ISMA 2014

International Symposium on Musical Acoustics

July 7 - 12, 2014 - Le Mans, France

Congress programme and abstracts

http://isma.univ-lemans.fr

Sfa

The French Acoustical Society gladly invites you to ISMA, the International Symposium on Musical Acoustics 2014. This conference will be held from July 7 to 12 in Le Mans at the University of Maine, at the site of its engineering school ENSIM.

Music and the science of acoustics have maintained close ties for a long time. Numerous researchers and engineers in acoustics come to this discipline due to their interests in music: to understand how instruments work through the means of mathematical models or experimental techniques adapted to the subtleties of musical phenomena, to analyze and synthesize the sounds produced by instruments, to decode the complex mechanisms of human perception. These are the sorts of elements which come together in the community of Musical Acoustics, today more visible and lively in numerous countries around the world. ISMA 2014 is the occasion to encounter the most recent advances of this field, with 130 papers, and 6 plenary presentations over the 6 days of the conference (5 days in Le Mans and 1 in Paris).

Music as we know it would not exist without the instruments made by the instrument builders. The conception and construction of instruments even today is often empirical and raise questions for the acoustician. Two original workshops are proposed on this theme : practical methods of instrument building presented by ITEMM (Institut Technologique Européen des Métiers de la Musique) will engender the meeting between instrument construction and acoustic research. At the Cité de la Musique in Paris will be workshops that combine the history of patrimonial instruments, instrument construction, musical performance, and acoustical science.

Because one can *hear* the solutions to its equations, acoustics is particularly well prepared for effective public dissemination of its subjects. Two events, a scientific concert by the musicians of Ophonius and a public lecture, will reveal the richness of the scientific approach.

Acoustics is well represented in Le Mans, through research, training, innovation, and dissemination, which today are gathered together in "Le Mans Acoustics", whose players wish to share with you their passion for these links between acoustics and music.

Enjoy the conference !

For the organizing committee
F. Gautier, J. Gilbert

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Université du Maine


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cnrs


Le Mans
Acoustique


ensim
Ecole Nationale Supérieure d'Ingénieurs du Mans


itemm

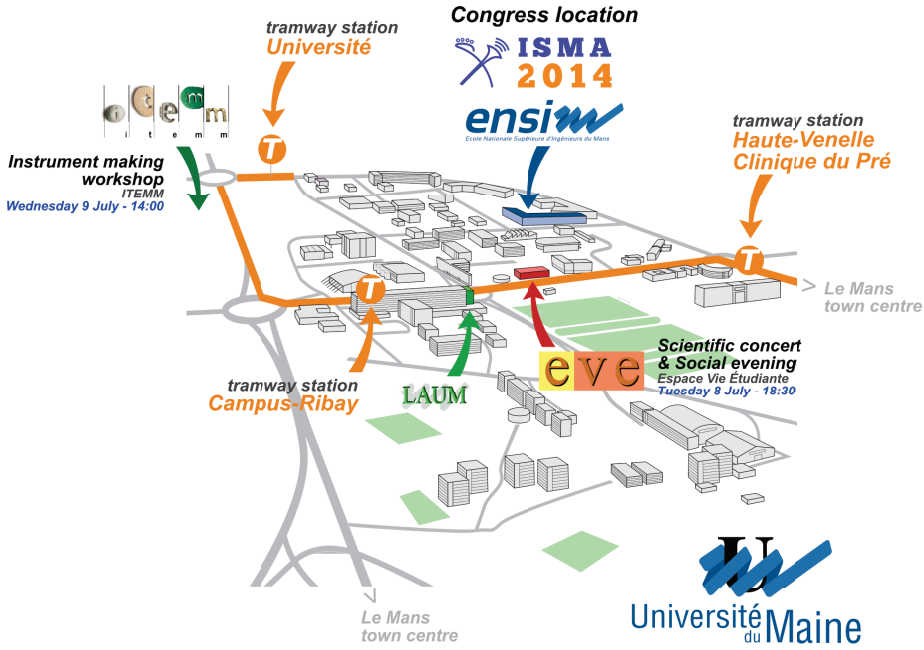

cité
de
la musique


Région
PAYS DE LA LOIRE


Conseil général
Sarthe


Le Mans
Métropole


Congress location
ISMA 2014
ensim
Travel to the Banquet
Thursday 10 July
Departure 18:15
UNIVERSITÉ
Haute Venelle - Clinique du Pré
Campus-Ribay
Instrument making workshop
ITEMM
Wednesday 9 July - 14:00
Scientific concert & Social evening
Espace Vie Étudiante
Tuesday 8 July - 18:30
Public lecture
P. Hoekje (in French)
Chapelle de l'Oratoire
Wednesday 9 July - 19:30
Reception at the City Hall
City Hall
Wednesday 9 July - 19:00
Le Mans
Cadran - Eplille
Hôpital
Théodore Monod
Gambetta - Muriers
LAFAYETTE
Eperon-Cité Plantagenêt
RÉPUBLIQUE
PRÉFECTURE
Travel to the Banquet
Thursday 10 July
Travel to the Banquet
Thursday 10 July
Leclerc-Fleurus
Gares
Zola
Mauluis
Jaurès-Pavillon
Train station
Churchill
SAINT MARTIN
Pontlieue
Atlantides-Sablons
Ile aux Sports
Epau-Gué Bernisson
ESPAL-ARCHE DE LA NATURE
Banquet
Abbaye de l'Epau
Thursday 10 July - 19:00


Congress location
ISMA 2014
ensim
Ecole Nationale Supérieure d'Ingénieurs du Mans
tramway station
Université
Instrument making workshop
ITEMM
Wednesday 9 July - 14:00
tramway station
Haute-Venelle
Clinique du Pré
Le Mans
town centre
Scientific concert
& Social evening
Espace Vie Étudiante
Tuesday 8 July - 18:30
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tramway station
Campus-Ribay
LAUM
Le Mans
town centre
Université du Maine


Rue Aristophane
ensim
Ecole Nationale Supérieure d'Ingénieurs du Mans
Poster room 2
LAUM
cafeteria
C02
amphithéâtre
C03
C08
C05
Lunch room
Preview room
Poster room 1
Conference room
Rue Aristote

Daily programme

Monday 7 July 2014	
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08:15	
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14:00	**Registration**
14:15	
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16:00	**Opening ceremony**
16:15	Conference room
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16:45	
17:00	**Plenary lecture M. Campbell**
17:15	Conference room
17:30	17:35
17:45	**Plenary lecture S. Vaiedelich**
18:00	Conference room
18:15	
18:30	**Promenade concert: La Fausse Compagnie**
18:45	
19:00	**Cocktails and dinner**
19:15	Poster room 1
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Tuesday 8 July 2014		
08:00		
08:15		
08:30		
08:45	**Keynote lecture J. Kergomard** Conference room	
09:00		
09:15		
09:30	Oral session S1a **Waveguides** Conference room	
09:45		
10:00		
10:15		
10:30	**Coffee break**	
10:45		
11:00	Oral session S1b **Regimes of oscillation** Conference room	Poster session P1 **Waveguides** **and Regimes of oscillation** Poster room 1
11:15		
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12:15		
12:30	**Lunch**	
12:45		
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14:00	Oral session S2a **Vibrating structures** Conference room	
14:15		
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15:30	**Coffee break**	
15:45		
16:00	Oral session S2b **Non-linearities** Conference room	Poster session P2 **Vibrating structures,** **Non-linearities** **and Excitation mechanisms** Poster room 2
16:15		
16:30		
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17:00	Oral session S2c **Excitation mechanisms** Conference room	
17:15		
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18:30	**Scientific concert: Ophonius** Espace Vie Étudiante, Université du Maine	
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19:30	**Cocktails and dinner** Espace Vie Étudiante, Université du Maine	
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20:30	**Social evening / open scene** Espace Vie Étudiante, Université du Maine	

Wednesday 9 July 2014

08:00		
08:15		
08:30		
08:45	**Keynote lecture I. Bremaud**	
09:00	Conference room	
09:15		
09:30	Oral session S3a	
09:45	**Materials for musical instruments**	
10:00	Conference room	
10:15	**Coffee break**	
10:30		
10:45	Oral session S3b	Poster session P3
11:00	**Instrument making**	**Materials for**
11:15	Conference room	**musical instruments**
11:30		**and Instrument making**
11:45		Poster room 1
12:00		
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12:30	**Lunch**	
12:45		
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13:45		
14:00	**Instrument making**	**Visit of ITEMM**
14:15	**workshop**	ITEMM, Le Mans
14:30	ITEMM, Le Mans	
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15:00		**Coffee break**
15:15		Poster session P4
15:30		**Tools for instrument makers**
15:45		ITEMM Hall
16:00	**Coffee break**	**Instrument making**
16:15	Poster session P4	**workshop**
16:30	**Tools for instrument makers**	ITEMM, Le Mans
16:45	ITEMM Hall	
17:00	**Visit of ITEMM**	
17:15	ITEMM, Le Mans	
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19:00	**Reception at the City Hall**	
19:15	City Hall, Le Mans	
19:30	**Public lecture P. Hoekje (in French)**	
19:45	Chapelle de l'Oratoire, Le Mans	
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Thursday 10 July 2014		
08:00		
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08:45	**Keynote lecture C. Waltham**	
09:00	Conference room	
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09:30	Oral session S4a	
09:45	**Cool instruments**	
10:00	Conference room	
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10:30	**Coffee break**	
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11:00	Oral session S5b	Poster session P5
11:15	**Impact excitation**	**Cool instruments,**
11:30	Conference room	**Impact excitation**
11:45	Oral session S5c	**and Player gesture**
12:00	**Player gesture**	Poster room 1
12:15	Conference room	
12:30	**Lunch**	
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14:00	Oral session S6a	
14:15	**Singing voice**	
14:30	Conference room	
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15:30	**Coffee break**	
15:45		
16:00	Oral session S6b	Poster session P6
16:15	**Perception**	**Singing voice**
16:30	Conference room	**and Perception**
16:45		Poster room 2
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19:00	**Banquet**	
19:15	Abbaye de l'Epau, Le Mans	
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Friday 11 July 2014	
08:00	
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08:45	**Keynote lecture S. Bilbao**
09:00	Conference room
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09:30	Oral session S7a
09:45	**Numerical simulation of musical sound**
10:00	Conference room
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10:30	**Coffee break**
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11:00	Oral session S7b
11:15	**Experimental methods**
11:30	Conference room
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12:30	**Lunch**
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14:00	**Closing ceremony**
14:15	Conference room
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Saturday 12 July 2014	
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10:00	**Scientific concerts at the museum**
10:15	**Interactive concert 1: organ J. Schweickart**
10:30	Cité de la Musique, Paris
10:45	room 1
11:00	**Coffee break**
11:15	**Interactive concert 2: North India rudra vina**
11:30	Cité de la Musique, Paris
11:45	room 2
12:00	**Coffee break**
12:15	**Interactive concert 3: ondes Martenot**
12:30	Cité de la Musique, Paris
12:45	room 3
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Plenary and keynote speakers

Murray Campbell

Musical acoustics for musicians
Monday 7 July 2014 17:00 Conference room

Murray Campbell studied physics at the University of Edinburgh, graduating BSc in 1965 and PhD in 1971. His research work in electron spin exchange phenomena included a lengthy collaboration with colleagues at the Ecole Polytechnique near Paris. In 1985 he founded the Musical Acoustics Research Group at the University of Edinburgh, and in 2000 was appointed Professor of Musical Acoustics. He is now Professor Emeritus and Senior Professorial Fellow at Edinburgh, where he continues to carry out research on the acoustics of lip-excited wind instruments. He is a Fellow of the Royal Society of Edinburgh, the Acoustical Society of America and the Institute of Physics. In 2000 he was awarded the Médaille Etrangère by the Societé Francais d'Acoustique. He is also an active musician, performing in and directing the Edinburgh Renaissance Band and the Scottish Gabrieli Ensemble, conducting a mixed voice choir, and playing trombone in a jazz ensemble and a symphony orchestra.

Stéphane Vaiedelich

Conservation and restoration of historical musical instruments
Monday 7 July 2014 17:45 Conference room

Stéphane Vaiedelich was violin maker and his work obtained several awards in international violin making competition (musicora price in 1999). He studied musical acoustic at the Paris university of Pierre et Marie Curie and obtained his master degree in material chemistry in 1992 (Université de Toulon et du Var). Head of the laboratoy of musum of music (research and conservation laboratory) since 2001 he received his master degree in conservation from La Sorbonne – Paris I, in 2002. Its researches focuse on history of musical instrument making and its conservation, wood properties, knowledge of material used in instrument making and Organology.

Jean Kergomard

Regularity and irregularity in acoustic wind instruments
Tuesday 8 July 2014 08:45 Conference room

Since 1973 Jean Kergomard is researcher at Centre National de la Recherche Scientifique, successively in Paris, Le Mans and Marseilles. His dissertation (1981) was entitled: Internal and external field of wind instruments. In Le Mans he studied several topics related to propagation in ducts, such as dissipation, discontinuities, effects of periodic and random diffusors, automotive mufflers, non-locally absorbing materials for aircraft engines, and musical instruments. Since 2000, in the Laboratoire d'Acoustique et de Mécanique in Marseilles, he has investigated self-sustained oscillations of wind instruments and modal decomposition in dissipative or active media. He recently was president of the French Acoustical Society (SFA) then of the European Acoustics Association (EAA), and presently is the Editor-in-Chief of Acta Acustica united with Acustica.

