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A DATABASE LINKING WOODY SPECIES, VIBRATIONAL PROPERTIES, AND USES IN MUSICAL INSTRUMENTS OF THE WORLD

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Abstract

Very many wood species are used for building instruments throughout the world, but very little is known about this diversity. Furthermore, comparable vibrational properties of woods including damping are scarce and highly scattered.

We present here the creation of a new specific relational database conceived as a tool to gather and study these aspects. It contains three main parts. 1) Botany (Tree/wood information; links to uses/properties). 2) Worldwide instruments (with woody species used for each part). 3) Viscoelastic vibrational properties of wood. Data sources are: our own field and experimental work; literature survey including many hard-to-obtain, non-English-language sources. Summary of data at present day: instruments =circa150; “instrument part/ species used” = c850; species with checked botany= c600; species used in instruments= c300; species with viscoelastic vibrational properties = c330 (covering about 5500 tests). Examples of the analyses made possible by this databank are shortly introduced. Efforts must also be pursued on: vibrational characterization of woods; collection of wood uses in worldwide instrument making cultures.

INTRODUCTION

Wood, the main building material of many musical instruments, affects their mechanical and acoustical behaviour. Different parts, instruments and organological families lend to a broad range of material requisites. Some description and analysis of these ranges for well-known instruments can be found in [Bucur 1995; Fletcher&Rossing 1998; Wegst 2006]. Considering the lesser-studied instruments of geocultural ensembles other than Western “savant” music shows an even greater diversity of functions-chosen species. This can be related to two main factors: cultural specificities (historical pathways of instruments, aesthetic tastes, specificities of musical repertoire and of modes of playing, craftsmanship culture), and differences in locally available species. This diversity in used species is very little known, neither qualitatively, geographically, and lesser so quantitatively.

A tentative for understanding such a subject cannot rely solely –important as it is, though- on differences in local flora as, on one hand instrument makers are generally highly selective towards their materials (either local or imported), on the other hand international wood exchanges date back at least to Egyptian and Roman antiquity. It sounds necessary to also take into account both cultural factors, and material properties

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of the chosen wood species. There are very few references on such topics.... Recently, [Yoshikawa 2007] proposed some comparison and analysis of different wood choices between Japanese and Western string instruments and stated that wood choice for Biwa (Japanese lute) top plate was extremely different from Western string instrument top plates woods, using two criteria combining density and vibrational properties. Several material criteria have been designed and proposed for the characterization of wood ability to a given use –for structural, "sounding" parts- in instruments [Aizawa 1998; Barlow 1997; Haines 2000; Wegst 2006; Yoshikawa 2007]. These criteria generally comprise at least density (ρ), specific Young's modulus (E/ρ) or sound celerity ($\cong \sqrt{E/\rho}$) and damping coefficient ($tan\delta$ or Q^{-1}). Very low damping was also found to be the most important factor in the judgement of woods for xylophone-type instruments [Hase 1987; Brancheriau & al 2006; Aramaki & al 2007]. Though, comparable vibrational properties of woods including damping are rather scarce and sources highly scattered.

Beside this, an issue now facing world-wide instrument making is that of availability, conservation status, ratios of endangered species –and eventually severe trade regulations for many important instrument making species- of the favourite materials.

With these different subjects in mind, collecting in one single reference the data currently available on woody species used in instruments, on mechanical/vibrational properties of different woods, and on conservation status of species, appeared to us like a useful tool for near future, either for makers, acousticians, organologists, or (ethno-) botanists. We created a relational database that gathers together and organize such information on wood species used in musical instruments throughout the world. All used woods are included, may they be the "favourite" one for an instrument, or a "substitution wood". In this paper we present mainly the "tool" itself: how it is built (data collection and organization), its main contents and functionalities at present day. Examples of possible analyses are shortly introduced as illustrations of its exploitation.

