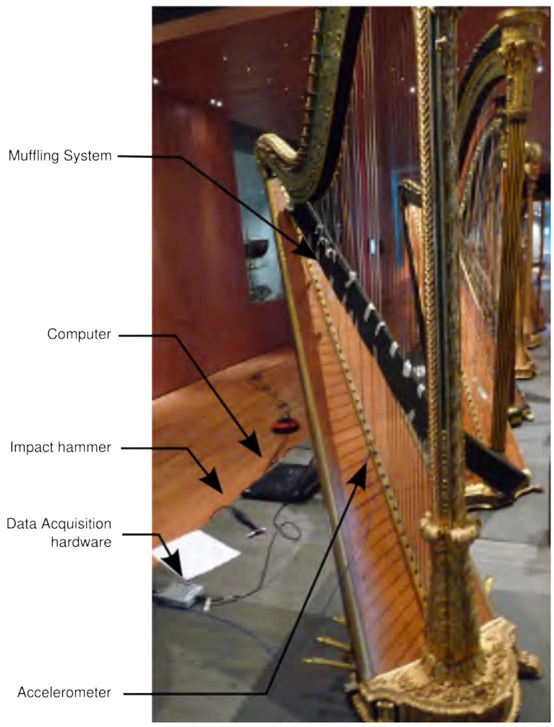

Figure 1: Experimental set-up at Musée de la musique.

The mobility contains a lot of information (modes in low frequencies, for example). Thus, an indicator is extracted from the mobility to characterise the global response of the instrument. This indicator is the Mean-Value of Mobility (MVM) [Le Carrou, 2010, Elie, 2012]. In figure 2, the mobility of the soundbox versus mobility of the soundboard is shown for 4 Cousineau's and 4 Erard's harps.

Results show that the MVM of each harp maker are found to be well separated. Cousineau's harps have greater soundbox's and soundboard's mobilities than Erard's. This result can be linked to the design of the instrument. For Cousineau, the soundbox is coopered in different wood species whereas for Erard it is a rounded back reinforced by internal ribs, face veneer in wood. This design reinforces the rigidity of the soundbox and then decreases the mobility. This kind of indicator and of representation may help to identify makers strategies over the years. Indeed, Cousineau tends to decrease both the soundboard and the soundbox mobilities whereas Erard seems to keep them stable.

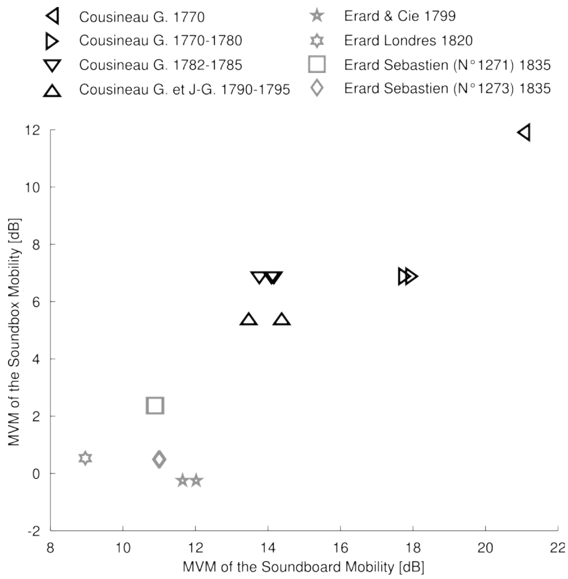

Figure 2: Mean-value of Mobility (MVM) of the soundbox versus MVM of the soundboard for 8 harps: 4 Cousineau (in black) and 4 Erard (in gray).

Acknowledgements

The authors would like to thank Francois Gautier and Joel Dugot for fruitful discussions.

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PLAYING THE UNPLAYABLE: BUILDING THE DATASET

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Introduction

It is obvious that the guitar is an instrument with a long musical tradition. In the last century, several studies show the acoustic properties of the guitar and analyze the sound they produce [Rossing, 2010][Fletcher, 1998]. Nevertheless, there are some aspects in the sound produced by some guitars that make them special, unique.

On the other hand, there are many singular guitars kept in the museums that have been a reference for the audience, players, luthiers and acousticians. The main goal behind this research is to create a mathematical model that explains the particularities of these instruments and, in a near future, let this model being able to digitally reproduce their original sound. This is specially interesting for those instruments which are not in good playing conditions.

This paper shows the early stage of this research. We analyze two guitars from the permanent exhibition at the Museu de la Música, in Barcelona, for extracting their parameters including physical, mechanical and acoustic details. All the features derived from this analysis feed a numerical model which is the responsible to explain the acoustic differences produced by the construction particularities.

Methods

This work is divided into three main blocks: the analysis of (1) mechanical and (2) acoustic properties, and (3) the first attempt in the creation of the dataset. Right now, we focus on two of the available guitars at the Museu de la Música, in Barcelona, specifically, the Antonio Torres MDMB 625 (1862) and Antonio Torres MDMB 626 (1859) shown in Figure 1.

Figure 1: Antonio Torres MDMB 625 (1862) and Antonio Torres MDMB 626 (1859).

Mechanical behavior

We started performing a modal analysis to extract the resonance parameters of the upper plate for both guitars (frequency, damping and mode shapes). The experiments were conducted using a single-reference testing methodology. We used a roving hammer test for excitation. While a larger number of finite matrix measurement points results in a higher description of the mode shapes, the number of measured points was restricted to ninety nine FRF's on each soundboard. In general terms, the test environment involves several factors which must be taken into consideration, as well as the appropriate boundary conditions of the soundboard, specially when the vibration behaviour is to be subsequently compared with numerical results. In our case, tests are performed under free boundary conditions by positioning the instrument on an undulated foam surface. The vibration signals (excitation and response) were measured and recorded in the form of time series and processed into inertance FRF data. To estimate the modal parameters from FRF measurements, a curve-fitting method was used.

Acoustic measurements

The second part of the study corresponds to the extraction of the acoustic impulse responses and steady state responses of the two presented guitars. Here again, some decisions must be taken for measurements. Guitar is positioned upon its waist, as it would be positioned if it was being played. Back plate and the strings are damped by absorption foams and the near surrounding is also covered with the same foam. Loudspeaker, generating the impulses, is placed in front of the sound hole, and the microphone is positioned at two different points inside the guitar body. First point is under the bridge, 3.5 cm below from the side-section view, and the second position is close to the neck, in the same height from the sectional view. Loudpeaker is connected to the power amplifier, and the sound sources (noise,sine-sweep, burst and impulses) coming out of DAW to the soundcard, connected to the computer. Microphone is omni-directional, Audix TM1 calibration microphone, which is also patched to the DAW via same

Figure 2: Setup for the acoustic impulse response measurement.

soundcard. Figure 2 shows the measurement setup. Twenty-five wave files are generated through the speaker, consisting of bursts, impulses, noises and sine-sweep examples. Distance between microphone and the loudspeaker is 15 cm in all recordings. Whole experiment took 80 minutes approximately, for each guitar. The acoustic level (dB_{SPL}) is also recorded for calibration.

Computing descriptors

Finally, we build up a dataset with all the relevant information extracted from the previous analysis.

Audio descriptors: A set of audio descriptors are derived from the recorded responses. We use the Essentia library to compute them providing near two thousand attributes for each file [Bogdanov, 2013]. In this research, we focus on timbre description of sound. Then, we include those statistics (mean, deviation, skewness, etc.) from descriptors related to the timbre (MFCC, Spectral Centroid, Spectral Roll-off, etc.) and their derivatives, as well as other information extracted from the impulse response (duration, decay, etc.). To avoid overfitting, we apply an attribute selection algorithm to determine which are the most relevant descriptors that explain the timbre variability the recorded sounds. All this information is wrapped up to create dataset for each of the two analyzed guitars.

Mechanical descriptors: In addition to the audio descriptors, we also include the information relative to the mechanical properties coming from the modal analysis (frequency, damping and mode shapes) and other relevant information (volume, construction details, conservation state).