Iris Brémaud

A "sound" choice: multi-criteria selection of material for instrument making from wood science viewpoint
Wednesday 9 July 2014 08:45 Conference room

Iris Brémaud is researcher at CNRS-National Centre of Scientific Research in the "Wood Team" of Laboratory of Mechanics and Civil Engineering in Montpellier. After training initially in plant biology and in guitar and lute making, in 2000 she specialised her work on woods for musical instrument making through her MSc in Wood Science and PhD in Mechanics. Her dissertation was on "diversity of woods used or usable in musical instruments making". She subsequently continued research on this topic, focusing on cross-cultural views and on the structure-chemistry-properties relationships in wood mechanics, as a Post-Doc researcher at Kyoto Prefectural University, then at INRA-National Institute for Agronomical Research in Nancy (France), and at EMPA-Swiss Federal Laboratories for Materials Science and Technology.
Her current research in Montpellier aims at a systemic approach of wood behaviour, diversity and cultural uses, by relating fundamental wood rheology to botanical origin and to traditional knowledge of wood craftsmen, still with a focus on musical instruments making.

Chris Waltham

An acoustical comparison of East Asian and Western string instruments
Thursday 10 July 2014 08:45 Conference room

Chris Waltham is a professor in the Department of Physics and Astronomy at the University of British Columbia. He has spent most of his research career in nuclear and particle physics, but started working in musical acoustics several years ago. He started by working on the vibroacoustics of harp soundboxes, and more recently has become interested in Chinese instruments, particularly the *qin* and the *xiao*. An enthusiastic woodworker, he has built celtic harps, a gothic harp, and four violins, one of which he plays in Vancouver's "Little Night Music" community orchestra.

Stefan Bilbao

The Changing Picture of Nonlinearity in Musical Instruments: Modeling and Simulation
Friday 11 July 2014 08:45 Conference room

Stefan Bilbao studied Physics at Harvard University (BA, '92), then spent two years at the Institut de Recherche et Coordination Acoustique Musicale (IRCAM) under a fellowship awarded by Harvard and the Ecole Normale Superieure. He then completed the MSc and PhD degrees in Electrical Engineering at Stanford University ('96 and '01, respectively), while working at the Center for Computer Research in Music and Acoustics (CCRMA). He was subsequently a postdoctoral researcher at the Stanford Space Telecommunications and Radioscience Laboratory, and a Lecturer at the Sonic Arts Research Centre at the Queen's University Belfast. He is currently a Reader in the Acoustics and Audio Group at the University of Edinburgh. He is the leader of the NESS project, funded by the ERC, which runs jointly with the Edinburgh Parallel Computing Centre over the period 2012-2017.

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Tuesday 8 July 2014 - Non-linearities

Conference room

Chair Persons: S. Bilbao, J. Kergomard

Tuesday 8 July 2014 - Excitation mechanisms

Conference room

Chair Persons: S. Bilbao, J. Kergomard

Tuesday 8 July 2014 - Waveguides and Regimes of oscillation
Poster room 1

Tuesday 8 July 2014 - Vibrating structures, Non-linearities and Excitation mechanisms
Poster room 2

Wednesday 9 July 2014 - Keynote lecture

Conference room

Chair Persons: R. Caussé, S. Yoshikawa

Wednesday 9 July 2014 - Materials for musical instruments

Conference room

Chair Persons: R. Caussé, S. Yoshikawa

Wednesday 9 July 2014 - Instrument making

Conference room

Chair Persons: M. Curtit, J. Cottingham

Wednesday 9 July 2014 - Materials for musical instruments and Instrument making
Poster room 1

Wednesday 9 July 2014 - Tools for instrument makers
ITEMM Hall

Thursday 10 July 2014 - Keynote lecture
Conference room
Chair Persons: J.-C. Valiere, P. Hoekje

Thursday 10 July 2014 - Cool instruments
Conference room
Chair Persons: J.-C. Valiere, P. Hoekje

Thursday 10 July 2014 - Impact excitation

Conference room

Chair Persons: X. Boutillon, M. Campbell

Thursday 10 July 2014 - Player gesture

Conference room

Chair Persons: X. Boutillon, M. Campbell

Thursday 10 July 2014 - Singing voice

Conference room

Chair Persons: B. Fabre, M. Kob

Thursday 10 July 2014 - Perception

Conference room

Chair Persons: A. Almeida, C. Fritz

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Poster room 1

Thursday 10 July 2014 - Singing voice and Perception
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Friday 11 July 2014 - Keynote lecture

Conference room

Chair Persons: T. Hélie, B. Gazengel

Friday 11 July 2014 - Numerical simulation of musical sound

Conference room

Chair Persons: T. Hélie, B. Gazengel

Friday 11 July 2014 - Experimental methods

Conference room

Chair Persons: T. Moore, C. Waltham

Abstracts

Mon 17:00 Conference room Keynote lectures

Musical acoustics for musicians [000146]

M. Campbell
University of Edinburgh, Acoustics and Audio Group, EH9 3JZ Edinburgh, UK
d.m.campbell@ed.ac.uk

Musical acoustics has traditionally been considered to be a scientific discipline, and musical acoustics research is frequently carried out in the physics or engineering departments of universities and technical institutes. However musical acoustics is an unusual science in that most of its principal topics of study, including the nature of musical sound and the functioning of musical instruments, are intimately bound up with the highly subjective activities and requirements of the practitioners of the art of music: the composers who create musical scores, the performers who bring the scores to life, and the craftsmen who provide the performers with the instruments through which music finds its voice. Communication and dialogue between scientists and musicians is vital if musical acoustics is to be relevant to musicians. One way in which this communication occurs is through the formal teaching of musical acoustics; courses of acoustics have been features of the academic training of musicians since the middle of the nineteenth century, and many acousticians have risen to the challenge of convincing classes of music students that science can enrich their understanding of music theory and practice. Another important route through which scientific ideas can be communicated to musicians is through specialised musical journals and web resources, which sometimes carry misleading or ill-founded ideas and claims. Fortunately there are many composers, performers and instrument makers who are fascinated by the scientific background to their art, and the involvement of such people in research projects contributes greatly to progress in musical acoustics.

Mon 17:45 Conference room Keynote lectures

Conservation and restoration of historical musical instruments [000147]

S. Vaiedelich
Musée de la Musique, 221 avenue Jean -Jaurès, 75019 Paris, France
svaiedelich@cite-musique.fr

Objects such as musical instruments that are part of a collection, and particularly those that are part of public collection, acquire a particular status: they disseminate material and immaterial cultural values. These musical instruments are simultaneously technical objects and works of art. They are also the vector of an artistic functionality. Musical instruments are not only at the heart of musical history but also at the crossroads of art history. The Musée de la musique is in charge of the conservation of part of the national collection of musical instruments. Traditionally, instruments under our charge may undergo interventions with three different scopes: to conserve the instrument, to prepare the instrument for presentation, to return the instrument to playable conditions. Whatever the goal, research in natural science, engineering, chemistry, physics and biology (for example) all contribute to the conservation and restoration of musical instruments. The link to acoustics is obvious when returning an instrument to playable conditions In this context we present our current scientific approach. A few case studies illustrate the use of musical acoustics to conceive and choose interventions made on instruments of the collection or their facsimile. By showing the link with problems usually treated by musical acoustics, we wish to continue the fruitful partnership between our two communities for the service of knowledge and conservation of our common heritage: musical instruments.

Tue 8:45 Conference room Keynote lecture

Regularity and irregularity in wind instruments with toneholes or bells [000145]

J. Kergomard
CNRS - LMA, 31 Chemin Joseph Aiguier, CNRS - LMA, 13402 Marseille Cedex 20, France
kergomard@lma.cnrs-mrs.fr

Homogeneity of emission and timbre of musical instruments is a difficult issue. Intuitively it can be related to the regularity of the geometry, even if this relation is another difficult issue. The present talk aims at contribute to the discussion about the regularity of both woodwind and brass instruments. Benade published a paper in 1960 where woodwinds were modeled as periodic media with regular toneholes. In 1974, with Jansson, he compared bells of brass instruments and exponential horns. He had a particular interest in both the definition and the effects of cutoff frequencies for wind instruments. Recently we discussed a definition of acoustic regularity in the context of woodwinds. This work is first summarized, then some open questions are discussed concerning instruments with toneholes and with bells, starting with an analogy between exponential horns and periodic lattice of toneholes.

Tue 9:30 Conference room Waveguides

Optimization of smooth bores of idealized wind instruments with respect to basic acoustic features [000116]

T. Hélie and G. Gandolfi
IRCAM, 1, place Igor-Stravinsky, 75004 Paris, France
thomas.helie@ircam.fr

In this paper, we consider a class of simplified smooth bores of wind instruments which are composed of a mouthpiece, a cylindrical or conical pipe and a bell. The acoustic model under consideration is based on a standard matrix formalism in the Laplace-Fourier domain for which analytic formula are available. The acoustic matrix of the mouthpiece is simply modeled as a volume, to be connected to the bore. The acoustic transfer functions of the bore are derived from the smooth connection of a few lossy acoustic pipes with constant-flared profiles (governed by a refined curvilinear 1D horn equation) concatenated with a radiation load model, which is consistent with spherical wavefronts. These models have proved to be relevant, based on a comparison with measurements on a trombone bell. Then, the geometric parameters of the complete model are optimized according to a constrained objective function. This function is designed in order to reach specific acoustic targets. As special care is devoted to the tuning of the first resonances according to a ideal harmonic sequence. Results are presented for some typical cylindrical and conical chambers, corresponding to a few sketched instruments without fingerings, that could correspond to some idealized clarinets, trombones, oboes, saxophones or horns.

This work is part of the ANR project CAGIMA.

Tue 9:45 Conference room Waveguides

Simplified formulas for the quantitative evaluation of the curvature-induced mistuning in wind instruments [000136]

S. Félix[a], J. Kergomard[b] and J.-P. Dalmont[c]
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simon.felix@univ-lemans.fr

When a duct is curved, as it is often the case in wind instruments, the induced shift in the resonance frequencies of the air column is frequency dependent, resulting in a complex, though generally small, inharmonicity. As, in cases of strong curvature, this inharmonicity can be musically significant, one wishes to take it into account in models and simulation tools, in order to predict accurately the acoustical properties of a wind instrument. To this end, we describe first an exact formulation of the sound propagation in a curved duct. Then, we derive simplified formulas, that allows to account for the effect of the curvature in a simple, 1D, model of the wave guided propagation.

Tue 10:00 Conference room Waveguides

Application of global stability approaches to whistling jets and wind instruments [000021]

D. Fabre[a], P. Bonnefis[a], F. Charru[a], S. Russo[b], V. Citro[b], F. Giannetti[b] and P. Luchini[b]
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In this talk, we will discuss the application of modern methods originating from numerical fluid mechanics, namely global stability approaches, to the modeling of musical instruments. Such methods, which expand the flow as the superposition of a steady base flow and small amplitude perturbations, are particularly suited to reproduce and explain the behaviour of hydrodynamic self-sustained oscillators, such as vortex shedding in the wake of bluff bodies (Giannetti & Luchini, JFM 2005) or path oscillations of falling objects (Tchoufag, Fabre & Magnaudet, JFM 2014). Combining linear, weakly nonlinear and sensitivity approaches, these methods predict the thresholds of self-oscillation, the amplitudes of the limit cycles and the dependency to small structural perturbations, and ideally complement heavier numerical approaches such as direct simulation. We will illustrate the potential of these approaches for two situations closely related to musical instruments. The first situation is the whistling of a corrugated pipe, a situation encountered in a musical toy called the "hummer". In this case, global stability allows to characterize the hydrodynamical instability mechanism responsible for whistling, which is linked to vortex shedding at the wall corrugations. The second is the "hole-tone" (namely a jet passing two successive holes), a configuration encountered in bird calls, the kettle of a teapot, or human whistling. Here also the approach leads to novel insight into the physical mechanism responsible for whistling. In particular we are able to prove that compressibility of the fluid plays a negligible role in the frequency selection, at least in the high-velocity regime. Application of these methods to other classes of instruments, especially flutes and free reeds, will also be discussed.

Tue 11:00 Conference room Regimes of oscillation

Pitch Flexibility of Brass Instruments [000065]

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To play a valved brass instrument in tune, the player must be able to bend the pitch with the lip. This study examines the influence of the structure of the instrument's impulse response on the extent to which the pitch can be bent. The impulse response of an easily playable brass instrument shows a reasonably well- defined pulse at one period of the nominal fundamental frequency of the instrument, corresponding to the propagation time from mouthpiece to bell and back. In an instrument where the frequencies of most of the strong air-column resonances are very close to integer multiples of the nominal fundamental, this reflected pulse is relatively tall in amplitude and narrow in time. In an instrument where these resonance frequencies depart more from multiples of the fundamental, the reflected pulse is somewhat lower and broader. The hypothesis tested here is that a lower, broader, reflection allows the player greater pitch flexibility than a taller, narrower reflection. This is studied in a numerical simulation combining a simple model of the lip with measured impulse responses of real instruments.