DATA SOURCES AND DATABASE ARCHITECTURE

Information gathered in our database covers multi-disciplinary fields: organology, instrument making, (ethno-) musicology, musical acoustics, wood sciences, forestry, botany, ethnobotany... Types of sources are international including in languages (6 up to now) and include both well-distributed and "confidential" published works, specialized web sites, unpublished thesis or reports, and our own "interviews" and experimental research on wood properties [Brémaud 2006]. Throughout the different data tables listed below, each individual information is associated to the original reference from which it comes from. All consulted references are listed in detail within a separate data table and readily accessible from any point in the database. The database is organized around three main themes: "Woody species and botany", "Wood uses in musical instrument and organology" and "Viscoelastic vibrational properties of woods". Their contents and the way there are inter-related is described below.

Data on woody species & botany

Though our database is not first intended as a "botanical" tool, botanical taxonomy and information are absolutely essential to attain its goals: The one and only way of setting up dynamic, automatic relations between, on one side the uses of wood species in numerous parts of instruments, and on the other side the vibrational

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properties of the material, is a unique botanical name. In order to insure this compatibility, the first step in the implementation of data is the collection of wood names into a "Woody Species" table. The "Botanical Name" attribute is the primary key and is defined by the form "*Genus species*" (without author name). Then each record lists separately: Family, Genus, species, author, "category" (Softwood, Hardwood – Temperate or Tropical, Bamboo/Reed, Palm) and optional information such as geographical range. Botanical names collected in original references are verified (mainly with [Mabberley 2000; Earle 2007] cross-checked with other botanical sources).

This main table "Woody Species" is linked to 4 sub-tables containing additional information when available:

-A "general wood properties" table containing qualitative information such as density range, wood colour and grain, observations on woodworking.

-A "Wood & Tree" table listing observations such as other uses of the wood and of the tree, tree dimensions, local and/or international availability of wood, conservation of the species ([CITES 2007; IUCN 2007] when applicable).

-A "Common Names" table, which serves as a small dictionary, with common names encountered, language and country.

-A "Synonyms" table lists some earlier (or invalid) botanical names that might be encountered. Misspellings that are sometimes encountered are also included as such.

Searches can be run on both these later tables, to make easier the finding of a given species without knowing its valid botanical name.

Data on wood uses in musical instruments

Information has been collected from sources covering different disciplines: Ethnomusicology; organology; instrument making; history of techniques and of arts; ethnobotany; wood sciences; musical acoustics.... In the first stage, priority has been given to lesser known information such as wood uses in traditional instruments around the world. It is completed with information "Western" ones and historical uses.

Data are sub-divided on one main datatable (instruments) and one main sub-table (association "instrument part - woody species"). The "Instrument" datatable is also linked to a table listing organological classification (according to [Hornbostel & Sachs; translation by Baines 1961]).

The "Instruments" datatable contains fields such as: general name; local name; organological classification; country and region of the world; type of music; type of making; observations (conditions of use, building, some anecdotes); references; optionally a picture. One individual is generally defined by "classification – instrument– type of music/building – region - reference" (i.e. a "classical guitar" built in Latin America may well use different woods than one built in Europe).

The centre part of the database is the sub-table "association of species-instrument part". Each "individual instrument" record is linked to (N parts * N species used for this part) records in this sub table. These records include fields such as: name of the part*; broad function* (structure, accessory, decoration); botanical name and given common name of the wood used; frequency of use* of this species; quality* and criteria of choice* when specified; date of the information; and optional fields such as techniques associated, availability, observations. Each record is linked to the reference it comes from. (Fields marked with a * can be used for sorting data in queries). When entering data, the botanical name of the woody species is selected from a list generated from the "wood & taxonomy" table, so as to avoid implementation errors such as

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misspelling and also to automatically correct erroneous or invalid names in all occurrences.

Data on vibrational properties

Data come from literature survey (including unpublished sources) and our own experimental work. These data are gathered in one main datatable.

The basic set of physico-mechanical data recorded in the "vibrational properties" table contains: measurement conditions (see below); ρ = specific gravity; E = Young's modulus; E/ρ = specific modulus; $\tan\delta$ = damping (or loss) coefficient, in longitudinal direction of wood (whenever data about anisotropy where available they have been recorded also, but these are not so numerous). "Damping" properties may be expressed by different parameters in literature, according to the original scope of the study and to the measuring method. These parameters mainly included: $\tan\delta$ = loss tangent or damping coefficient (or η = loss coefficient or viscosity coefficient); λ (or δ_{log}) = logarithmic decrement; Q = quality factor; α = temporal damping. Relationships between these parameters are summarized below (eq. 1).

$$\tan\delta \cong \eta \cong \frac{\lambda\,(\text{or }\delta_{\log})}{\pi} \cong Q^{-1} \cong \frac{\alpha}{\pi f} \qquad (1)$$

if $\tan\delta << 1$ *(for wood in longitudinal direction the order is* 10^{-3}*).*
f=measurement frequency.