Results

Rihgt now, we have basically stablished the methodology to collect data from guitars. We are aware that our dataset is too small to extract conclusions, but we observe how data is normally distributed in clusters for some of the selected attributes from audio descriptors extracted from the

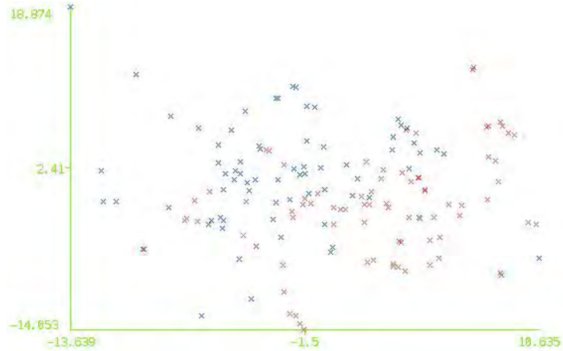

Figure 3: Distribution of two derived audio descriptors for MDMB 625 and MDMB 626 in blue and red colours respectively.

impulse response audio files. Figure 3 shows the distribution of the first combination of collected features using Principal Component Analysis (PCA) for MDMB 625 and MDMB 626 in blue and red colours respectively.

Discussion

We have not discovered the model to predict the guitar sound according to their physical properties yet, but we think the proposed methodology is statistically consistent with our purposes and proves the acquisition methodology is correct. Our next step is start growing the measurement dataset up to a minimum of 10 guitars.

Acknowledgements

This research has been partly supported by the Museu de la Música in Barcelona, and the Musical Creation and Performance 2014-SGR-1382 research group.

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WHY VIOLINS ARE NOT AUTHENTICATED BY MEANS OF PLAYING TESTS

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Introduction

Stradivari and Guarneri 'del Gesu' may well be the greatest violin makers ever, but it takes an expert opinion based on visual and historical (rather than tonal) evidence to say whether a particular example is genuine [Curtin, 2010]. Playing and listening tests never enter the authentication process, and this suggests the difficulty of reliably correlating playing qualities with an instrument's age and maker, even if according to Langhoff [1994], "any musician will tell you immediately whether an instrument he is playing on is an antique instrument or a modern one." The purported ability of players to tell apart new and old violins was first scientifically tested in the Indianapolis experiment [Fritz, 2012] which showed that players seemed unable to do so. The study was however relatively small in terms of the number of violins tested (six) and the size of the test space (a hotel room); in addition, the participants were criticised for not being all of sufficiently high calibre to perform such a task. A second study was thus conducted in Paris [Fritz, 2014] to address these issues and criticisms, and to investigate whether first-class soloists and better conditions would lead to a different outcome in terms of distinguishing old from new instruments.

Methods

Procedure:

The Paris experiment [Fritz, 2014] was a large-scale study aimed at understanding better how soloists evaluate instruments. Only the question of the players' ability to distinguish old from new instruments will be discussed here, and what is not directly linked to that particular question but is needed to understand the methodology used will only be briefly summarised. The experiment was divided in two sessions: one in a small rehearsal room, the other one in 300 seat concert hall, well-regarded for its acoustics (Auditorium A Coeur de Ville in Vincennes, on the outskirts of Paris). In both sessions, players spent about 50 minutes choosing from among 12 violins a replacement for their own for an upcoming tour. Their task was, within this context, to i) remove any violins that seemed unsuitable; and (ii) choose the four they liked most, and then arrange these in order of preference. They were allowed the greatest possible freedom to test the instruments as each saw fit. At the end of the second session, each soloist was presented with a series of violins (one at a time, in random order), and given 30 seconds to play each one before guessing what kind of instrument it was. If he/she was unclear about the meaning of the question, he/she was prompted to guess whether the violin was new or old. The series consisted of: 1. That player's favourite old violin; 2. The player's favourite new violin; 3. An old and a new violins the player found unsuitable; 4. The old and the new violins that in the first session were most often included in top-four lists, and that were on average most highly ranked within those lists; 5. The old and the new violins that were most often rejected as unsuitable in the first session. If it happened that two of the above criteria described the same instrument, the player was simply given one less instrument to judge.

When testing violins in real life, players typically use their own bows, which through constant use have become, in effect, extensions of their right arms. We therefore asked the soloists to use the bow they normally played.

Soloists wore modified welders' goggles, which together with much-reduced ambient lighting made it impossible to identify instruments by eye.

Violins:

Six old (including five by Stradivari) and six new violins (built by professional makers in Europe and North America, between several days and two decades old, and antiqued to help eliminate any tactile clues to age, such as unworn corners and edges) were assembled. None of the test instruments were unusual in terms of size, proportions, or set-up. While not all had the same strings, all had very typical combinations of a steel E-string and metal-wound synthetic-core lower strings.

Participants:

Ten internationally renowned soloists were invited, ranging in age from 20 to 62. Laureates of major international competitions, they were all used to play Old Italian violins.

Results

If the instrument was new, a correct guess was "modern," "new," or some similarly unambivalent attribution. If old, a correct answer was any that suggested the instrument was an Old Italian, regardless of whether it was attributed to the right maker (thus "Guarneri del Gesu" was considered correct for a Stradivari. Five answers (e.g. "19th Century French") were considered indeterminate.

The soloists played between six and eight violins each, and made a total of 69 guesses – 33 of them about new violins, and 36 about old.

Soloists' guesses are compiled in Figure 1 and summarized by category of instrument in Table 1. Considering all guesses about all instruments, 33 were wrong, 31 right, and 5 indeterminate. These guesses were rather evenly divided between old and new violins (36 and 33 respectively - see Table 1), so the data rather clearly demonstrate the inability of the players to reliably guess an instrument's age, whether the instrument is in fact new or old.

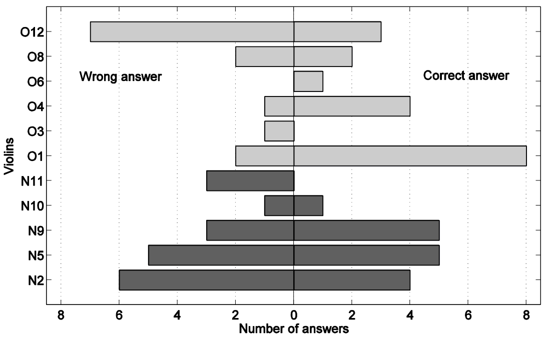

Figure 1: Soloists' guesses about the age of each test instrument. Five indeterminate guesses about old instruments are not represented here.

Type of violins	*Correct*	*Wrong*
New	*15*	*18*
Old	*18*	*13*

Table 1: Soloists' guesses about the age of old and new test instruments

Table 2 shows the distribution of right and wrong guesses about the top-choice instruments (i.e., the instrument to replace a soloist's own). The preponderance of wrong guesses can be attributed to chance, or there may be an easily understandable tendency to believe one's favourite violin is old. Indeed, out of the seven wrong guesses about top-choice violins, five were due to guessing that three new violins (N5, N9 and N10) were old.

Violin	*Correct*	*Wrong*
N5	*1*	*3*
N9	*0*	*1*
N10	*0*	*1*
O1	*2*	*1*
O4	*0*	*1*
total	***3***	***7***

Table 2: Wrong and right guesses about the five violins chosen as the single-favourite by at least one soloist

Figure 2 compares the number of right and wrong guesses made by each soloist. One soloist had five right and one wrong, while another had five wrong, two right, and one indeterminate. The other soloists were somewhere in between, including three with an equal number of right and wrong guesses. Without further testing, it is not possible to know the extent to which the results of any given soloist are due to skill or to chance.