Tue 11:15 Conference room Regimes of oscillation

On the Playability of Wolf Note [000010]

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In the musical world, a wolf note is an unpleasant warbling note often found on heavier strings of bowed string instruments, especially the cello. Past research suggested that the wolf note, which is an obvious playability issue, intimately relates to the minimum bow force for the playing of a steady note. This paper explores the correlation between the measured minimum bow force of a cello and the subjective judgements of its wolf note by players. In our experiments, acoustical measurements of the minimum bow force were carried out on the tested cello after making controlled mechanical changes. Psychoacoustical tests on the wolf note with experienced musicians were then employed to investigate the variations of ease of playing induced by these changes. The results strongly suggest a direct link between the measurable acoustical parameter and perceptual preferences, which might inform efforts to improve the quality of the bowed string instrument in the future.

Tue 11:30 Conference room Regimes of oscillation

Harmonics generation in flute-like instruments [000097]

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This paper presents a preliminary study about the control of the spectral content by recorder players. The variation of the spectral content has been identified to be due to a change in the mouth volume. This is interpreted as following. A tuning of the vocal tract resonances may maximize the acoustic coupling that occurs with the resonator. This induces jet velocity fluctuations that strongly modify the instability mechanisms of the jet, a crucial feature of the auto-oscillation. A simplified model of jet velocity instabilities is proposed and yields promising results. The symmetrical properties of the jet perturbations are identified to be crucial for the strength of the different harmonics.

Tue 11:45 Conference room Regimes of oscillation

A revised dependence of the edge tone frequency for the first hydrodynamic mode [000113]

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The first hydro dynamic mode of the edge tone according to many publications over the years seemed to have a different behavior being a simple f∼1/L relationship than higher hydrodynamic modes, L refers to the geometric distance between flue and edge. However a correction is appropriate due to the position of the feedback dipole field near the edge, see ref.1 and applied by ref. 2. A new analysis of the precise data (ref.3) with increased length L' by the thickness of the jet (see ref. 4) with a modified function f∼1/L'^ n yields consistently n=1.2. This result

is interesting in view of the theoretical deduction of the edge tone by Crighton ref. 5. In fact the evaluation of the dispersion relation of the feedback problem should be modified by an accurate approximation of the phase velocity, not restricted being relevant at very small Strouhal numbers only, see ref.6. In this experiment, actually by most similar experiments with quasi laminar flow Strouhal numbers reach up to the order of 1. The fit value of n based on above data matches the thus modified result of Crighton by replacing the power n=3/2 by n=1.25 in his relation.

1. Powell, A., JASA 33, 395(1961), 2. Aussserlechner et al., JASA 126, 878 (2009), 3. Bamberger, A. et al., JAMM 84, 632 (2004), 4. Verge, J.-P. et al., JASA 101, 2925(1997), 5. Crighton D. G., JFM 234, 361(1992), 6. Ronneberger D., private communication (2014)

Tue 12:00 Conference room Regimes of oscillation

Attack transients in clarinet models with different complexity - a comparative view [000068]

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Recent works on simplified clarinet models using results from dynamic bifurcation theory have allowed to predict the evolution of the amplitude of sound (the amplitude envelope) for a gradual increase of the blowing pressure. The unrealistic model that predicted the amplitudes to attain very small values, far below the precision of a computer, was later corrected by the addition of stochastic noise to the model. The two models are useful in explaining and understanding why the oscillations appear with a delay relative to the threshold of oscillation that is predicted by purely steady-state models.

Both the model of the instrument and that of the noise are extremely simplistic, raising the question of its applicability to real instruments. These models can however be made gradually more complex by introducing more realistic details in the reed or in the resonator, and applying parameter profiles with more complex shapes or noise amplitudes. This presentation shows the differences encountered in the time-evolution of the acoustic wave simulated using two models of different complexity, one with an instantaneous reflection function, another with dispersion. The article explores to which extent can the dynamic predictive model be used to describe the time evolution of more realistic models, and hopefully that of the real instrument.

Tue 12:15 Regimes of oscillation

Formant Analysis of Altered Notes in a Diatonic Harmonica [000081]

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Professional diatonic harmonica players are able to play half-step notes which are not in the standard frequency settings using bending techniques. By changing the shape of the vocal tract, the timbre of the sound changes and the notes bend. This way, players are able to play a full chromatic scale by using altered notes. This paper tries to explain the altered notes phenomenon in terms of formants. Our experiments demonstrate that there is a relation between formants and pitch frequency while a note bends.

Tue 14:00 Conference room Vibrating structures

Modal Analysis of the Persian Music Instrument Kamancheh: An Experimental Investigation [000082]

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The kamancheh is an originally Persian bowed string instrument which is a spike fiddle with a membrane closing the sound box. The resonance box is usually made of elm wood and includes no sound holes; therefore, it is novel in terms of acoustical analysis. In this paper, it is further assumed that the membrane processes isotropic properties subjected to some pre–stress. Experimental modal analysis is performed on the instrument with focus on the membrane's vibration across a frequency range from 150 Hz to 3.2 kHz. An in–house measurement setup is formed by a Polytec PSV400 scanning laser vibrometer while the bridge sitting on the membrane of the kamancheh is directly excited by means of electromagnetic shaker with periodic chirp signal. The dynamic responses measured

by the vibrometer are next treated in a modal post–processing stage in order to extract the modal data, i.e. natural frequencies, mode shapes and damping with a high level of accuracy. The experimental data are employed to compare with a finite element model from literature to have a first image of the membrane behaviour.

Tue 14:15 Conference room Vibrating structures

Modification Design of Harmonic Sound Plate with Equal Width for Metallophone [000012]

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The percussion sound of metallophone bar is related to structural modal parameters, in terms of natural frequencies and mode shapes. The harmonic sound plate (HSP) that is a special shape of plate can produce the harmonic sound effect, i.e. the overtone frequencies possess integer ratios with respect to the fundamental frequency. The HSP is potentially applicable to construct a brand new percussion instrument similar to metallophone or xylophone. This work investigates the modification design of HSP so as to make a commercial percussion instrument. The basic design of HSP is first reviewed by showing its percussion sound characteristics relevant to structural vibration modes. The percussion sound spectrum of the HSP reveals three major frequencies with harmonics corresponding to different vibration modes. The prototype of new metallophone consisting of a set of HSPs is also introduced. The initial design concept is to enlarge or reduce the size of HSP proportionally in order to fit the pitch frequency. The metallophone set becomes bulky and not easy to play. Design considerations for the improvement of commercial product of metallophone are discussed. Finite element analysis (FEA) is then adopted to perform sensitivity analysis on geometry parameters and determine final design of HSP geometry such that the HSPs can not only generating harmonic sound effect for different pitch frequencies but also have about the equal width. The conceptual design of new type of metallophone can be finalized and ready for manufacture.

Tue 14:30 Conference room Vibrating structures

Radiation Efficiency and Sound Field Measurements on Stringed Musical Instruments [000042]

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The radiation efficiency, η, is defined as the ratio of the acoustical power output to the mechanical power input. The mechanical power input and acoustical power output were measured on a set of freely suspended stringed musical instruments in an anechoic chamber. The instruments were excited on their bridges using an instrumented impact hammer and the velocity response was measured using an accelerometer. The sound pressure response from the instrument was measured at 324 locations on two concentric measurement spheres using two microphones. The power input was determined by taking the cross power spectrum of the force and velocity. A spherical-harmonic decomposition algorithm was used to calculate the source strengths of the monopole, dipole and other higher-order contributions to the radiated sound fields. Using these source strengths, the acoustical power output was calculated for monopoles and dipoles. The total radiation efficiency and that of the individual components is presented in the frequency range 80 Hz to 2000 Hz. The three instruments studied were a classical guitar (BR2), a carbon fibre steel string guitar (X10) and a violin. At lower frequencies within this range the output power for all three instruments is dominated by monopole radiation. At higher frequencies the dipole components contribute more to the output power. It was found that the peak values of η do not coincide with known body modes for the two guitars. Normalised sound pressure fields are shown for frequency ranges where the sound pressure profile changes from a monopole to a dipole.

Tue 14:45 Conference room Vibrating structures

Prediction of orthotropic ribbed plates' vibro-acoustics mechanisms: application to the piano soundboard [000040]

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Since the strings of a piano cannot radiate sound due to their small sections, the vibrations are transmitted through the bridges to the piano soundboard to increase radiation. This complex structure is made of a main spruce panel ribbed by several beams (ribs) in a direction orthogonal to the grain, and by two curved beams (bridges) in a direction nearly parallel to the grain.

To understand the influence of superstructures (ribs, bridges) on the vibro-acoustic behavior of the soundboard, an analytical modeling is presented here based on a variational approach taken into account plate's and ribs' energies.

The study is carried out on a simplify rectangular soundboard with special orthotropy and a single straight bridge. Bending, torsion and offset of beams are taken into account.
In order to calculate the eigenmodes of the ribbed orthotropic plate, the whole vibratory problem is decomposed on the basis of simply supported unribbed plate modes. Examples of modal shapes of the soundboard and images of the plate's velocity field in response of a driving force applied to the bridge are given. The influence of the bridge and the localization phenomenon above roughly 1kHz will be discussed.
This analytical methodology appears as an alternative for the finite element modeling and is particularly adapted for a parametrical study. The numerical tool developed can be used by piano manufacturers to predict the influence of the numbers/geometry of ribs and bridges on the sound of the instrument.

Tue 15:00 Conference room Vibrating structures

Vibro acoustic modeling of wall vibrations of a trumpet bell [000098]
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A considerable acoustic effect of structural bell vibrations has been consistently observed in a series of experiments on whole brass wind instruments (e.g. Acustica **91**(3), 578-589, 2005 or J. Acoust. Soc. Am. **128**, 3161-3174, 2010) as well as on trumpet bells without bends and braces (ISMA 2014, same authors). Those straight bells have been especially manufactured with the aim to allow physical modeling using simplified axi-symmetric 2D models and to avoid many of the complications of real world musical instruments. Good agreement was achieved between such structural simulations and corresponding experiments, besides the fact that the usual manufacturing process did not allow to keep wall thickness constant around the perimeter, a fact which cannot be taken into account by axi-symmetric modelling. Good agreement was also achieved between input impedance simulations and experiments done with and without damping sandbags. Theoretically wall vibrations have been modelled as distributed air density fluctuations due to the vibrating boundary. Transmission function measurements, however, consistently deviated from theory, triggering an exhaustive search for possible explanations. Investigating several possible reasons for that divergence increased the understanding of underlying mechanisms and eventually led to a hypothesis explaining the observed results. New preliminary measurements do confirm the postulated effect and their results are in good agreement with theory now. The bottom line is that wall vibrations of trumpet bells can affect input impedance and transfer function in a frequency range containing two to four natural notes in a region around the bell's structural resonance by up to several dB.

Tue 16:00 Conference room Non-linearities

Nonlinear Effects at Woodwind Toneholes [000016]
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Direct numerical simulations of the aeroacoustics of the recorder are used to study the flow of air near a tonehole. Our calculations are based on the Navier-Stokes equations and are thus able to study the nonlinear effects that occur at high sound pressure levels. We find, in agreement with recent experimental work, that nonlinear effects are largest on the downstream edge of a tonehole that is inside the recorder tube. Quantitative results for the velocity field are presented and the effect of undercutting of the tonehole are also described.

Tue 16:15 Conference room Non-linearities

Derivation of Nonlinear Coupling Coefficients in Internal Resonance Formulation of Cymbal Vibrations [000127]
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This paper is devoted to the construction of sound source of electronic cymbal, which can provide natural behavior. The parameters describing the internal resonance in cymbal were measured. Tone of cymbal greatly depends on the strength of excitation. This is caused by the energy transition, which is called internal resonance, from some vibrational modes to higher-order modes when the cymbal vibrates at large-amplitude. Sound source of electrical cymbal is required to reproduce dynamic change of cymbal tone. In addition, to synthesize the cymbal tone with a little latency, it is important to reproduce the internal resonance by low calculation cost. In our previous study, the sound synthesis algorithm for cymbals by time temporal changes of paralleled oscillators those express vibrational

modes is proposed. Moreover it became clear that the amplitude of high-order modes is proportional to the square of the amplitude in low-order modes with a sinusoidal excitation. However, the proportionality coefficient equivalent of non-linear coupling coefficient is only derived experimentally. In this paper, we measured the internal resonance for some companion modes whose eigen frequency ratio is 1:2. Therefore we derived non-linear coupling coefficients using parameter of eigenmodes. Further, we compared them with the non-linear coupling coefficients determined experimentally in a real cymbal due to confirm the suitability of formula. As a result, we confirmed the suitability. This result contributes to construction of a sound source of cymbals expressing natural behavior.

Tue 16:30 Conference room Non-linearities

Nonlinear Effects in Drum Membranes [000103]

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The linear behaviour of drum membranes has been extensively studied and is now well understood. Particular attention has been devoted to modal analyses of circular drum heads, and good agreement has been found between experiment and theory. Up to now, however, there has been relatively little investigation into the relevance and nature of nonlinear effects in drum membranes.