Damping properties being highly dependant on hygrothermal conditions and frequency range, special care had to be taken concerning the compatibility of the measurement conditions between different studies. The vast majority of implemented data had been obtained on wood samples that were stabilized in "standard air-dry" conditions (20°C & 65% Relative Humidity). Stabilized conditions between 18-25°C and 55-65%RH have been accepted as their effect (about 6% change of $\tan\delta$ on Spruce [Obataya & al 1998]) would be small as compared to intra- and inter-specific wood variability. Frequency of measurement was for the majority of tests between 200-800Hz. Here again, we accepted some performed at 800-2000Hz, as in this range the frequency dependence remains moderate [Ono & Kataoka 1979; Nakao & al 1985] and its effect would be small compared to wood variability. When available, data obtained at higher frequencies are recorded separately.

Architecture & relations

The general structure and organization of the database is presented in a schematic view on Figure 1.

All the different data contained in one table can be related to any other information of the other tables through the links with the unique "*Botanical name*" attribute. All information is also related to the original reference it comes from.

Implementation and consultation of data uses three main formularies "Woody species", "Instruments" and "Wood Properties" each of these containing sub-formularies for detailed information. Several tools are included to facilitate the navigation between the different categories of information or the search for a specific data.

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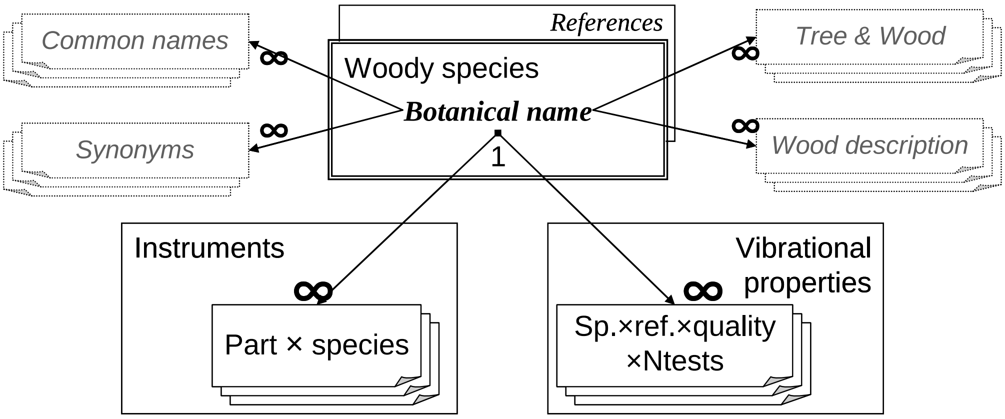

Figure 1: Schematized structure of the database and its relations. (Links to wood properties are also possible with any other existing database with records defined by "botanical name")

AMMOUNT OF DATA CURRENTLY CONTAINED

At present day, the "Woods: Uses in Instruments & Vibrational Properties" database gathers data from 73 references.

A general summary of information contained:

-596 woody species with checked nomenclature (represented by at least one of the information 'wood used in instruments' and/or 'wood vibrational properties');

-336 species with viscoelastic vibrational properties (covering >5500 tests);

-307 species with links to their uses in musical instruments (these species are associated to about 1000 common names);

-154 musical instruments "individuals" (=instrument*region and type of making)

-about 850 records "instrument part – used species" (including circa 650 for parts with a structural function).

The repartition of these data according to organological families and regions/cultures of the world are presented on Figure 2.