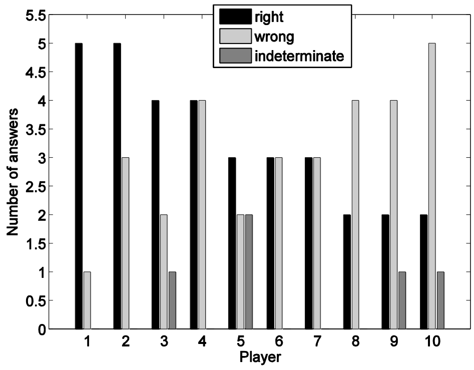

Figure 2: Number of indeterminate, wrong, and right guesses made by each soloist

Discussion

Soloists readily distinguished instruments they liked from those they did not, but were unable to tell old from new at better than chance levels. This emphatically confirms the findings of the Indianapolis experiment – and indeed many informal listening tests conducted over the years.

There is no way of knowing the extent to which our test instruments (old or new) are representative of their kind, so results cannot be projected to the larger population of fine violins. Similarly, they cannot be projected to the larger population of top-class soloists. However, these results may explain why playing tests are never used to authenticate old violins. The judgment of highly experienced players, while acute in terms of preference, seems to be utterly unreliable in regards to age, maker, and country of origin.

Acknowledgements

We would like to thank our collaborators on the wider project in which this study takes place: Hugues Borsarello, Fan-Chia Tao, Thierry Ghasarossian and Indiana Wollman. We thank as well all dealers, makers, players, and collectors for their kindness and trust in making available these valuable instruments. Special thanks go to the ten soloists for their participation, enthusiasm, and patience!

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THE APPLICATION OF X-RAY CT SCANNER TO THE DOCUMENTATION OF EARLY MUSICAL INSTRUMENTS

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Introduction

Computed Tomography (CT-scanning), developed by Hounsfield (1973) and Cormak (1963), has been diffusively applied in many field of research in wood science and technology, including preservation of Wooden Cultural Heritage.
This technique allows to obtain a 3D representation of the inside structure of an object in a totally non-destructive manner, and with a resolution that allows to assess the innermost structural and constructive aspects.
In view of combining stylistic and historic knowledge with the objective evidence offered by the analyses towards a more reliable method of attribution based on objective and systematic documentation, a project study has been carried out on the instruments belonging to the Music Conservatory of Florence, Italy.

Methods

In X-ray CT the representation of the inner structure of the object is made possible by means of a 3D reconstruction of the linear attenuation coefficients measured during the scanning, and that can be assumed to be proportional to the mass density of the materials constitutive of the structure.

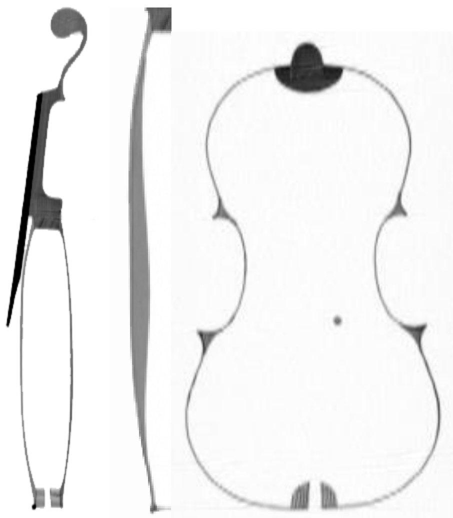
Using a Medical CT-scanning Lindgren (1991a-1991b) normalized the X-ray absorption coefficient in each volume elements (voxels, Herman, 1980) with the corresponding absorption coefficient for water according with the definition of CT-numbers. Lindgren found a linear relationship between CT-numbers and density of wood.

The image represented on the screen is therefore obtained assigning a different level of grey to the density value measured, applying an arbitrary scale (Hunsfield units) that is proportional to the density of water.
All instruments were scanned using a volume rendering multi-slice HISpeed CT scanner (General Electric and Siemens) provided by Istituto Andrea Cesalpino of Terontola (Arezzo) and by the Department of Image Diagnostic of the Hospital of Careggi in Florence (Italy).

A standard set of cuts was selected in order to provided an objective documentation of the following features of each instrument of the violin family:

- curves of the belly and back
- relationship between the curves
- relationship between curves and thickness of each board
- angle of the neck in relation to the line of the soundboard
- position, shape, thickness and height of the bass bar
- shape of the blocks

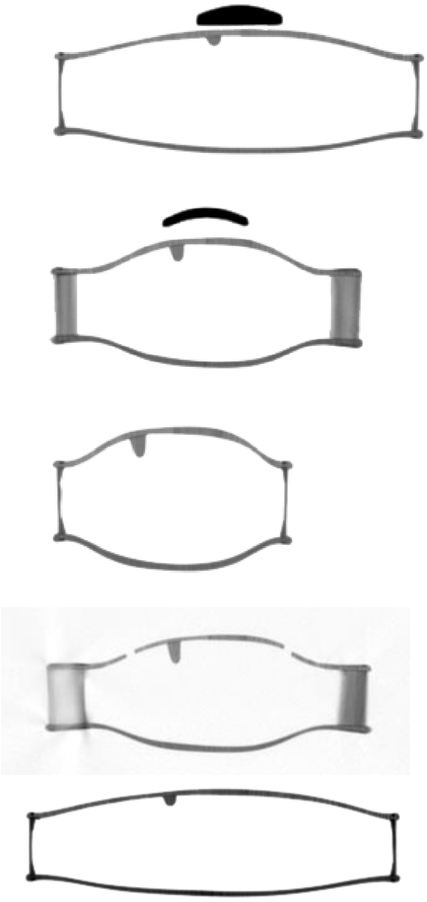
Longitudinal and latitudinal cuts document the arching along the center of the instrument, the position of the neck, the actual profile of the ribs and the shape of the blocks.
A sub-sagittal cut shows the shape and length of the bass bar in relation to the belly.



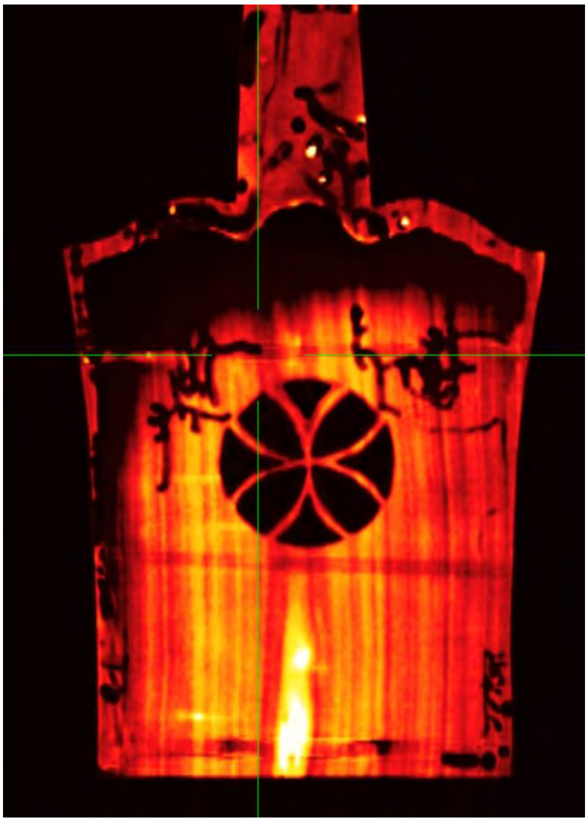
Five axial cuts were selected at the following points:

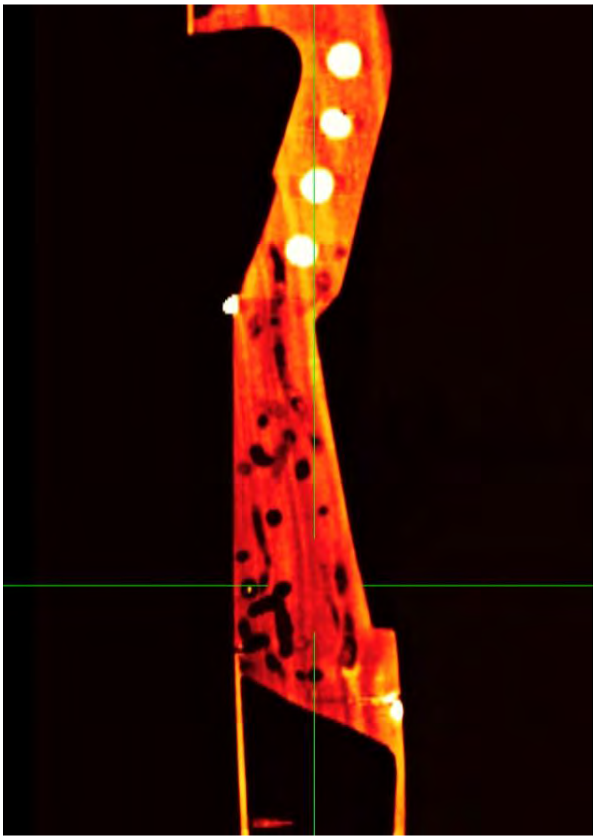
- maximum upper width
- upper corners
- minimum width
- lower corners
- maximum lower width

These document the development of the arching of belly and back, also in relation to each other and to the thickness of the boards and the position, thickness and section of the bass bar.



On top of useful information for the identification of the instruments and for their stylistic comparison, the CT study also allows to acquire important knowledge on the conservation of the instruments and in particular on biological damage.





COMPARISON OF DIFFERENT EXPERIMENTAL APPROACHES IN THE TOMOGRAPHIC ANALYSIS OF ANCIENT VIOLINS

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Introduction

X-ray computed tomography (CT) is becoming a common technique for the non-destructive structural analysis of ancient manufacts of cultural relevance, providing luthiers, art historians, conservators and restorators with a unique tool for the characterization of musical instruments [Rigon, 2010; Sodini, 2011]. Additionally, CT-derived information aid in the replication of original masterpieces and have an important role in the valuation, insurance, and identification of valuable stringed instruments [Zanini, 2012; Sodini 2012, 2013].

The experimental setup to choose is related to the kind and accuracy of the information to be extracted. Some applications of the technique require to examine extremely small details in selected parts of a violin, as in the evaluation of small cracks and thin patches, or in the characterization of larvae and eggs of wood-destroying insects [Bentivoglio-Ravasio, 2011]. Other approaches, on the other hand, require less precise measurements of the size of the violin and its main components. Sometimes the presence of metal parts, such as strings and keys, requires a high dynamic range X-ray detector. Other parameters to be taken into account are related to the general organization of the experiment, such as the time required for the whole measurement, the distance of the laboratory from the instrument owner, its availabilty and, of course, the cost of the service.

The study described has been dedicated to a deeper understanding, from a qualitative point of view, of advantages and disadvantages of three different approaches in the morphological study of a violin: a conventional clinical CT, a commercial micro-CT system and a micro-CT synchrotron beamline.

Methods

The data acquisitions were performed in three different laboratories, with three radically different tomographic systems:

- a state-of-the-art clinical tomographic system at the Cattinara Hospital of the Trieste Ospedali Riuniti, Italy;
- a GE Phoenix v|tome|x L 240 micro CT station at the Faculty of Mechanical Engineering, Brno University of Technology, Czech Republic;
- the SYRMEP micro-CT synchrotron radiation beamline at Elettra-Sincrotrone Trieste, Italy.

The measurement were performed on the same violin in order to compare the results. The instrument was an old (~1850) Austrian violin with several cracks, defects and woodworm attacks.

Results

The final results were compared on the basis of several considerations: the main concern was obviously related to the quality of the final reconstructed images, taking into account the spatial resolution and the dynamic range of the final images, as well as the presence and relevance of recostruction artifacts. The other parameters we considered, in order to compare the different approaches also from the point of view of the working conditions were related to the time necessary for the acquisition and reconstruction, to the amount of scans performed in a typical measurement, to the amount of data generated, the computing system necessary to manage them, and to the availability and cost of the access to the different facilities.

Acknowledgements

We would like to ackowledge the X-ray Micro CT and Nano CT laboratory of the Central European Institute of Technology at Brno for their collaboration in the use of the GE Phoenix station and the Unità Clinico Operativa di Radiologia of the Cattinara Hospital at Trieste for their collaboration in the use of the clinical CT system.

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THE USE OF MICRO-COMPUTED TOMOGRAPHY TO STUDY THE INTERNAL ARCHITECTURE OF WOODEN MUSICAL INSTRUMENTS

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Introduction

The construction of wooden wind instruments involves many hidden details that are difficult to measure. Previous studies have included destruction of rare specimens.[1] Although X-rays and CT scanning in particular may allow one to see the internal architecture of wind instruments, [2] no current publications have included detailed measurements.

Working in collaboration between the depts of Music and Engineering, we applied Micro Computed Tomography (µCT) as a technique of non-destructive analysis to wind instruments. µCT is a relatively new technique that has come into use in diverse scientific and engineering applications.

Computed tomography uses x-rays to create cross-sections of a 3D-object, thus producing a virtual model without touching the original, as in a medical "CT scan". The data that create this digital model are expressed as pixels. The term *micro* indicates that the pixel sizes of these scans are in the micrometer range (one thousandth of a millimeter).[3] µCT thus permits extremely fine measurements. With appropriate software, µCT permits sophisticated reconstruction and viewing of specimens as if from infinite points of view. The views may be seen as 3-D surface renderings or as slices through the object (tomograms). The value of such methods in analyzing fragile, complex objects is self-evident.

Methods

We studied six objects: a wooden mouthpiece by Charles Sax, associated with a Charles Sax 9-keyed ophicleide in C, circa 1820; a wooden tenor saxophone mouthpiece by Adolphe Sax, 1876; a boxwood recorder by Cahusac, 1738-80; curved cors anglais by Guillaume and Frederic Triebert; and a classical hautboy reed.

We used a Zeiss X-Radia 400 µCT unit, modifying the data processing algorithms to permit separation of disparate materials such as metal, cotton and wood. This permits evaluation of some metallic objects, previously impervious to X-ray studies.

Results

1. µCT permitted us to establish the construction and dimensions of the Charles and Adolphe Sax mouthpieces.[4] Internal details which were not recognized by visual studies and hand measurements were noted. Using µCT we created digital files showing the internal anatomy of these mouthpieces, permitting us to create playable replicas by 3-D photocopying.

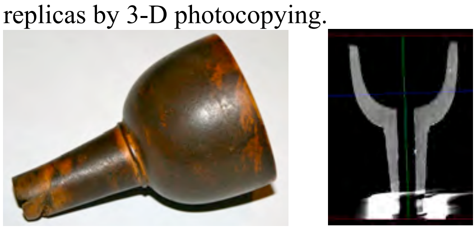

Figure 1, visual and µCT views of an ophicleide mouthpiece

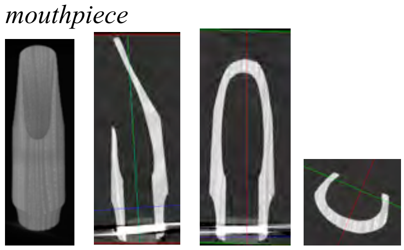

Figure 2, µCT surface and tomographic views of a tenor saxophone mouthpiece.

2. We studied a recorder by Cahusac, which is of interest because it plays at the modern Baroque pitch of A415; it has been measured and copied by a well-known recorder maker. This allowed us to compare µCT and traditional methods of measurement. Using µCT data files, we replicated the foot joint without taking measurements, creating a more accurate copy than was made by hand methods, while preserving the tuning of the original.

Figure 3, µCT surface rendering and tomogram of Cahusac foot joint

3. We studied curved cors anglais by Guillaume Triebert, Paris, circa 1820; and by his son Frédéric Triebert, Paris, circa 1845. The Trieberts were renowned for their curved cors anglais, a favorite instrument of Berlioz. Through

circa 1840, curved cors anglais were covered in leather to prevent leaks; later specimens are not leather covered, yet do not leak.