Stiff strings and stiff plates, however, have seen a good deal of such investigation: pitch glides and the migration of energy towards higher frequencies are typical phenomena that can be found at high striking amplitudes. Such effects result from nonlinearities that arise due to coupling between transverse and longitudinal wave motion in the material.

It has recently been shown that nonlinear effects, similar to those encountered in stiff strings and plates, can be important for drum membranes, both from a physical and a perceptual point of view. While existing tension-modulation techniques provide a useful starting point for modelling the effects of these nonlinearities, a complete nonlinear model is required for a more accurate, and ultimately more realistic, description.

In this study a nonlinear finite difference time domain model of a tom-tom is used, alongside experimental evidence, to highlight and quantify the relevance of nonlinear phenomena in drum membranes. The model includes geometrical membrane nonlinearities, and full air coupling between the two drum membranes. Experimental evidence is obtained from measurements of internal and external sound pressure fields around the drum.

Tue 16:45 Conference room Non-linearities

Spectral Enrichment in Brass Instruments Due to Nonlinear Sound Propagation: a Comparison of Measurements and Predictions [000088]

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Since the discovery nearly twenty years ago that nonlinear propagation of the internal sound wave in a trombone was primarily responsible for the "brassy" timbre in fortissimo playing, it has become increasingly clear that nonlinear distortion even at moderate sound levels can contribute significantly to the tonal character of a brass instrument. Previous work has explored the effects of bore profile and viscous damping on the rate at which spectral enrichment due to nonlinear distortion develops in brass instruments. This paper reviews evidence from experimental measurements and numerical simulations of nonlinear propagation in brass instruments with different bore shapes and sizes, and discusses the possibility of deriving a quantitative prediction of the relative importance of nonlinear spectral enrichment in a brass instrument from measurements of its bore.

Tue 17:00 Conference room Excitation mechanisms

Lipping down on the trombone: phases of lip motion and pressures [000071]

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Simple physical models describe the motion of brass player's lips as a superposition of two modes: in one, the upper lip bends like a cantilever into the mouthpiece; in the other, one or both lips undergo vertical strain to vary the aperture. These motions are investigated here on a trombone using high speed video and microphones to record

mouth and mouthpiece pressures. In all cases studied, the lips move horizontally into the mouthpiece before the pressure increases in the mouthpiece, which in turn precedes the lip opening. The horizontal component of the lip deflection leads the mouthpiece pressure by a small phase angle. For low pitch notes, both modes have significant amplitudes while the motion is mostly vertical at higher pitch. In all cases the playing frequency f0 appears to lie between those of the cantilever mode and vertical modes. . The opening of the inter-lip aperture is close in phase to the mouthpiece pressure. By 'lipping down', players can vary the playing frequency smoothly between compliant and inertive loads. All of the observations are consistent with a simple model in which each lip is superposition of a horizontal cantilever mode and a vertical mode, with frequencies that the player lowers when lipping down.

Tue 17:15 Conference room Excitation mechanisms

A Single Valve Brass Instrument Model using Finite-Difference Time-Domain Methods [000089]

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Performance of a valved brass instrument, as for all musical instruments, is inherently time varying. In addition to lip dynamics the player also has control over the length of the air column through the use of valves; to date, this time-varying feature of the instrument has seen relatively little work at either the experimental or theoretical level. Three situations can be considered when investigating valve effects on a brass instrument: static, fully depressed; static, partially depressed; and a time-varying transition between valve configurations. In a static setting, fully depressing a valve increases the total tube length, thus lowering the resonance frequencies of the instrument. In a static, partially depressed configuration, the effect on the input impedance is nontrivial due to the existence of multiple paths and constrictions that increase the boundary layer effects. Finally, during transitions between configurations, transient effects on the wave propagation cannot be ignored.
This paper presents a finite-difference time-domain (FDTD) model of a brass instrument with a single working valve. FDTD methods allow for the flexible simulation of time varying systems and are therefore well suited to the synthesis of brass instrument sounds, as well as experimental validation. Experimental impedance measurements of a simplified brass instrument are made for the instrument under static conditions. These measurements are then compared to the simulation results to verify the model. Future work is then considered for the time varying valve configurations and how these could be investigated in the laboratory.

Tue 17:30 Conference room Excitation mechanisms

Comparative Study of Different Physical Models Describing the Reed Behaviour in Real and Artificial Playing Conditions [000045]

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The general aim of this work consists in classifying single cane reeds according to the quality perceived by musicians, *i.e.* to understand which physical parameters can explain this quality. The work is divided into two families, one dealing with perceptive tests and analysis, the other dealing with physical parameters measurement and identification. We present here the work dealing with physical parameters.
The aim of this paper is to assess the validity of the different physical models describing the reed-lip-mouthpiece system by comparing theoretical and experimental results obtained "in vitro" and "in vivo".
The "in vitro" experiment uses a simplified clarinet made with a cylindrical tube, a mouthpiece, a reed and an artificial lip. The output of the simplified instrument is connected to a negative pressure source which enables to generate auto-oscillations. The mouthpiece is equipped with pressure and displacement sensors which measure the mouthpiece pressure and the displacement of the reed tip. In the "in vivo" experiment, the pressure in the mouth, the pressure inside the mouthpiece and the displacement of the reed are measured while playing the simplified instrument. Using signals measured with "in vitro" and "in vivo" systems, both sets of parameters are estimated using an identification method.
Results show that the 1DOF model (spring - mass - damping) is the simplest one which enables to predict the measured displacement from the measured pressure drop.

Tue 17:45 Conference room Excitation mechanisms

Sensing lip protrusion and vibratory motion in the mouthpiece during trumpet playing using a Theremin [000114]

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Methods of measuring the acoustic variables in the mouthpiece of a brass instrument using microphones are well developed. Optical techniques are often used to good effect to visualise the lips of the player but determination of the three dimensional nature of the motion is hindered by refraction due to the shape of the mouthpiece. The electrical conductivity between the lips has also been utilised recently to study lip motion. In this study the protrusion into the mouthpiece and vibratory motion of the lips is sensed using their effect on the capacitance of a Theremin pitch antenna. The lips are found to generally protrude into the mouthpiece to a greater extent for higher pitch ranges and for higher dynamic levels. Bending significantly flat of an instrument resonance is found to require greater amplitude of lip motion (and implicitly greater mouth pressure) in order to maintain radiated sound pressure.

Tue 11:00 Waveguides and Regimes of oscillation

Measurements of Longitudinal Waves in Piano Strings and Their Dependence on Transverse String Displacement [000050]

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The existence of longitudinal waves in vibrating piano strings has been previously established, as has their importance in the characteristic sound of the piano. Work by Bank and Sujbert (J. Acoust. Soc. Am. **117**, 2268-2278, 2005) and others has established a theoretical framework describing the origins of these waves. This theory indicates that longitudinal waves should appear with frequencies equal to the sum and difference frequencies of the transverse waves. Additionally, the amplitudes of the longitudinal waves should be quadratically related to the transverse displacement of the string when struck by the hammer. These predictions were tested by simultaneously measuring the power spectra of the transverse string motion and the sound produced by a piano string while being driven at two different frequencies by two independent drivers. The results indicate that longitudinal waves do appear at the sum and difference frequencies of the two driving transverse waves and that the amplitudes of these waves are linearly proportional to the amplitudes of each individual driver, in agreement with the established theory. Therefore, provided the amplitude of the transverse waves creating the longitudinal waves are linearly proportional to the initial string displacement, the amplitude of a longitudinal wave is indeed proportional to the square of the transverse displacement induced by the hammer. Measurements of the power in longitudinal waves in a piano string when the string motion is induced in the normal manner by depressing a key on the keyboard show this quadratic dependence on transverse displacement to be a good approximation.

Tue 11:00 Waveguides and Regimes of oscillation

Modeling of a woodwind mouthpiece using a finite-element method and characterization of its acoustic input impedance [000035]

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The mouthpiece and the reed are crucial elements providing the excitation of the air column of single reed wind instrument. The amount of knowledge on the mouthpiece behaviour and its role on the quality of sound production appears very low when the it is considered crucial by the musicians. The present work has been realized in a woodwind factory where the production of high quality mouthpieces is very important. An impedance measurement system based on the Three Microphone Three Calibration Method [Gibiat 1990] (TMTC) is available and of common use by the research team of the factory. The aim of our work has been to verify if it was possible to numerically model the behaviour of a mouthpiece and to compare it with an impedance measurement. The mouthpiece has been placed as it is when played by the musician; the reed replaced by the impedance measurement system. To be able to compare the obtained results with a numerical simulation the internal shape of the mouthpiece has been digitalized. The obtained file has then been used as boundary conditions for a numerical simulation. This numerical simulation has used a finite elements solver that leads to the acoustic pressure and acoustic intensity giving easily the impedance in frequency domain. A comparison of the measurements and the simulation shows that it is possible to use the numerical finite elements simulation to test various modifications on the mouthpiece shape. Results showing how differences on the mouthpieces geometry rely to impedance differences and comparison as well as the limits of our protocol will be presented on some examples of real mouthpieces.

Tue 11:00 Waveguides and Regimes of oscillation

New lattices of sound tubes with harmonically related eigenfrequencies [000140]

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In 1994, first author of the present paper and J. Kergomard published in acta acustica a paper entitled: "Latticies of sound tubes with harmonically related eigenfrequencies". These lattices are made of a succession of truncated cones of same length which have to respect certain rules. When looking at the proper modes with closed-open boundary conditions (i.e. reed wind instruments case), the solution were found to be stepped cone, that is cones made with a succession of cylinders which cross sections follow the law $S_n = S_1 n(n+1)/2$. At the end of the paper, the authors wrote "Finally, it remains to be demonstrated rigorously that no other shapes of horn lattices have harmonically related eigenfrequencies". Finally, in the present paper we show instead that other stepped horns have this property.

Tue 11:00 Waveguides and Regimes of oscillation

Numerical Computation of the Transfer Functions of an Axisymmetric Duct with the Extended Discrete Singular Convolution Method [000080]
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This work takes part of the "cagima" project (supported by the ANR) which investigates the defects of the tuning of reed musical instruments as well as their homogeneity of emission and timbre. The goal consists in replacing the traditional approach adopted by instrument makers by a global and rational approach in the design of new instruments /ab initio/ (called "logical instruments"), minimizing some identified defects. In this context, an interactive virtual model, predictive and configurable is proposed. Several approaches are available in the literature but the main difficulty is to design digital instruments that are accurate (according to measurements) and that can be implemented in real-time. In this paper, an approach based on the Extended Discrete Singular Convolution method (EDSC) is proposed. The temporal operator (including the fractional derivative term for viscothermal losses) is implemented according to the EDSC formalism. The method allows a fast, straightforward and accurate computation of the transfer functions of an axisymmetric duct with an arbitrary profile. The computation of the case where the losses are dependent from the diameter causes no noticeable difficulty. The results are compared to measurements of a trombone bell.

Tue 11:00 Waveguides and Regimes of oscillation

Graph models of wind instruments : computing the natural frequencies of some elementary ducts [000015]
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A graph-based modelling approach for wind instruments with tone and register holes was recently proposed in [1]. This preliminary work remained at a rather theoretical level with high degree of generality, focussing nevertheless on musical acoustics applications while laying foundations for concrete applications. The purpose of the present work is to present first simulation results in order to validate these theoretical results. For this task, elementary ducts are investigated, for which great knowledge has been accumulated for a long time through the impedance, transfer matrix and modal decomposition approaches, which can thus serve for checking. The duct profiles focussed on belong to a musically useful class∼: cylinders and stepped cones, as studied by Dalmont and Kergomard 20 years ago. The case of a cylindrical duct with one tonehole is also presented. One interesting feature of the approach is that mode matching is automatically satisfied : the natural frequencies and the eigenmodes are computed at once by the method, even for geometries with large discontinuities. In a companion paper at this conference [2], this modelling approach is used within an optimization procedure for the design of simple wind instruments.
[1] G. Le Vey, "Graph-based models for woodwinds", SMAC 2013, Stockholm, July 2013.
[2] G. Le Vey, J.F. Petiot, "Graph-based model optimization of wind instruments: preliminary results", ISMA 2014, Le Mans, Submitted.

Tue 11:00 Waveguides and Regimes of oscillation

To what extent can a Linear Analysis predict the Behaviour of a Flute Model? [000026]
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Although they have been widely studied for years, some aspects of the behaviour of flute-like musical instruments remains poorly understood. The study of a physical model of the instrument has demonstrated its interest in the understanding of various phenomena, such as the hysteresis related to regime changes or the variations of the frequency with the blowing pressure.

As it involves both nonlinear and delayed terms, an in depth study of the state of the art flute model requires specific numerical methods, which are often computationally expensive. The simplification of the model through its linearisation around a non-oscillating trivial solution is thus particularly interesting, due to the simplicity of the calculations. The information provided by such an analysis in terms of oscillation frequency or oscillation thresholds of the different periodic solutions have been highlighted in previous work [1].

Surprisingly enough, the present study shows that this simple linear analysis provides information about the stability zones of the different periodic solutions (i.e. the different registers), and allows to predict, in some cases, the register resulting from a transient of the mouth pressure. Such information can be obtained without solving the nonlinear equations and without computing the steady-state oscillations of the model.