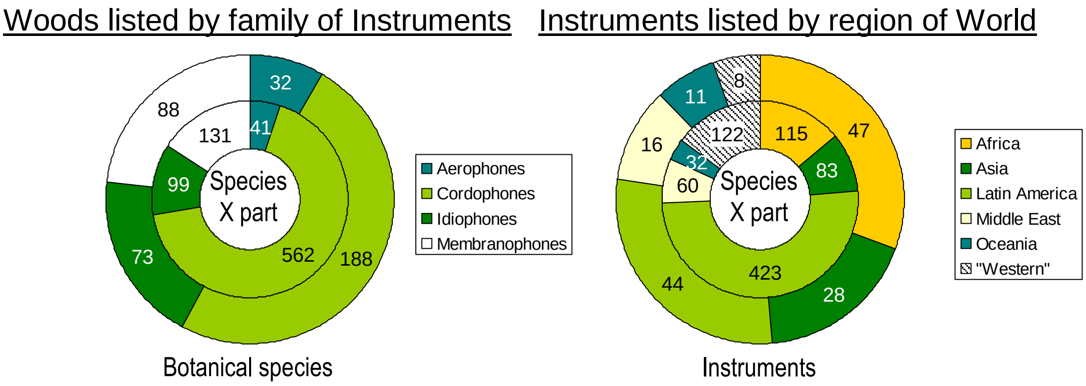

Figure 2: Repartition of information contained in the database according to: (left) organological families (number of species used and number of records of use); (right): regions/cultures of instrument making (number of instruments and number of records of use).

Wood species that are used in cordophones represent nearly 2/3 of all 307 species with uses in instruments. The total number of occurrences "species*part" is very high (due to the composed structures of many of these, and the fact that decoration and accessories are taken into account in this graph). Still, Idiophones and membranophones woods are quite well represented by 73 and 88 species and about a hundred of occurrences, but more data is needed for aerophones. As for now, ¾ of the instruments recorded are from Africa, Asia and Latin America. We are currently implementing more instruments and uses for "Western" instruments and Middle-East.

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Concerning the table "woody species & vibrational properties", the repartition of data between broad categories is shown on Figure 3.

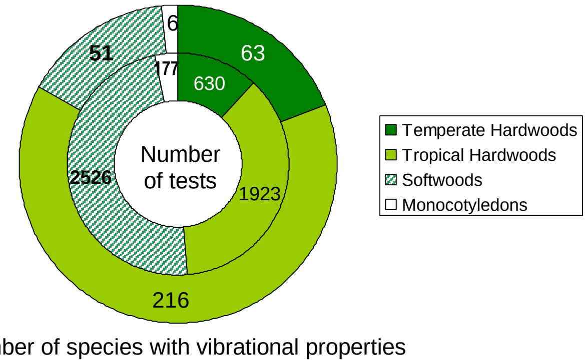

Figure 3: Repartition between categories of species of "vibrational properties" data: Number of species with properties (outside ring); number of vibrational tests (inside ring).

Tropical hardwoods represent nearly 2/3 of the species (which is still quite limited considering their diversity), temperate ones 19% and softwoods 15%. In contrast, the later benefited of nearly half the total number of tests, which corresponds to the higher research effort that has been run on woods for "Western" string instruments top plates. It would be interesting to get more knowledge on vibrational properties of monocots (reed, bamboos, palms...).

For the moment, the overlapping of the "wood used in instruments" and "woods with vibrational properties" recovers 47 species (about 15% of wood used in musical instruments of the world). Their repartition is shown on Figure 4 for the different families of instruments.

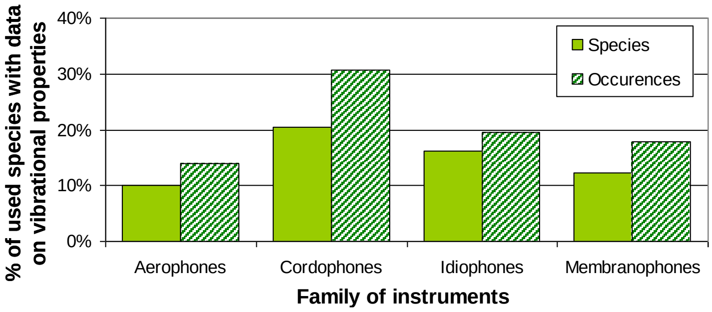

Figure 4: Proportion of species with listed used for which vibrational properties are already retrieved, depending on the different organological families.