The method of making these instruments has long been speculated; none have been dissected, nor have radiologic studies beyond plain films been published. Their manufacture is surmised as boring a straight joint, cutting wedges almost across the tube, then steaming, bending, gluing and securing with leather to close the gaps. Modern craftsmen making period instruments use this method.

μCT shows that the actual construction of these two specimens is not as simple as this. The G. Triebert joint is cut fully through and held together by shims and pegs placed at 120 degree angles around the bore. The newer F. Triebert specimen is more complicated yet more secure. The joints were cut fully, the remaining wood was counterbored and internally bored tubes of the same or similar wood were placed to secure the joins. These were also held in place by pegs. Only then were the tone holes drilled. These details, which are not visible on plain radiographs,[5] are very clear on μCT, which allows visualization of fine detail.

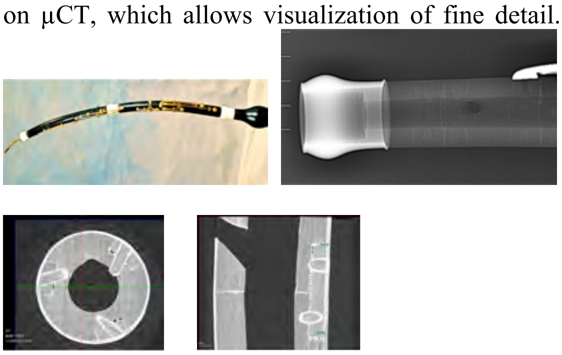

Figure 4. G Triebert curved cor anglais; standard radiograph showing pins; μCT in transverse and sagittal views showing shims and pins

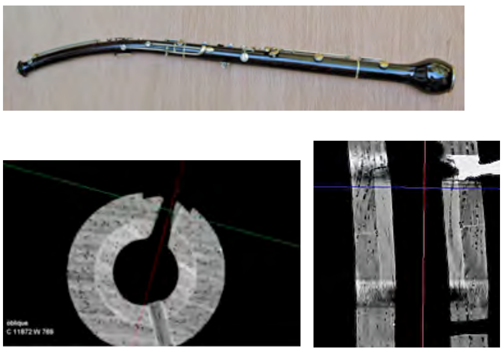

Figure 5. F. Triebert half-curved cor anglais; transverse and sagittal μCT views of the inserted join.

4. Evaluating a classical hautboy reed, μCT allowed us to see the architecture of the metal staple upon which the reed is built, the original diameter of the cane used for the reed and the dimensions of the shaped cane. Digital subtraction of the cane and cotton elements permitted detailed evaluation of the metal tube, a technique not previously available.

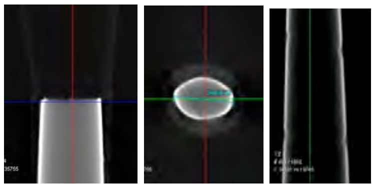

Figure 6, metal tube of an oboe reed; the thread and cane have been subtracted. The right figure shows scoring of the tube, which helps fix the cane in place.

Discussion

In a first musicological application of the new technology, μCT, we have discerned details of wooden instruments that could not be seen on plain radiographs; obtained more accurate measurements than can be obtained by hand; and determined unique methods of instrument construction which could not be discerned by inspection, endoscopy or plain Xray. This reveals μCT as a valuable and powerful method for assessing the internal architecture of wooden musical instruments. The limitations of μCT include expense, difficulty in setting up fragile instruments, limited field of view, prolonged exposure times, artefact from metal elements and the need for technical expertise; these will be reviewed.

Acknowledgements

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[4] Adolphe Sax emphasized the importance of mouthpiece design for his instruments. Robert Howe, "The Invention and Early Development of the Saxophone, 1840-55". *J American Musical Instrument Society* 29:97-179, 2003.

[5] The pegs are not clearly seen in radiographs published as figure 20 in Robert Howe, "Nineteenth-Century French Oboe Making Revealed: a Translation and Analysis of the Triebert et Cie "1855" *Nouveau Prix-Courant*". *Galpin Society Journal* 64: 79-116, 2011, at 101. In this same illustration, the bore-within-a-bore design of the F Triebert curved cor anglais is not visible; the contrast of a traditional radiograph is too coarse to reveal them.

MULTI-RESOLUTION X-RAY COMPUTED TOMOGRAPHY FOR RESEARCH ON WOODEN MUSICAL INSTRUMENTS

Jan Van den Bulcke (1), Denis Van Loo (2,3), Manuel Dierick (2,3), Matthieu Boone (2,4), Bert Masschaele (2,3), Kristof Haneca (5), Koen Deforce (5), Luc Van Hoorebeke (2), Joris Van Acker (1)

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Introduction

The use of X-ray CT has increased considerably in the last decade. Actually, in recent years X-ray micro-CT (µCT) has seen a breakthrough in many research domains and is becoming a routine microscopy technique. Most researchers use commercially available desktop micro-CT scanners. UGCT (Ghent University Centre for X-ray Tomography) however develops in-house open modular scanners for more experimental freedom, both for applied research in various fields as for research on tomography itself. UGCT is a collaboration between three research groups operating as an open user facility offering researchers from different fields access to the infrastructure and expertise [Dierick et al, 2014]: the Radiation Physics group, the Geology group and the Laboratory of Wood Technology. The scanner park at UGCT allows scanning from submicron resolution of very small samples up to scanning of large objects at resolutions depending on sample size. We hereby present the Nanowood scanner, a flexible multi-resolution scanner which was specifically designed for wood. Different examples will highlight the possibilities and opportunities of such a scanning tool for research on wooden musical instruments.

Methods

Nanowood is the a multi-resolution X-ray scanner developed at UGCT. It consists of an 8-axis motorized stage with two X-ray tubes and two X-ray detectors, specifically designed to obtain very high resolution scans as well as scans of larger objects. The system offers a large range of operational freedom, all combined in versatile acquisition routines (standard or fast scanning, tilling, helix, etc). It has a generic in-house developed CT scanner control software platform [Dierick et al, 2010] that allows full control of the scanner hardware. Reconstruction of the scans is performed with Octopus [Vlassenbroeck et al, 2007]. The latest developments include GPU-based helix reconstruction and phase-contrast filtering using dedicated algorithms such [Boone et al, 2009; De Witte et al, 2010. Thanks to the flexibility of Nanowood, this state-of-the-art scanner can be deployed in many different fields of research with an interest in non-destructive visualization of the internal structure of objects in a high-throughput chain, but Nanowood is dedicated to wood research sensu lato [Van den Bulcke et al, 2011]. The modular and flexible set-up (Figure 1) allows scanning with a resolution of 0.2 mm for samples of 37 cm in diameter and a maximal length of approximately 20-30 cm down to approximately 400nm for objects that have about the size of a splinter.

Figure 1: Nanowood X-ray CT scanner @ Woodlab-UGent.

Results

Different examples are shown in Figure 2, showing the opportunities and possibilities of X-ray CT scanning in the framework of wooden musical instruments.