[1] R. Auvray, B. Fabre, and P.-Y. Lagrée. Regime change and oscillation thresholds in recorder-like instruments. The Journal of the Acoustical Society of America, 2012, vol. 131, p. 1574.

Tue 11:00 Waveguides and Regimes of oscillation

Experimental Study of Attack Transients in Flute-like Instruments [000079]

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The stationary behavior of flute-like instruments is fairly well understood. Models and experimental studies allow to predict and to understand the influences of the principal parameters (flow velocity, position of the edge, etc) on the sound if these parameters stay constant in time. Depending on the instrument, these parameters can be fixed by the flute maker or by the musician. In musical playing, the musician plays on them to act on the sound. Some parameters can vary rapidly, like during the attack transients. The response of the instruments to these variations is crucial to determine their quality, in musical use. The target of this study is to understand the influences of these parameters on the characteristics of attack transients.

The study presented is based on measurements on an actual recorder in musical context. Parameters of attack transient for acoustic and musician control are extracted from the data. Relations between these parameters are searched by taking into account the characteristics of the instruments. This study is a first step in the understanding of the possibilities of the musicians' control and of the physical limitations.

Tue 11:00 Waveguides and Regimes of oscillation

Several ways to stop a note in a clarinet - a comparative view of note extinctions [000069]

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In a self-sustained instrument, the sound is maintained as long as energy is supplied to the oscillating system, and the control parameters are kept in a range that permits a periodic regime. Stopping a note is thus a voluntary action, in opposition to what can happen in plucked strings, membranophones, xylophones etc.

In a reed instrument two basic methods of stopping the note can be identified, although usually the musician will use a combination of these. One is to stop the oscillation of the reed by using the tongue, or less likely by using a stronger biting force that can close the reed. The other is to cut the supply in air from the lungs, or to reduce it below a critical level that is called the threshold of oscillation. These two methods have very different consequences on the characteristics of the sound of the note extinction. Using simulations and experiments, this presentation identifies the main characteristics of each of the extinction methods. Whenever possible, an investigation into the causes of the effects identified in the description are justified with basic models or further experiments.

Tue 11:00 Waveguides and Regimes of oscillation

The irish Uillean pipe: a story of lore, hell and hard D [000074]

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The irish Uillean pipe is a bellow-blown bagpipe that resembles other baroque musettes (french musettes de cour) such as the english Northumbrian pipe and french Musette. According to A. Baines, it appeared in Ireland in the late seventeenth century, in a version somewhat simpler than the instrument known in the present days. It is surely among the most evoluated bagpipes nowadays with a rather complex playing. The lowest note of the chanter has the noticeable characteristic, searched after by musicians, of having two different timbres. One of these, known among musicians as the hard D, is strikingly louder and clearer than the other, the soft D. The contrast between them is traditionally a much appreciated quality of an instrument. In this paper, we concentrate on this particular note and show that the soft D corresponds to a standard regime (Helmholtz motion) and the hard D to a double Helmholtz motion similar to that observed in bowed string instruments.

Tue 11:00 Waveguides and Regimes of oscillation

Timbre Related Geometry Analysis of Classical Guitars [000087]
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The timbre of acoustic guitars is an interaction between cultures, musicians and instrument makers since centuries. The main goal in this investigation is to use shape and frequency data to determine the radiation behaviour through specific changes of the geometry for the different body components. Using a 121 microphone array the radiation pattern of 32 classical guitars are measured and backpropagated. Here the eigenvalues and the forced-oscillation pattern are calculated, the latter covering each plucked note from open keys up to the 12th fret. Furthermore the data of the geometryshapes has been documented. During the research 78 radiated forced-oscillation patterns and their related frequencies, the spectral centroids, the influence of curving and thickness of soundboards, aging of the instruments and used tone wood were examined.

Tue 11:00 Waveguides and Regimes of oscillation

Accessing the homogeneity of guitar tones [000133]
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One of the issues faced by classical guitar makers and players is to avoid highly pronounced discrepancies in terms of intensity and decay when moving from a note to the next or a close one. For instance, the so-called "dead tones" phenomenon often occurs in the high treble range (first string), where some tones appear to be decaying significantly faster. A first study (Ricateau et al 2012) has evidenced this particular aspect by measuring the Energy Decay Curves and conducted an analysis thanks to the measurements of the mechanical admittance at the bridge. Our study proposes a measurement scenario to obtain a more complete picture of a particular instrument from the lower bass range to the high treble range. This scenario is intended to be undertaken in the maker's workshop, leading to a characterization of the instrument available in a reasonable time laps. The analysis relies on robust and precise signal processing tools, namely High Resolution method, applied both for estimating decaying properties of each tone and decomposing the mechanical admittance. The synthesis model initially proposed by J. Woodhouse (Woodhouse, Acta Acustica, 2004) is then employed for accessing the assumption that the homogeneity properties mostly originates from the coupling conditions at the bridge, namely the values of the admittance matrix around the string partial frequencies.

Tue 11:00 Waveguides and Regimes of oscillation

Numerical Simulation of the Production of Pedal Notes in Brass Instruments [000028]
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Conical brass instruments, such as saxhorns, show an input impedance with almost harmonically distributed peaks, which allows to play notes whose frequencies approach a harmonic series. Conversely, all brass instruments with a

long cylindrical section (notably trumpet and trombone) have their first impedance peak heavily shifted towards low frequencies (38Hz for a trombone instead of 62Hz if the first resonance frequency was belonging to the harmonic series formed by the upper peaks). However, trombonists can play the so-called "pedal note" despite its frequency close to 62Hz, around a minimum of the imput impedance.
Previous publication showed interesting numerical and experimental results when using alternatively a saxophone reed and a brass mouthpiece on both a trombone and a saxhorn.
In this paper, we reproduce numerically and extend these results using Moreesc, a numerical tool based on the modal decomposition of the bore which allows changing parameters during the simulation. By simulating alternately brass mouthpiece and saxophone reed and using modal fits of measured trombone and saxhorn impedances, we examinate this mysterious regime of oscillation. This first allows to check the robustness of this phenomenon regardless of the numerical method. Then, the ability to continuously morph from an impedance to another allows to study the transition between cylindrical and conical instrument's behavior. The influence of the number of modes taken into account is also investigated.

Tue 11:00 Waveguides and Regimes of oscillation

The influence of the cone parameters on the sound of conical woodwind instruments [000017]
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Proponents of the Pulse Forming Theory (see for instance Heptner, TIBIA 12(1), pp. 325-329, 1987) claim that the reed closing time in wind instruments remains approximately constant over most of their playing range. Another study (Ollivier et al., Acta Acustica united with Acustica 90(6) pp 1192-1203, 2004) might provide an explanation for this phenomenon in terms of the geometry of the cone. Specifically, for a Helmholz motion, the ratio N of the cone (which relates its length to the lenght of the missing part of the cone) is expected to be the same as the ratio of the opening time to the closing time of the reed displacement signal. The objective of this paper is to find out with the aid of simulations via physical modelling whether the geometrical ratio of a cone Nc corresponds to the ratio of the time domain reed displacement signal Nt. For this purpose, two cones which are identical except for the parameter Nc will be taken, and a simulation will be made to obtain the pressure inside the mouthpiece (which, as shown by Ollivier et al., is in phase with the reed displacement). The ratio Nc of the cone will be compared to the ratio Nt of the obtained signal. Additionally, two lengths of each cone will be simulated, which means that the geometrical ratio Nc will be shortened, expecting the ratio Nt of the time domain mouthpiece pressure signal to shorten accordingly. Results will be presented and discussed.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

The string 'after length' of the cello tailppiece : History, acoustics and performance techniques [000135]
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In a long term study of cello tailpieces, we have first identified the vibrating modes of a cello tailpiece mounted on a dead rig [1], and have worked on the possible influence of the wood on theses modes [2]. The influence of the position of the tailpiece on the modes and on the sound has also been explored, by varying the "after-length", i.e. the distance of the tailpiece to the bridge which leaves a small length of vibrating string. Experiments on the physical parameters involved will be described, and the perceptions of sound changes were exposed at SMAC2013 à Stockholm.
Here, our study takes a more historical path to identify the trends and theories on this "after-length", and the changes in the history of the cello and playing techniques, and we read texts of the 19th century mentioning its role on the sound of the cello will be studied."

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Bell Vibrations and How They Affect the Sound of the Modern Trumpet [000049]
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Within the last decade several experiments have verified that bell vibrations can affect the sound produced by brass wind instruments. Measurements on trumpets have indicated that the bell vibrations can either increase

or decrease the acoustic transfer function, that the sign of the change is frequency dependent, and that these observed effects cannot be attributed to direct radiation from the vibrating bell. Kausel, et al. have proposed that these effects can be explained by an expansion and contraction of the walls enclosing the air column that is induced by the internal standing wave. (J. Acoust. Soc. Am. **128**, 3161-3174, 2010) Since the sign of the effect changes at specific frequencies, if the coupling between the internal air pressure and the vibrating wall is indeed responsible for the effects there must be structural resonances that occur at these frequencies that result in a change in the phase relationship between the air column and the wall vibrations. Furthermore, the mode shapes at these resonances must have no nodal diameters or the mean volume change will be close to zero. The work reported here demonstrates the presence of these structural resonances. The mechanical transfer function between the mouthpiece and the bell of a trumpet was measured and it was found that there are indeed body resonances with frequencies that match the frequencies at which the bell vibrations change from reducing the acoustic transfer function to enhancing it. However, computer modeling indicates this coupling may not explain all of the experimental observations.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Forced oscillation mode relations of acoustical guitars [000007]

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Seven classical guitars are investigated in terms of their forced oscillation patterns driven by all 78 tones played on the instrument on all six strings up to the 12^{th} fret. The forced oscillation patterns are correlated with the first four eigenmodes of the instruments, the Helmholtz resonance, the wood monopole mode (0,0), and the two dipole modes (1,0) and (0,1). Strong correlations between the eigenmodes are consistently found for all guitars, so no orthonormal relations are found between these eigenmodes. For the forced oscillation patterns, the mode shapes are much more consistent, while the phases change dramatically depending on the driving frequency. Additionally, a strong dependency on the string driving point is found, which in some cases is clearly audible. For the same frequency, the forced oscillation patterns driven by different strings even at the eigenmodes of the guitars are also quite different. These findings are not consistent with the standard theory of forced oscillations.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

How to apply a plaster on a drum to make it harmonic [000099]

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It was known in Indian antiquity that adding a plaster to a drum reduced "the harshness of sound", meaning it produced an almost harmonic sound [1]. This was observed experimentally for the tabla by Raman in the 1920's [2]. It was also known in ancient India that it required a skilled musician to apply the plaster to improve the harmonicity. Originally, this plaster was temporary and made out of clay. Nowadays, it is replaced on some instruments, such as the tabla, by a permanent application obtained with many layers of "syahi masala". In this paper, we propose an analysis of the plaster effect on the harmonicity of the instrument. For this purpose, a tabla membrane having a varying mass density is modeled: using a perturbation of the density on the wave equation of the membrane, we compute the changes in the eigenfrequencies when adding a thin circular mass at the center of the membrane. An optimization procedure based on the gradient algorithm is proposed for reaching harmonic eigenfrequencies for the non-homogenous membranes by applying many such layers. Finally, this algorithm is tested for different initial densities with and without additional constraints.

[1] The Natyasastra, ascribed to Bharata-muni, translated by Manomohan Ghosh, Bibliotheca Indica, 1951
[2] C.V. Raman and S. Kumar, "Musical drum with harmonic overtones", Nature (London), 104, 500-500 (1920)

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Modal Analysis of a Brazilian Guitar Body [000019]

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The Brazilian guitar is a countryside musical instrument and presents different characteristics that vary regionally by configuring as a sparse group of string musical instruments. Basically, the instrument diversity comes from different geometries of resonance box, shapes of sound hole, types of wood, different tunings, and number and arrangement of strings. This paper intends to present the numerical and experimental modal analysis of a Brazilian

guitar, without strings, in a free boundary condition. The modal analysis technique is applied in the determination of the natural frequencies and the corresponding mode shapes. The main dimensions of an actual Brazilian guitar body are used to build the computational model geometry. The numerical modal analysis uses finite element method (FEM) to determine the dynamic behavior of the vibroacoustic system, which is composed by the structural (wood components) and acoustic (fluid inside guitar box + sound hole) systems coupled. The experimental modal analysis is carried out in an actual Brazilian guitar body, where the structural modal parameters (frequency and mode shape) are extracted and used to update the numerical model. Finally, numerical and experimental results are compared and discussed