With no surprise, the highest level of links "uses & properties measured" is observed for cordophones; on the other hand, woods used in world idiophones would deserve more research on vibrational properties. Observed levels of correspondence are higher for the occurrences than for the species, which means that the most frequently cited species are those for which more vibrational data are available, which makes sense.

Acoustical characterization of woods actually used in instruments clearly deserves more research. Though, these degrees of correspondence between "Species used in instrument" and "species with vibrational properties" are already quite high, considering that: *) diversity of woody species is enormous (maybe about 50,000 for tropical trees and shrubs); **) up to now our database records all frequencies of uses and mainly instruments from other cultures and areas than "Western music"; ***) most studies on vibrational properties of wood were not related to worldwide traditions of instrument making. The proportion of species used in instruments for which vibrational

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properties are already retrieved in our database is compared on Figure 5 between the different regions/cultures.

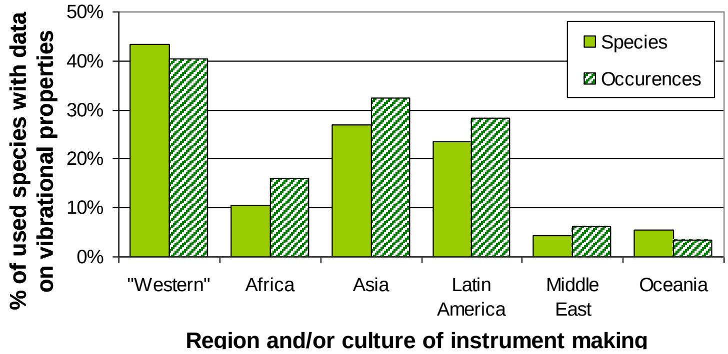

Figure 5: Proportion of species with listed used for which vibrational properties are already retrieved, depending of region/culture of instrument making.

The highest correspondence is, as expected, for Western instruments: about 40% of species, which is quite good considering that many "substitution" species are listed. Vibrational data are also found for an honest proportion of woods used in Asian and Latin American traditional instruments (more so for the most frequently used species). Specific research would be needed in instrument making woods from Africa, and critically on those from Middle-East and Oceania.

EXAMPLES OF POSSIBLE QUERIES AND ANALYSES

Many queries can be run on the whole database, to provide both qualitative and quantitative synthesis on a variety of subjects. Some possible analyses from this databank include:

i) *material variations for a given part* & ii) *cross-cultural comparison of material choice*. All species recorded in a part of instrument can be sorted out and compared, either for one single instrument (ex: woods used for top plates or body of classical guitars, including those manufactured on different continents), or in an intercultural view (ex: woods for top plates and body of cordophones in different cultures; species used in "xylophones" in the different continents). The analysis on wood choice can be based on acoustic properties whenever data exist for the species.

iii) *range of variation in vibrational properties for a given wood species, covering several researches*. Wood being a highly variable material, the confrontation of as many data as possible provides a more accurate description of a species. The acoustic properties of closely related species can also be compared, such as different species of "Spruce" or "Rosewood" for example.

iv) *pointing out lesser-known species as viable alternatives to threatened species*. It is possible to select species used in instruments according to their conservation status. Endangered ones can be compared, on the basis of their vibrational properties, to other species, including all those with no recorded uses in instrument yet.

SUMMARY

A specific relational database has been created to gather together different categories of information related to the woods used in musical instruments over the world. At present day, it contains information on more than 150 instruments; more than 300 instrument making woods covering 560 occurrences in structural parts (840 in all parts); vibrational properties including damping for ~330 species either currently used in making or not; and various information about the species themselves. Such a tool is by essence dynamic and the amount of data is being regularly increased.

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This database will allow qualitative and quantitative analysis related to the choice of wood-materials in musical instruments, both in a given instrument and in a cross-cultural perspective, and also related to the knowledge of the variability of woods' vibrational behaviour. It can also give some clues on the current issue of wood availability and threatened species in the field of instrument making.

The overlapping between woods actually used in instruments and those that have been tested for vibrational properties reveals also that much more effort is needed in material "acoustical" characterization, especially for tropical, and Mediterranean species.

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