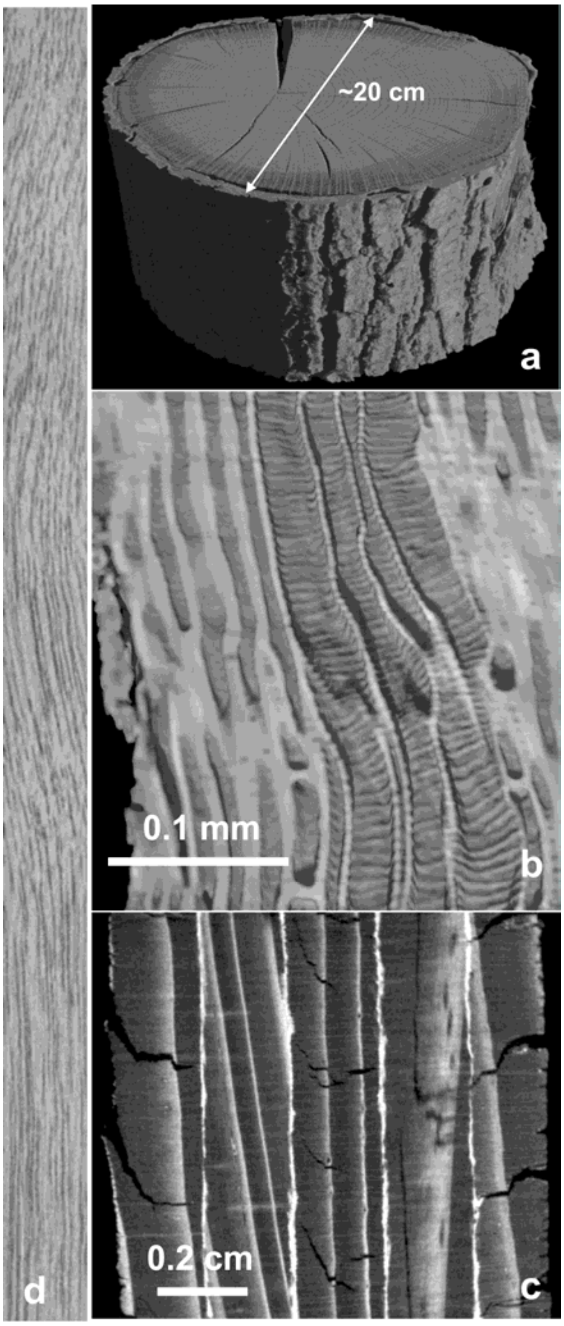

Figure 2: Examples of X-ray CT scanning. See text for explanations.

Figure 2a shows a large wood stem, illustrating the maximum size that can be scanned with Nanowood e.g. for evaluation purpose of instruments of certain sizes. Figure 2b shows a high resolution rendering of a small piece of wood (approx. 0.7 mm wide) with a resolution of approx. 0.75 micron [Haneca et al, 2012] for the purpose of wood identification [Van den Bulcke et al, 2009]. Figure 2c shows a cross-section through a piece of plywood, illustrating the visualization of glue lines [Van den Bulcke et al, 2011] and assessment of their condition, possibly of interest for wooden musical instruments as well. Figure 2d shows the internal structure of a beam of pernambuco wood just before making the violin bow, in order to evaluate straightness of grain.

Discussion

The fast evolving field of X-ray computed tomography and its broad employability make it one of the leading techniques for non-destructive visualization and quantification in many different research fields. The flexible Nanowood scanner offers a wide range of opportunities, yet size can be a limiting factor when studying wooden musical instruments. Another scanner at UGCT, HECTOR [Masschaele et al, 2012], can be used to scan larger and heavier objects at high resolution and therefore complements the Nanowood scanner. Combining both scanners a wide range of wooden musical instruments could be analysed for a large range of purposes such as general evaluation, glue line inspection, wood identification, coating inspection, growth ring analysis, etc. Access to the scanner can be obtained via the European project Trees4Future (www.trees4future.eu).

Acknowledgements

The authors acknowledge the fruitful collaboration with all current and former team members of the UGCT, as well as the project SimForTree of IWT Flanders (Strategic Basic Research – SBO 060032) for financial support for obtaining the equipment.

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THE AGEING OF WOOD

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The ageing of wood

Wood ageing is an important subject in Japan, not only for appropriate conservation of wooden cultural properties but also for expanding lifetime of wooden products. Researchers generally accept that a few hundred years of aging improves the stiffness and hardness of wood while it significantly reduces the shear strength and toughness (Kohara, 1952, 1954; Hirashima et al., 2004a, 2004b, 2005; Yokoyama et al., 2009). The mechanism of wood aging is still under debate: the improved performance of the aged wood has not been convincingly explained, though its brittleness can be explained by the degradation of polysaccharides and the crosslinking of lignin (Yokoyama et al., 2009). It has been suggested that the acoustic quality of wood is improved by ageing (Noguchi et al. 2012). However, the enhanced sound velocity of aged wood has not been convincingly explained yet.

Recent studies have suggested that the color of wood is tightly connected to its age, and the effects of natural ageing can be reproduced by heating (Matsuo et al. 2011). The color of wood might be an indication of its ageing, unless its original color varies widely.

The effects of ageing have so far been explained by irreversible chemical changes such as depolymerization and condensation in wood polymers, but we have recently found that the mechanical damping of aged wood sometimes increases when it once experiences highly humid condition. This fact suggests that the damping of wood is "temporarily" reduced by long-term ageing. Such a reversible effect of ageing should be considered for appropriate conditioning of old wooden instruments.

Artificial aging is an important topic in wood engineering. This process allows for the reliable lifetime prediction of wooden structures and it may enable us to fabricate quality musical instruments without waiting for hundreds years. Various thermal treatments have been proposed to accelerate aging, but complete reproduction of naturally aged wood has not yet been realized. In this paper, the recent progress in wood aging and the unanswered questions related to this process are introduced to stimulate further detailed discussions on this topic.

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AN EXAMPLE OF THE TRADITIONAL APPROACH IN MUSICAL INSTRUMENTS IDENTIFICATION AS STARTING POINT. THE CASE OF THE NONEMACHER'S MANDOLIN.

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Introduction

This paper will illustrate a traditional workflow to identify a musical instruments through the help of two very accessible imaging techniques: radiography and computed tomography.

A mandolin with a mark CN on the pegboard and the upper rib, attributable to Christian Nonemacher (active in Genoa during the XVIII century), with features typical of a Neapolitan mandolin (4 double courses) - quite different to those usually visible on his Genoese instruments (6 double courses) - was radiographed and analyzed with a computed tomography to discuss and possibly confirm his attribution.

Methods

When studying a "hidden" musical instruments collection that for years has been "forgotten" and has not been the object of studies and researches as it is the case of the Musée d'art et d'histoire in Geneva, we often find instruments without attribution or with incorrect ones.

Working on the whole collection demanded to collect a great quantity of data on many objects rather than deepen the study on a single one. Moreover, the lack of a scientific laboratory and/or collaborations with scientific partners prevented an extensive use of scientific imaging and analysis on the objects. The uncommon features visible on the mandolin (unaccessible because its wooden rose glued on the soundhole) requested to study its internal structure and to compare it with the few instruments known.

The only technique applicable was the radiography, as it was available at the museum, while at the local hospital it was possible to perform a computed tomography.

Results

The radiography and the computed tomography provided information on the internal bar system as well on the number, the shape and the dimensions of the metal irons used to fix the neck to the body, wich confirmed the initial attribution.

At the same time, the visual analysis of the instrument and the comparison between the images obtained and the information available on the Nonemacher's existing instrument confirmed the original state of the instrument and excluded any major intervention of adaptation (pegboard reduction or neck substitution).

Discussion

The approach described in the article illustrates the practices usually adopted by a museum conservator to study and identify an object: photography, microphotography, sometimes microscopy, measurements with rulers and calipers, visual observation and style analysis are the empirical tools use everyday, sometimes flanked and supported by radiographies or computed tomographies.

The preliminary informations obtained are necessary and constitute the starting point to plan more in-depth analysis (chemical, acoustical and physical) in order to answer to more specific questions (i.e. history of technique, varnish analysis, wood identification).

STUDY AND CHARACTERIZATION OF ANTONIO STRADIVARI'S HANDWRITINGS

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Introduction

The Museo del Violino in Cremona holds the most important collection of Antonio Stradivari's finds from his workshop, as well as different wooden forms, drawings, annotations and tools. After Antonio Stradivari's death in the first half of the 18th century, the content of his workshop was acquired by Count Cozio di Salabue and eventually transferred to his heirs until, in 1920, it came into the hands of Giuseppe Fiorini who donated it to the City of Cremona ten years later. Over the centuries new annotations and handwritings were added to the original finds, often imitating Stradivari's handwriting. Today, a lot of Stradivari's items in the museum have annotations, few letters and words or longer lines, written by one or, sometimes, even two or more hands [Pollens, 1992; D'Agostino 2005].