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Dependence of the acoustic power produced by a woodwind on the tonehole size [000061]
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It is well known that for a given note the position of woodwind toneholes can be chosen by the maker in a certain portion of the instrument, provided that the radius is properly chosen: a wide radius needs to be located further from the reed than a narrow one. In our work a simplified problem with one radiating source only is investigated: the problem of a short diaphragm at the end of a cylindrical tube, excited by a clarinet-like reed/mouthpiece. We consider tubes of different lengths provided with diaphragms of different radii, in order to keep a fixed playing frequency. Obviously the power radiated by the orifice decreases when the diaphragm radius decreases. But it is not intuitive that when the radius is large enough, the power is found to be almost independent of the radius. Indeed it can be shown that the radiated power depends only on the output flow rate. Moreover energy considerations show that the ratio between the input pressure and the output flow rate does not depend on the length, thus on the diaphragm radius. Finally when losses are ignored, the input pressure depends on the excitation pressure in the mouth but is independent of the tube. This simple explanation is confirmed by both numerical calculation and experiment, but experiment confirms the importance of nonlinear effects with flow separation due to sharp corners.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Non-Linear Behaviour in Sound Production of the Rhodes Piano [000062]
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The Rhodes piano is a generic example of a mid-sixties to eighties keyboard, used in such diverse musical genres as Jazz, Funk, Fusion or Pop. Its unique sound is mainly due to its specific mechanical and electromagnetic tone production. The mechanical part of the tone production consists of a small diameter tine madeof stiff steel wire and, strongly coupled to the tine, a tone bar made of brass which acts as a resonator. The lower tine is struck by a rubber hammer and vibrates in front of a magnetic pick-up which converts the change in the magnetic flux to an alternating voltage which can be amplified and made audible by an external amplifier. In this work we present a series of measurements taken with a high-speed camera and a piezolectronic transducer that show: a) Opposed to common belief, the tine and tone bar are not alike in pitch or resonance frequency. Their fundamental resonance frequencies are several hundred to more than 1400 cents apart. b) After an extremely short transient the tine vibrates in a perfect sinusoidal motion without appearance of higher harmonics. c) The lower dimensional tine forces the higher dimensional, stronger damped tone bar to vibrate in perfect phase or anti-phase with its lowest *eigenfrequency* pointing to a quasi- synchronisation behaviour. d) The non-linear, *growling* sound is produced due to the position dependant non-linearties in the magnetic field and are best audible in the lower register of the rhodes where the tines have a larger deflection.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

A Power-balanced Model of a Valve Exciter Including Shocks and Based on a Conservative Jet for Brass Instruments: Simulations and Comparison with Standard Models [000053]
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In most of models of brass instruments (and also of the glottis), the jet is governed by an equation of Bernoulli type (with basic, non stationary or lossy versions). In this exciter part, this model is known to be of first importance because it is responsible for the non-linearity which allows the emergence of self- oscillations. However, this model infringes a fundamental physical property: it does not preserve a well- posed power balance between the reed

(possibly lip-reed) and the jet. In particular, the energy stored in the reed is not given back to the jet. In the case of brass instruments and of the glottis, a second similar problem is concerned with shocks, when they are modeled by increasing the values of the mass, damper and spring for negative heights. Indeed, at the contact time, both the kinetic and the potential energies are artificially increased. In this paper, we propose a model of a valve exciter which includes shocks, with a special care to a well-posed power balance: first, the modeled of the jet is built for basic assumptions; second, a model of shocks is proposed. These models can be recast in the framework of the so-called "port-Hamiltonian systems" which guarantees well-posed power-balance. Finally, simulations (that preserve a discrete-time version of the power balance) are performed for these new models and compared with standard models.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Mechanical Analysis of the Voicing Process in the Harpsichord [000100]

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The harpsichord is one of the keyboard instruments that belongs to the plucked strings family. It has been widely used between the 17^{th} and 18^{th} centuries, before being replaced by the *piano forte*. With the 20^{th} century started a new interest for the harpsichord. Studies have tackled the problem of restoration, sounboard analysis, and plucking mechanism modelisation of this instrument. Few studies have investigated the relationship between the voicing process, the sensations on the keyboard and the string vibrations. Voicing a harpsichord aims to give the instrument an homogenous response over its whole tessitura. One effect of the process is the plectrum resulting shape after its cutting. This shape is of great importance to model correctly the plectrum bending during its contact with the string. We investigate in this paper how the plectrum shape is related to the tactile sensations experienced by the musician on the keyboard as well as the initial condition imposed to the string. To achieve this goal, we need a complete model of the plucking mechanism, from the action produced by the finger on the key to the string vibrations. We present here a model linking the force exerted on the key, the key and the jack motions, the plectrum deflection and the string vibrations. Several plectrums that had been voiced differently by an instrument maker were then used on a harpsichord. Various inputs needed for the model were measured and fed into it. The results shows relationship between the plectrum shape and the input force on the key in actual harpsichord playing condition.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Physical Modeling of Nonlinear Player-String Interactions in Bowed String Sound Synthesis Using Finite Difference Methods [000125]

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Sound synthesis for continuously excited musical instruments requires, for realism, a time varying input, simulating the player's gesture. Recent increases in computing power have allowed for increasingly detailed physical modelling techniques, for purposes of both experimental validation and sound synthesis. Finite difference methods are appropriate to such complex scenarios, as they are sufficiently general to handle the various interactions that occur in the instrument. A two-polarisation physical model of a bowed string is designed, with bow-string and finger-string nonlinear interactions. The Hunt and Crossley damped collision model is used for contact interactions in a plane orthogonal to the bow, and a "friction curve" model describes the relative velocity dependent friction forces in a plane parallel to the bow. A finite difference scheme is implemented for this model, allowing for numerical simulation of the full system. Sound examples are given to illustrate the range of bowed string gestures that can be artificially reproduced with such a model.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Numerical Modeling of String/Barrier Collisions [000112]

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The collision of a string with a distributed rigid barrier plays a role in various musical instruments. The effects can range from minor but salient, as in the case of a freely vibrating guitar string in contact with the instrument neck, to major, as in the case of stringed instruments such as the sitar or tambura. Other examples are associated with playing gestures, such as the string/fretboard/finger interaction. Numerical design for such a highly nonlinear interaction, whether for purposes of model validation or sound synthesis, poses many challenges. The finite difference time domain method is applied here, in a Hamiltonian formulation, with collisions modelled through the use of a potential penalizing penetration; such a design may be analysed in terms of energy conservation or dissipation, leading to convenient stability conditions. Implementation issues for the resulting algorithms will be discussed. Various perceptual features will be illustrated, as well as numerical features such as strict energy conservation/disspation, and the degree of interpenetration. Extensions to the "doubly nonlinear" case of geometrically nonlinear string vibration in conjunction with distributed collision will also be discussed.

Tue 16:00 Vibrating structures, Non-linearities and Excitation mechanisms

Classification of marimba mallets based on objetive parameters measured with a striking apparatus [000126]

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Percusionists know that using different mallets while playing the marimba greatly changes the tone. In this work we propose a simple method to provide an objetive classification of the marima mallets based on well known objetive parameters related to the timbre. With this aim, an experimental striking apparatus is conceived and used to produce repeatable marimba tones. The mallets are pre-classified and labelled into 3 groups according to its hardness: 'hard', 'medium' and 'soft'. Objective parameters related to the timbre are measured and analyzed from the measurements in order to provide the input for a mathematical model used to classify the mallets according to its hardness.

Wed 8:45 Conference room Keynote lecture

A "sound" choice: multi-criteria selection of material for instrument making from wood science viewpoint [000115]

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Wood is the constitutive material of a wide variety of musical instruments and therefore contributes to their global behaviour, "quality" and identity, may it be acoustical, technical or aesthetical. This talk aims at synthesising the various aspects of wood science (physics-mechanics, botany, perception of wood) that can explain the traditional choice of material in instrument making, but also that can contribute to finding alternative solutions. A focus will be given to cases where wood properties are expected to contribute to the instrument's acoustical response. Different levels of variability in vibrational properties can be encountered: (i) organological families and parts/functions; (ii) cross-cultural comparisons; (iii) choice of species through makers' traditional knowledge; (iv) empirical/perceptual qualification of wood pieces within a species; (v) variability of properties within a piece or stock; (vi) effects of surrounding hygrometry on vibrational properties. For levels (i) and (ii), analysis of a worldwide relational database created by the author allow some typologies by organological functions, however a cross-cultural comparison indicates that there may not be a unique "standard" for wood choice and properties. Understanding levels (iii) and (iv) requires interdisciplinary experiments and collaboration between scientists and makers; ongoing works seek to discriminate wood characteristics most involved in maker's choice and analyse their significance in terms of vibrational properties. At level (iv), vibrational properties can vary as much within a given piece -e.g. a soundboard- as between different pieces, and (level vi) changing humidity causes transitional destabilisation in damping that can overtake natural variability. This typology is discussed in terms of methodological requirements for obtaining datasets representative of an instrument making situation.

Wed 9:30 Conference room Materials for musical instruments

Woods for Wooden Musical Instruments [000038]

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In spite of recent advances in materials science, wood remains the preferred construction material for musical instruments worldwide. Some distinguishing features of woods (light weight, intermediate quality factor, etc.) are easily noticed if we compare material properties between woods, a plastic (acrylic), and a metal (aluminum). Woods common in musical instruments (strings, woodwinds, and percussions) are typically (with notable exceptions) softwoods (e.g. Sitka spruce) as *tone woods* for soundboards, hardwoods (e.g. amboyna) as *frame woods* for backboards, and monocots (e.g. bamboo) as *bore woods* for woodwind bodies. Moreover, if we consider the radiation characteristics of tap tones from sample plates of Sitka spruce, maple, and aluminum, a large difference is observed above around 2 kHz that is attributed to the relative strength of shear and bending deformations in flexural vibrations. This shear effect causes an appreciable increase in the loss factor at higher frequencies. The stronger shear effect in Sitka spruce than in maple and aluminum seems to be relevant to soundboards because its low-pass filter effect with a cutoff frequency of about 2 kHz tends to lend the radiated sound a desired softness. A classification diagram of traditional woods based on an anti-vibration parameter (density ϱ/sound speed c) and transmission parameter cQ is proposed. Also, the effect of plate thickness can be deduced from the resonance frequency of a bending wave in a thin plate, the driving-point impedance of an infinite plate, and the mean frequency interval of resonance modes of a finite plate.

Wed 9:45 Conference room Materials for musical instruments

Mechanical Property Relationships in Sitka Spruce Soundboard Wood [000110]

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As a musical instrument construction material, wood is both musically and aesthetically pleasing. Easy to work and abundant, it has traditionally been the material of choice. It is not, however, without its challenges. As manufacturing of musical instruments continues to increase and supplies of suitable wood decrease, a need to maximize and optimize the use of available timber arises. Historically, distinct mechanical properties of wood have been compiled using separate samples of the same species. For any species, a great emphasis has been placed on describing average properties from a given region. Nonetheless, due to the great variation in wood properties even within a controlled region, manufacturing processes require direct measurements of the mechanical properties in order to construct acoustically consistent musical instruments. In this paper, non-destructive mechanical property tests have been developed so that they can all be performed on a single wooden specimen. In this way, relationships between mechanical properties of clear straight-grained quartersawn timber can be investigated. Measured properties include Young's modulus in the longitudinal and radial directions using a three point bending test, shear modulus using a two point square plate twist test and Poisson's ratios using a tension test, both in the longitudinal-radial plane, density and moisture content. Commonly used North American Sitka spruce of three different grades is studied. Relationships between various mechanical properties and other simplifications are proposed. These relationships are shown to reduce the number of measurements required by musical instrument builders wishing to construct acoustically consistent instruments.

Wed 10:45 Conference room Instrument making

Rapid creation of tuning maps for a clarinet using analytic formulas [000037]

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One measure that a clarinetist uses to judge an instrument is its ability to play in-tune, over the entire range of the instrument without a large amount of added effort on the players part. Thus, in order to design the most "playable" clarinet we must know the actual playing frequencies, which depend on several control parameters including the blowing pressure, reed opening and the input impedance. We can now rapidly deduce these frequencies (analytically) from the different control parameters and input impedance curve. Four effects are known to influence the playing frequency and are examined separately within the analytic formulas: the flow rate due to the reed motion, the reed dynamics, the inharmonicity of the resonator and the temperature gradient within the clarinet. Numerical simulations have been used to test the validity of the analytic formulas in the first playing register of the clarinet. These numerical simulations have the added ability to distinguish in which register the clarinet is playing depending on the chosen value of reed opening and blowing pressure. This paper will present the "maps" which

can be created from the analytic formulas and numerical simulations which show, over the full range of blowing pressures and reed openings possible, the expected resulting playing frequencies for a particular clarinet. These resulting maps could be used by an instrumentalist or manufacturer to better understand the expected tuning homogeneity over the range of an instrument and perhaps aid in the future design of an even more "playable" clarinet.

Wed 11:00 Conference room Instrument making

Monitoring of the making process of a handcrafted electric guitar [000020]

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Even if the making process is highly standardised, handcrafted "identical" solid body electric guitars may present notable differences in their vibratory behaviours. The vibratory behaviour is usually measured at the end of the production, that is on ready-to-play instruments. In order to know where the differences originate, and with the aim of trying to make "identical" guitars more identical, a vibratory study during the making process can be done. In this paper, a handcrafted solid body electric guitar was measured at six successive stages of the production. Mode tracking is performed from early production stages with separated parts (neck, body) until later stages with the whole guitar. It is shown that the isolated neck and body modes determine the whole guitar modes. This allows the guitar maker to select or fix necks and bodies early in the making process, in order to reduce the variability between "identical" guitars.