The present preliminary research is aimed at identifying the items whose annotations may be attributed to the hand of Antonio Stradivari.

The finds that are object of this research were selected on the basis of their historical importance and the study was performed through a rigorous paleographical method and different spectroscopic techniques as well as IR reflection technique and X-ray fluorescence.

Methods

The handwriting of documents certainly attributed to Antonio Stradivari was studied both in its general shape and analytically, considering each letter and the most significative bindings. Starting from this detailed paleographical analysis, the finds selected by the Museum conservator with uncertain annotations were examined and compared with the original ones. The finds and the inks of the different finds were analysed by "ELIO" portable ED-XRF spectrometer, with a Large Silicon Drift Detector, a resolution <135eV, tube power 10 to 50 kV, 5 μA min / 200 μA max. The organic materials were investigated by an IR ALPHA-R spectrometer (Bruker) with external reflection technique, resolution 4 cm^{-1}, spectral range 4000 – 360 cm^{-1}, software Opus, working distance 15 mm.

Results

The analyses performed on the finds showed generally a strong alteration of the inks, with a strong chromatic variation and a widespread corrosion of the cellulosic materials.

A shellac protective film was characterized on the wooden finds [Derrik, 1989]. The elemental composition of different inks was performed and the results could be correlated to the paleographical ones.

All the inks analyzed seem to have a classical elemental composition of the Iron gall inks, with a variation in the Fe and Cu contents [Bicchieri et al, 2008].

A high concentration of Calcium was detected in all the wooden finds attributed to Antonio Stradivari.

Discussion

Different handwritings of Antonio Stradivari were identified by the paleographic study and the XRF analysis could support the attribution by the ink composition, especially in the Cu content that seems to be a marker in the Stradivari ink identification. The high content of Ca in the wood could be ascribable to a preliminary treatment by Calcium caseinate.

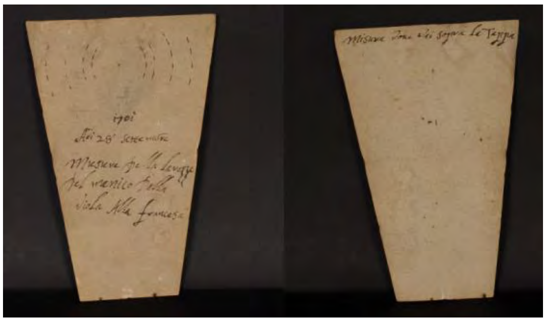

Figure 1: Antonio Stradivari handwritings on paper finds

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COMPARATIVE STUDY OF RUCKERS INSTRUMENTS

Simon Egan, Manu Frederickx, Livine Huart, Dr. Pascale Vandervellen

Musical Instruments Museum, Belgium

Introduction

It was communicated at the first COST meeting in Paris, February 2014, that the Musical Instruments Museum (MIM), Brussels, is currently engaged in a comparative study on Ruckers instruments. The focus is on 18 harpsichords and virginals in its collection. Eight people from the MIM and eight people from outside (Laboratory department of the Royal Institute of Cultural Heritage, Antwerp University, Erasme Hospital, …) are involved in this research project which aims first to document the complete history of each instrument from its original to its actual state, and secondly to determine the best restoration options. As with Stradivari's or Guarneri's instruments, most of the Ruckers instruments have been altered: their keyboard compass has been increased, their soundboard barrings reinforced, their strings and jacks replaced, etc., and their original decoration changed for restoration purposes or to follow new decorative fashions. Furthermore numerous falsifications and copies of Ruckers instruments have been made as early as the 17th century, sometimes with great talent. It is not always evident to identify all or parts of the instruments originally made by the Ruckers family.

Methods

To fulfil the aims defined several paths of investigation are being perused. Beside iconographical research to gather information about Ruckers instruments represented in paintings, research in museum archives to establish the instruments provenance, and organological analyses including visual examination of the instruments, photographic documentation and measurements resulting in an exhaustive database with plans of the instruments, we are using several facilities such as:

- dendrochronology of the soundboard to obtain identification, dating and geographic provenance of the wood used;
- CAT scanning or x-radiographs to better understand the internal structure;
- ultra-violet and infra-red imaging, macro-photographs, pigment and medium analyses, stratigraphy of the paint layers (X-ray fluorescence, FTIR, Micro-Raman spectroscopy and scanning electron microscopy), characterization of the paper pulp composition (transmitted light microscopy) to distinguish the various stages of the instruments decoration.

Results

Different researchers such as Grant O'Brien [O'Brien, 1990] have established the main characteristics of Ruckers instruments but there still remain many unanswered questions about the materials and technics used by them and their contemporary Flemish virginal and harpsichord makers. The first results of this multidisciplinary approach show to what degree these methods of examination can help to distinguish the various stages of the Ruckers instruments history.

Discussion

To what degree do these advanced techniques of exmination lead to a greater understanding of the Ruckers production at its origin, and to the actual state of the instruments now? In what ways do they provide irrefutable evidence in deciding the authenticity of part, or all of an instrument? How far do they help in the supplying information for conservation and restoration?

Thanks to all the team involved in this project, e.g., Joris De Valck, head of the mim conservation workshop, Simon Egan, mim painting conservator and photograph, Agnès Esquirol and Livine Huart, mim painting conservators, Michel Tuerlinck, instrument maker and draughtsman; Marcel Vekemans, musicologist, Emily Ackermans, student in conservation-restoration of the Antwerp University, Pr. Dr. Balériaux, neurologist at the Erasme Hospital, Dr. Christina Currie, Catherine Fondaire, Dr. Steven Saverwyns, Dr. Marina Van Bos and Ina Vanden Berghe, scientists at the Royal Institute of Cultural Heritage, and Arjan Versteeg, instrument maker and dendrochronologist.

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INVESTIGATIVE METHODS FOR THE STUDY OF HISTORICAL GUITARS: ANTONIO DE TORRES, A CASE STUDY

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Introduction

While scholars may continue to debate the actual contributions that Torres has made to the design of the modern guitar, there can be no doubt that in the history of the classical instrument Torres stands as the one pre-eminent figure in guitar design. No other maker since Torres has exerted quite the same influence on guitar design. This significance can be compared to that of Stradivari on the violin makers' tradition.

It is estimated that Torres' output was approximately 320 guitars. In 1997 José Romanillos, in his updated catalogue, claimed to account for eighty-eight of these instruments. However, a number of instruments were included on questionable grounds.

Today, twenty-seven years since the first published catalogue, the number of identified instruments has risen to about one hundred. Yet the number of spurious examples is much higher, and there are more people whom claim to own a guitar by Torres than he actually made. There are more fakes and questionable instruments than in the case of any other Spanish guitar maker.

Methods

By using a number of well-preserved examples of genuine guitars made by Antonio de Torres, and which represent a cross section of Torres' work, this paper sets out scientifically to explore the 'fingerprint' of this most celebrated maker. In order to fully understand the genius of Torres' work, and to identify which guitars were made by his hand, a brief survey of his construction methods and materials were made. This was achieved by internal examination of the guitars using x-ray and other penetrating techniques, thus enabling one to study Torres' construction more closely. It was also necessary to identify the woods that Torres used by employing microscopic techniques. The paper labels inside his guitars, and the tool marks left behind by Torres, were also scrutinized. With the assistance of Peter Ratcliff, the soundboards were dated using dendrochronology and the results were cross-referenced with other Torres guitars helping to build up a profile of this maker. A comparative study of both Torres' predecessors and contemporary guitars was also undertaken. This enabled one to authenticate his guitars by applying and establishing these newly developed analytical techniques.