Wed 11:15 Conference room Instrument making

Impedance Analysis on a Real Instrument and its Impact on the Manufacturing Process [000039]

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In recent years, the field of knowledge in musical acoustics has grown considerably but collaborative works between scientists and instrument makers remain rare. Such collaboration exists on clarinet and saxophone making around tools that have been developed in the field of experimental acoustics. This collaborative approach has been driven in the Research and Development department of Henri SELMER Paris, an historical factory for the production of wind instruments, around the use of impedance measurement. The use of this particular tool now classic in all acoustic laboratories in the study of the linear part of the wind instruments, has been systematized during the development and the improvement of our prototypes leading to an impressive number of impedance curves. Based on the idea of a musical ideal of a saxophone in terms of tuning and emission, a methodology for the use of this huge amount of impedance results has been defined, in order to highlight the deviations from this ideal and to analyze and consider the changes in terms of bore profile. We will present the analysis of existing instruments, explore and analyze the difficulties experienced on the archetypal alto saxophone. Essential correlations with the feelings of musicians will also be presented with selected examples from the prototyping work within the plant.

Wed 11:30 Conference room Instrument making

Comparison of clarinet making over time - Seeking correlations between the player's perception - intonation, timbre, response - and objective measurements [000117]

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As part of ANR project CAGIMA, a set of six clarinets was selected, consisting of instruments made between the end of the 18th century and today (including a german-style clarinet), as an illustration of some of the evolutions of the making. The following measures have been realized: resonant frequencies of all fingerings (mouthpiece replaced with some equivalent volume), high precision mapping for the bore and the tone holes from a 3D digitalization of the moldings. Using resonance modeling softwares, and by computing the input impedance based on the geometry, some relations have been deduced between this geometry, the intonation, the inharmonicity, and the resonant frequency quality factors. Performance tests have been made on these instruments with professional clarinet players. The measure of performance parameters using instrumented mouthpieces allows to establish correlations between the musician's perception and the qualities and flaws of the instruments.

Wed 11:45 Conference room Instrument making

Evaluation and classification of steel string guitars using bridge admittances [000072]

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In this study, 18 nominally identical acoustic guitars coming off the same production line and post-classified by the manufacturer as either "bassy" (i.e., with a more prominent bass response), "mid-even" (i.e., well-rounded and sounding even from string to string) or "treble" (i.e., with a brighter sound that cuts through the band) were investigated. The goal is to find features of the guitar admittance that can help musicians make a more informed instrument selection based on their preferred playing style (e.g., strumming, fingerpicking). We conducted dynamic (input admittance) and acoustical (live recordings) measurements to examine features such as frequency, amplitude and modal damping of the first few structural modes, trend of the band-averaged admittance, harmonic content of the admittance, temporal features of the plucked response, and long-time average spectra (LTAS). These physical properties were investigated independently as well as in conjunction with perceptual assessments by musicians collected during a classification task. Despite very low agreement across guitarists as well as between musicians and the manufacturer, results show that guitars categorized as "bassy" by the manufacturer have a lower frequency for their breathing mode. This is an indicator of the respective guitar bodies having a lower stiffness-to-weight ratio, which may be caused by using thinner plates or plates carved from softer and denser wood. The most common feature of the "treble" guitars was lower averaged mobility in the frequency range of 600-4000 Hz. This suggests a weaker string-to-body coupling at those frequencies, which may contribute to a longer sustain for higher partials.

Wed 12:00 Conference room Instrument making

May a bow buckle when playing violin? [000009]

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The playing qualities of a violin bow, which are basically determined by the mechanical properties of the wood and the taper of the stick, may be strongly affected by the adjustment of camber (concave curvature of the stick). Increasing camber essentially allows the player to reach a higher playing hair tension. However, it is well known among makers that a bow may become unplayable if its camber is increased beyond a certain limit, which depends on the stiffness of the stick. On a too much cambered bow, any attempt to apply a high normal force on the string results in unwanted lateral bending of the stick, which gives the player the sensation that the bow is uncontrollable. From a mechanical point of view, this behavior strongly evokes the phenomenon of buckling. Considering that a bow stick is a slender structure subject to a high compressive force once tightened, it is obvious that the critical buckling load of the stick has to be higher than the typical playing tension of the bow. However, the possible occurrence of buckling during playing has not been clearly demonstrated until now. In this paper, it will be shown experimentally and numerically that a bow may buckle, even it is played at a tension lower than the critical buckling load of the stick. A remarkable result is that this phenomenon occurs when the bow is loaded by a transversal force, although the critical buckling load is associated to compressive loads.

Wed 11:00 Materials for musical instruments and Instrument making

Violin making "tonewood": comparing makers' empirical expertise with wood structural/visual and acoustical properties [000118]

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The "resonance woods" for the making of violin family have benefited from more research than other instrument making woods, but the interactions between different disciplines and viewpoints in this field has seldom been addressed. The objective of this study is to improve the understanding of the interactions between physic-mechanical properties of resonance wood, their natural variability, and the actual expertise of violin makers in the selection and qualification of their raw material. An in-depth "socio-technical" survey has been designed to identify violin makers' opinions and practices on both qualitative and quantitative grounds. In parallel, tonewood

samples of various "qualities" were characterized for their physical and vibrational properties (density, anisotropic specific moduli and damping coefficients), acoustical "performance indexes", and visual/structural characteristics (growth-ring uniformity and percentage of latewood). Measured properties were different between viola and violin soundboards (mainly for density), but no significant differences between plates of the two highest grades (attributed by wood suppliers) could be shown. Correlations between visible structural characteristics, density and vibrational properties in spruce "resonance wood" were not typical of classical softwoods and highlight the peculiarity of this pre-selected material, which can be discussed through microstructural explanations. Empirical choice by violin makers, based on perceptual criteria that can be visual, physic-mechanical, auditory, are relevant to the acoustic properties measured but will require a more detailed study to evaluate the respective contribution of these different fields of perception. We also intend to construct a model to evaluate the properties of a full violin plate from sampling fabrication offcuts.

Wed 11:00 Materials for musical instruments and Instrument making

Developing a hybrid wind instrument: using a loudspeaker to couple a theoretical exciter to a real resonator [000093]

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A hybrid wind instrument generates self-sustained sounds via a real-time interaction between a computed physical model of an exciter (such as human lips interacting with a mouthpiece) and a real acoustic resonator. Successful implementation of a hybrid wind instrument will not only open up new musical possibilities but will also provide a valuable research tool. However, attempts to produce a hybrid instrument have so far fallen short, in terms of both the accuracy and the variation in the sound produced. The principal reason for the failings of previous hybrid instruments is the actuator which, controlled by the physical model of the exciter, introduces a fluctuating component into the air flow injected into the resonator. In the present paper, the possibility of using a loudspeaker to supply the calculated excitation signal is explored. A theoretical study using established physical models is carried out, yielding useful rules for choosing the best loudspeaker for a given resonator. Acoustical coupling and feedback stability are considered. Experimental studies are reported which provide the loudspeaker's "electrical input to dynamic volume flow rate" transfer function. Simulations of the entire system, along with initial experimental investigations, confirm a coherent self-sustained operation.

Wed 11:00 Materials for musical instruments and Instrument making

Evasive manoeuvres of bowed-string instruments: The effect of wolf suppressors on wolf tones [000128]

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In this study, different designs of wolf suppressors for bowed-string instruments are compared and assessed with respect to their efficiency to reduce the wolf-tone liability of violins and cellos. The common type of wolf suppressor is considered which consists of a mass that is fixed on the string section between the bridge and the tailpiece. It is found that not only the damping and the mass of the wolf suppressor play an important role, but also that its geometry can be decisive for the resonances that it adds to the instrument and by which wolf tones can be tackled. Moreover, the diversity of wolf tones is illustrated in experiments that also demonstrate what the attempted cure can achieve in the respective cases. The degree to which the unpleasant phenomenon is attenuated depends sensitively on the "tuning" of the wolf-suppressor subsystem: By changing the position and other mounting parameters of the wolf suppressor on the string section, the resonances of this subsystem can be adjusted - rendering it a tunable vibration absorber.

Wed 11:00 Materials for musical instruments and Instrument making

Effect of the Ebony Crown on the Higher Register of the Classical Guitar [000059]

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The luthiers expertise developed over the years by André BRUNET, Master Luthier and Director of the Bruand Lutherie School led him to ask Jean-François JARRY to run experiments. Those experiments are design to qualify and quantify the effect of the alteration Mr. BRUNET has integrated in his Guitar designs over the years. Varying

the material of a crown on the head of the classical guitar is one of the latest experiments run at the Lutherie School. The head of a guitar was altered in order to be fitted with crowns and two crowns with the exact same geometry were manufactured, respectively in Mahogany and in Ebony. The Mahogany crown matches the Mahogany neck of the Guitar used for this experiment. Through the recording of a great number of notes and their analysis using the Praat software, the effect of the Ebony crown has been enlightened: Especially for the higher register of the guitar, the timbre is enhanced in its proportional higher frequency components.

Wed 11:00 Materials for musical instruments and Instrument making

Graph-based model optimization of wind instruments: preliminary results [000031]

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Recently, a graph-based modelling approach of wind instruments has been proposed [1] with the aim of computing natural frequencies in a way different from the usual impedance/transmission lines-based way. It can be easily applied, even to 2D or 3D networks of waveguides, under the assumption of 1D propagation, having complex geometries with branchings and discontinuities, allowing to study in the same framework musical instruments with or without toneholes. One important feature of this new approach is that mode matching is automatically satisfied from the very beginning of the procedure. In another paper of this conference [2], simulation results validated the approach. In the present work, this model is integrated within a gradient-based optimization loop for the design of instrument shape [3]. Simple geometries, involving few design variables, are considered here for the optimization of the inharmonicity of the resonator. The results are compared to those of the usual approach, in order to validate the procedure in very simple situations, and to emphasize the interest of the method. References [1] G. Le Vey. Graph-based models for woodwinds. In SMAC2013, Stockholm Music Acoustics Conference, Stockholm, July 2013. [2] G. Le Vey. Graph models of wind instruments : computing the natural frequencies of some elementary ducts. In ISMA 2014, Le Mans, France, July 2014. Submitted. [3] Petiot J-F. and Tavard F. Design and manufacturing of an artificial marine conch by bore optimisation. In Acoustics 2008, Paris, France, June,July 2008

Wed 11:00 Materials for musical instruments and Instrument making

Experimental Study of a Guitar Pickup [000138]

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A guitar pickup is a magneto-dynamical transducer sensitive to the velocity of metal strings. The characterization of these pickups is generally limited to the measurement of their electrical output impedance. Although the information given by this measurement is relevant, it is not sufficient to describe the behavior of such a sensor. In particular, a measurement of the transfer function "string velocity / generated output voltage" should provide valuable information regarding the frequency response of the sensor, its sensitivity, its (non) linearity , etc. . It would also allow the experimental study of the influence of various parameters (components, geometries, locations, styles of play, etc.) on the behavior of a pickup In this context, a test bench has recently been developed at LAUM , which allows the analysis of the influence of different parameters on the behavior of a simplified sensor (size and type of magnet, height of the coil , number of turns , gap between the magnet and string , ...) . The results of this analysis will be presented, discussed and compared with results obtained from an analytical model available in the literature. Finally, the study of different microphones guitar available on the market will also be addressed.

Wed 11:00 Materials for musical instruments and Instrument making

Passive simulation of electrodynamic loudspeakers for guitar amplifiers: a port- Hamiltonian approach [000083]

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Because of technological constraints, transducers are usually not ideal. In musical and audio applications, this is the case of electrodynamic loudspeakers used eg. in guitar amplifiers. Thus, to build realistic numerical simulations of such systems, it is important to pay close attention to their nonideality. These systems include several nonlinearities, mainly due to mechanical suspensions, magnetic properties and temperature variations. Another difficulty, reported in the literature, is concerned with the non standard behaviour of the coil, that can be represented by a

fractional order system. At the same time, it is not so straightforward to model such refinements while preserving basic physical properties such as causality, stability, passivity. In this paper, we introduce a new modeling of loudspeaker which accounts for both the fractional order dynamics and some relevant nonlinear effects, such that the power balance is guaranteed. We focus on the electromagnetic and mechanic modelings of the tranducer, while we apply a standard passive acoustic load on the diaphragm and neglect thermic phenomena. The approach is based on the formalism of the "port-Hamiltonian Systems" in the continuous-time domain, which naturally preserves the energetic behavior of elementary components as well as the power exchanges including for the nonlinear cases. By transcribing this property in the digital domain, we guarantee the stability of the simulations. Several real-time audio examples will be presented to illustrate the combined or separated effetcs of the proposed refinements(magnetic and mechanic nonlinearities, fractional order derivative).

Wed 15:00 Tools for instrument makers

Low Cost TMTC-based Impedance Spectrometer as a Reference Tool for Instrument Makers [000094]
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The acoustical impedance is one of the indissociable factors in the studies of sound production in woodwind instruments. Its experimental acquisition is obtained with impedance spectrometers, which has been developed since 1970. Most of the recent methods present practical requirements of hard access, although these same requirements ensure better and more accurate results, like the semi- infinite calibration ducts. In order to suggest an accessible and efficient tool for instrument makers, an adaptation of the apparatus proposed by Gibiat and Laloe in 1990 was built. Recicled or cheap materials were used for the mechanical parts. Also, all the computational tools were based on free softwares. The apparatus that works with the TMTC method was tested for simple ducts (cilindrical PVC tubes) and for variations of the brazilian woodwind instrument called pífano. The results are shown and discussed in this paper.