Results

The current catalogue of known Torres guitars, as a result, can be revised and extended by adding approximately twenty recently discovered examples. It was found that many spurious Torres guitars can be readily discounted by close scrutiny and comparison with the many facets that are now understood to define a genuine Torres guitar.

Discussion

With guitars ever increasing in value — perhaps recently bridging the gap between guitars and violins — the need to develop methods for authentication of guitars is becoming ever more important.

This kind of work could also be extended to other prominent makers where there are also problems of attribution, among them Pierre René Lacote and Johann George Stauffer of the early nineteenth century, Santos Hernandez and Domingo Esteso in the early twentieth century.

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With special thanks to Peter Ratcliff (dendrochronology), Lewis Jones, Sue Newton-Short, Malcolm Maxwell, David Whiteman, and the Staff of Nuffield Health, Brighton (x-ray imaging).

Biography

Dr James Westbrook is a British-based organologist whose particular interest is in guitar construction. He is the author of two popular books: *Guitars through the Ages* (2002) and *The Century that Shaped the Guitar* (2006) as well as co-author of *The Complete Illustrated book of the Acoustic Guitar* (2012). He has given papers for Cremona Mondomusica, The American Musical Instrument Society and The San Francisco Conservatory of Music. James has recently published in *Early Music*, *The Journal of the Lute Society* and *the Soundboard Journal* and contributed a chapter in

Inventing the American Guitar: The Pre-civil War Innovations of C. F. Martin and his Contemporaries. In 2010 James was awarded the O'May studentship, for his Doctoral research in to Guitar Making in Nineteenth-Century London at the University of Cambridge. He is a consultant and specialist for *Brompton's* a London auction house, specializing in musical instruments, as well as a part-time luthier and restorer. James is currently a member of the Research staff at The University of Cambridge, Music Faculty, and he holds a Wolfson College, Cambridge, Research Fellowship; investigating 'The Life and Work of David Rubio'.

“A MISSED LINK IN THE HISTORY OF THE SPANISH GUITAR:

BENITO CAMPO GUITAR 1840 AND DIONISIO AGUADO’S TRIPODIUM”

Daniel Gil de Avalle

1. Guitar-Maker and Luthier, Spain

Introduction:

ANALYSIS OF THE ROMANTIC GUITAR BENITO CAMPOS LABELED 1840: evolution of the classical-romantic guitar towards the modern guitar during the second half of the XIX century. The guitar was restored by the Spanish guitar-maker and luthier Daniel GIL DE AVALLE and is part of his private collection of romantic guitars.

Figure 1: Label

ANALYSIS OF THE RECOVERING AND RECONSTRUCTION OF DIONISIO AGUADO’S TRIPODIUM: A revolutionary device in the XIX century, missed in time till the point that there was none left. We reconstructed an exact copy from the Benito Campo’s guitar subject of this research. Aguado’s influences. The copy of the tripodium is property of the guitar-maker and luthier Daniel GIL DE AVALLE.

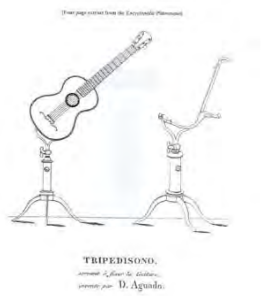

Figure 2: Aguado’s Tripodium Design

Methods:

RESTORATION OF THE BENITO CAMPO ROMANTIC GUITAR 1840,
“THE MISSED LINK”

<u>Woods:</u>
Body: Brazilian Rosewood
Top: Spruce
Fingerboard: Cameroon Ebony
Bridge with saddle: Brazilian Rosewood
Neck: Honduras Cedar

<u>Characteristics of Modernity:</u>
Quality woods
5 fan-shaped bars (Spanish style)
Cameroon ebony fingerboard on neck
Not embed 12 fret, nodal point
Ribs width

<u>Still lack of:</u>
Body measure proportionality
Wood machine-heads
628 scale length
Lack of vibrant surface (smaller plantilla)

<u>Construction</u>
Fine construction with selected woods.
Very solid construction with no marks or cuts.

Figure 3: Analysis and Restoration

A PIECE OF HISTORY: BENITO CAMPO GUITAR 1840 “THE MISSED LINK” AND DIONISIO AGUADO INFLUENCES

It shows drill holes at the bottom and neck joint heel. With a fantastic appearance and a wonderful set of Brazilian rosewood back and ribs and spruce top, this is a link guitar.

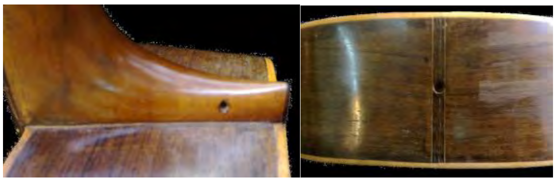

Figure 4: Drill holes at the bottom and neck joint heel

It was built after Aguado's return from Paris to Madrid; in this time Benito Campo becomes his Publisher. Aguado travelled to Paris in the 20s of the XIX century; he was tired of the conservative atmosphere prevailing in that period among luthiers established in Madrid. In Paris he contacted some important constructors like René-François Lacôte and Etienne Laprevotte, who built several instruments for him following his instructions such as Maria Antoinette of Laprevotte, a string-instruments constructor who dealt with the task of making the ordered guitar, in many aspects, as if it was a violin. When Aguado brought those instruments to Spain, he went on investigating with them on the acoustic of the guitar.
This Benito Campos Guitar of 1840 seems to be the guitar with which Aguado starts to work on his most popular harmonic proportions, since 12 fret is on nodal point, what means that if we divide the scale length in two the result is one eighth. Moreover, all the frets are metrically divided for a perfect tune, and the scale length is proportionally connected with the body length, consequently, the harmonics, fifth harmonic, La, third and fifth of the chord can be heard without any type of harmonic problems…That is the great innovation of this instrument.

BENITO CAMPO'S GUITAR AND DIONISIO AGUADO'S TRIPODIUM

What makes this guitar so special is the extrange tripod standing it. It is called tripodison, tripodísono, tripodium or even, '*fixateu*r', in French, and it was conceived in 1836 by the Spanish guitar-player Dionisio Aguado, guitar virtuoso composer and pedagogue. In fact, Aguado is considered to be one of the most innovative teachers of the XIX century. The most remarkable of fact of Aguado's School is the Tripodium, a device that affixes the guitar and is used, according to the author, to obtain the following advantages:

a) The guitar is isolated, it trembles more and the harmonic leave more clearly.
b) It is advisable for ladies not to hurt their breast
c) Due to the position, the most difficult passages get easier.
d) The frets which are closer to the mouth may be performed more easily.
e) Due to the position, the most difficult passages get easier.
f) The frets which are closer to the mouth may be performed more easily.

Results:

THE MISSED LINK

This guitar still lacks the completely modern proportions but it is breaking into a transformation; it is much more sophisticated than other more basic guitars of that time, with wider hips as compare to other contemporary guitars and very much the same that the Maria Antoinette guitar (Laprebotte) some years before, its evolution is the same: 12 fret nodal point, connecting the scale length with the body, and the bridge placed on its third part.

Figure 4: Restored guitar and Rebuilt Tripodium

GUITAR AND TRIPODIUM A PERFECT CONJUNCTION

Now, after more than a century, the two fixation pieces coincide perfectly with the two holes made in the wood of the bottom and neck joint heel of Benito Campo's instrument. Until now, these holes appeared in several guitars of that period, what explained the use of this device in theory, but it never was tested in practice before, since the tripodium life was short and there was no tripodium remaining in time.

Figure 5: The tripodium fits the drill holes at the bottom and neck joint heel

Acknowledgements

This work of restoration I carried out would not have had the same result without the research of the Guitar Professor Pablo DE LA CRUZ CONCEJAL, the design of the Technical Engineer Joaquin PIERRE of an exact reproduction of Dionisio Aguado's Tripodium, as well as the cooperation in the research work and translation of my wife Enca GONZALEZ

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