Wed 15:00 Tools for instrument makers

Experimental Validation of Adjusting the Resonances of a Simplified Bass Clarinet Through Modal Active Control [000105]
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This paper reports the experimental results of modifying the resonances of wind instruments using modal active control. Resonances of a simplified bass clarinet (a cylindrical tube coupled to a bass clarinet mouthpiece including a reed) are adjusted either in frequency or in damping in order to modify its playing properties (pitch, strength of the harmonics of the sound, transient behaviour). This is achieved using a control system made up of a collocated loudspeaker and microphone linked by an observer, which contains a model of the system, and a controller. Modifications of the transfer function, input impedance and radiated sound of the instrument are obtained.

Wed 15:00 Tools for instrument makers

Introducing Modal Analysis to Luthiers through an Experiment without Analyzer or Transducers [000011]
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Sound quality of stringed instruments (as violins and guitars) is strongly related to the vibration of their bodies, which has awakened the interest to different people. On one hand, luthiers have explored, majorly through empirical procedures, about how different structural designs cause variations in tonal quality of stringed instruments. On the other hand, scientists have tried to explain the vibrations of stringed instruments; typically using a powerful technique called modal analysis. Trying to link scientific research with instrument making seems adequate, but explaining vibrations using modal terms to luthiers is usually a hard task: applying modal analysis requires a strong background of experimental mechanics. In order to introduce modal analysis during a course of violin acoustics, a classroom activity was implemented in this work. A book separator is clamped at around one quarter of its terminations using rubber bands (resembling the first free mode of a bar), a peg is arbitrarily attached (resembling a transducer) and a finger drives six points (resembling an impact hammer) through the length of the separator.

A graph is created using six points in a row as a spatial representation of the measurements in the separator, and extending each point to obtain an arrow of magnitude proportional to the distance of the corresponding point to the nearest rubber band: straight up if the finger and the peg follow the same direction or straight down if both are contraries. After performing the experiment, students were capable of interpreting mobility measurements of a free bar.

Wed 15:00 Tools for instrument makers

The PAFI project : a collaborative approach for developing tools for instruments makers [000124]
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The history of musical instruments shows that they have mainly been developed empirically. The engineers and the researchers in acoustics can nowadays propose many sophisticated tools to characterize and to model complex mechanical systems (by identifying modal characteristics of a vibrating structure or a column of air), to characterize materials (by measuring mechanical modulus), to analyze musical sounds (by proposing tools for processing and representing sound signals). Adapting such tools to the specific context of instrument's maker workshop is a real challenge: a collaborative approach involving makers and acousticians is allowing the development of a software and hardware platform called PAFI (Plateforme d'Aide à la Facture Instrumentale). Such a tool is designed to have moderate cost and has to include robut protocols which are easy to set up. This communication reports the progress of this PAFI project. Several examples of collaborative actions will be presented: development of specific training sessions for instruments makers, development and use of a tool called "Lutherie tools", examples of application of PAFI tools on wind and stringed instruments and on bows.

Thu 8:45 Conference room Keynote lecture

An Acoustical Comparison of East Asian and Western String Instruments [000144]
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Over the last two centuries, several string instruments central to Western culture have received sustained acoustical examination. Considerable progress has been made in understanding why instruments are built the way they are, although an acoustical distinction between great instruments, and the merely competent, remains elusive. Might expanding our horizons shed some light on this issue? String instruments from other cultures have not had much attention from the musical acoustics community, although there is a small but growing body of literature on East Asian instruments. This talk will review that literature and point out the contrasts and similarities between instruments of the Western and East Asian traditions.

Thu 9:30 Conference room Cool instruments

Comparative study on the timbre of occidental and African plucked string instruments [000096]
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Two main families of instrument classification methods have been developed so far. On one side, the oldest one is the classical organology (Tranchefort, 1980), and aims to define the main classes of instrument based on their sound production mode. On the other side, computing sciences have developed Machine learning dedicated to music, cal- led Music Information Retrieval (MIR) (Klapuri, 2004; Herrera-Boyer et al., 2006). MIR is the interdisciplinary science of retrieving any meaningful information from mu- sic, which can be whether learned first (i.e. supervised classification), or discovered without any a priori know- ledge (i.e. unsupervised classification). Within these two approaches, the timbral complexity of ethnic music ins- trument raise major problems, making

difficult the definition of instrument classes and their automatic recognition. In this study, we performed an acoustic characteriza- tion of the timbre of various plucked string instruments of Africa, with the goal of quantifying the tim- bral complexity within this instrument family. As a first step, a complete set of acoustic descriptors is used pro- ject to project the timbral signature of each instrument in a multidimensional space integrating many physical components of the timbre (e.g. temporal profile, spectral content). Then, methods to reduce the dimensionality of this representation space have been used to conserve only dimensions optimizing the certain criteria, such as the inter-class discrimination. As a second step of analysis, unsupervised analysis of data visualisation/structuration (e.g. clustering) have been used to quantify the disper- sion of the acoustic timbre. A complexity measure of the timbre has been derived from this dispersion. This study presents an inter-note / inter-instrument / inter-cultural (ethnic / occident) comparative results.

Thu 9:45 Conference room Cool instruments

Simple Plucked and Blown Free Reeds from Southeast Asia [000025]

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The origins of the free reed mouth organs of Southeast Asia are lost in the prehistory of the region. This paper explores principles of construction and acoustical properties for two of the simplest, and presumably earliest, such instruments. The plucked, mouth-resonated lamellophone, common throughout the region and known by various names, is made by cutting the sides of the vibrating tongue from a single piece of wood, bamboo, or metal. The tongue is not plucked directly, but is excited by plucking the frame. The instrument is played by placing the reed tongue over the lips of the player using the vocal tract as a resonator. It is possible in some of these instruments to produce tones by blowing as well as plucking. The free reed horn, also given a variety of names by different ethnic groups, consists of the horn of a water buffalo or cow hollowed out and fitted with a single metal or bamboo free reed with at about half its length. Sometimes a section of bamboo is substituted for the horn. Three pitches are possible when this horn is played by blowing the reed: one with both ends of the horn open, one with the narrow end closed with a hand, and a third with the wide end closed. The pitches can be bent somewhat by adjusting the hand position.

Thu 10:00 Conference room Cool instruments

The Zurna : an Ottoman Oboe [000034]

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The Zurna is an Ottoman Oboe, emblematic and famous instrument from the 18 c. It was played outside and used for the announcement of Court celebrations or events. Modern avatars are still used throughout the Middle East. Some rare historical instruments are kept in national collections such as Musée de la musique (Paris), Musée d'Instruments de musique (Brussels) or Correr Collection (Venezia). The zurna has the particularity to be equipped with a removable wooden part, called the "fork", inserted into the tube to receive the reed. It offers the possibility to change the tune of the instrument by closing the first hole, the second hole becoming the first one, very useful for musician on horseback. The geometry of the fork is rather peculiar and makes the bore very unusual, with large cylindrical parts. This geometry is analysed on the acoustical point of view and some hypotheses on the functioning of the instrument are made regards to the anharmonicity of the resonance frequencies. Another specificity is that the zurna is made with light woods such as apricot which lead to porous pipes. So, the zurna has to be soaked in oil to be playable. Historical instruments have to respect strict rules for the best conservation and it can not be soaked in oil again. However, the impedance of a virtually playable historical zurna can be extrapolated from the measured input impedance "as it is", in which the quality factors of the impedance peaks are artificially enhanced. The validity of the enhancement procedure is validated on cylindrical wooden tubes.

Thu 11:00 Conference room Impact excitation

Real-Time Physical Model of a Piano-Hammer String Interaction Coupled to a Soundboard [000055]

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A methodology and working implementation for synthesis of physical models, solved with symplectic and multi-symplectic finite difference algorithms running on a Field Programable Gate Array (FPGA), capable of auralising

instrument models in real-time, presented by the author, is extended to synthesize the physical model of a grand piano-hammer/string-course interaction coupled to a soundboard. The piano hammer string interaction is modeled as a non-linear hysteretic impact model and iterated with a finite difference time domain integration scheme. The three strings of the course are iterated numerically with a symplectic Euler scheme time integrator and central finite difference approximation of the spatial domain. The soundboard is modeled as a 2-dimensional Kirchhoff plate with a non-linear normal load distiburtion resulting from the inclusion of a virtual piano bridge, and orthotropic material properties due to different Youngs moduli in the respective grain directions of the wood. The coupling between the strings and the soundboard is modeled by an impedance coupling at the interaction point, allowing vibrations from the soundboard to couple back to the strings, influencing the vibrations of the strings. The model is implemented on two XILINX ML605 FPGA development boards connected by a high speed IO port via the on-board SMA ports. The implementation is capable of auralising the sound radiated from the front plate and integrated to two virtual listener positions in real-time. It is possible to change physical parameters like the coupling strength, parameters of the hammer model, the tune of the strings and multiple others while playing.

Thu 11:15 Conference room Impact excitation

Modeling and simulating the dynamics of the grand piano action [000139]

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The grand piano action has been developed empirically over two centuries. In its modern version, it provides a remarkably accurate control of the hammer velocity and its impact time. By means of an elementary 1-DOF model, we show why it is mostly preferable to consider and simulate the dynamics by computing the reaction force in response to a motion imposed by the finger rather than the opposite. We present a complete dynamical model based on that proposed earlier by Lozada: 6 rotating bodies (key, damper, whippen, jack, escapement lever, hammer), pivots subject to dry and viscous friction, 13 contact zones with reacting and dissipative forces, 3 of them (hammer-jack, jack-escapement button, hammer-check) being also subject to Coulomb friction. This model introduces discontinuities on the velocities. The problems raised by the usual regular-dynamics formulation are discussed and a non-smooth dynamics approach is proposed. The results of the numerical simulation of the model are in very good agreement with the measurements for levels of playing ranging from *piano* to *forte*.

Thu 11:30 Conference room Impact excitation

Collisions in Drum Membranes: a preliminary study on a simplified system [000109]

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Collisions play an important role in musical acoustics. Extensive study has already been performed on this subject for a number of systems, with notable examples being the hammer-string collision in the piano, and the mallet-membrane collision relevant in drums.

This paper uses experiments and modelling to investigate collisions in the snare drum. This is an interesting percussion instrument, as two collision mechanisms feature prominently. Initial excitation usually results from collision between a striker, such as a mallet, and the upper ('batter') membrane. Ensuing membrane and cavity vibrations then give rise to secondary collisions between the lower membrane and a number of metal wires ('snares') that are tensioned across it. These collisions are crucial for the sound qualities of the snare drum, and so a proper understanding of their nature is essential for accurate sound synthesis models.

In this preliminary paper, a simplified experimental setup will be studied, consisting of a drumskin with a single snare stretched across it. The system can be excited either by plucking the string, or by striking the membrane with a mallet. A setup involving a high speed camera and a laser vibrometer will allow the motion of the snare and membrane to be captured.

Experimental results will be used in comparison with a novel numerical model that describes both the mallet-membrane and string-membrane collisions. The interactions are described by a non-linear force expressed in terms of a power law, similar to one used in the past for modelling the hammer-string collision in pianos.

Thu 11:45 Conference room Player gesture

Tonguing on brass instruments - Highspeed Visualization and Benchmarks of fastest Tempi [000057]

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The tongue is crucially involved in playing wind instruments and in the articulation of speech. The documentation of the playing techniques with respect to the shape and the motion of the tongue started first with the use of syllables (tata, ...) for didactic reasons; today techniques such as ultrasound or MRI (Schumacher et al 2013) have been used to visualize tongue motion in high quality. However, modern MRI recordings are limited to 4-20 images per second and spatial resolution is restricted by manual data acquisition. This research shows results of a 3D-recording of tongue-movement, visualizing a four point high-resolution trajectory inside the mouth recorded at a samplerate of 250Hz by means of an Electromagnetic Articulograph (Carstens AG501). In addition to this qualitative exploratory study, another quantitative study (n=206) has been done to evaluate the maximum tempi that can be played on brass instruments. Benchmarks of tempi for different instruments and various experience-levels of the players for 'single tonguing' and 'double-tonguing' have been evaluated over 30 seconds for continuous sixteenth notes. The average tempi (median) in BPM (Metronome values) for four 1/16 notes in the first two seconds have been for 'single tonguing' 109 for amateur, 120 for students and 123 bpm for professional players (167 for the fastest player, i.e. 11 notes per second). For 'double-tonguing' the averages are 149 for amateur, 170 for students and 172 bpm for professional players (238 for the fastest player, i.e. 16 notes per second).

Thu 12:00 Conference room Player gesture

Influence of the instrumentalist on the electric guitar vibratory behaviour [000101]
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The sound of the electric guitar is based on the conversion of the string vibration into an electrical signal. The string vibration may be affected by couplings with the body, mostly when there is a frequency coincidence between the modes of each sub-structure (strings and body). These kinds of coupling are generally analysed in experimental conditions far from playing conditions. The aim of this paper is therefore to quantify the influence of the guitarist on the guitar vibratory behaviour. Particular modes of the guitar's structure are therefore studied for different classic instrumentalist positions. The modal frequencies and dampings of the instrument are identified using an operational modal analysis. This method, based on the natural excitation technique using the analysis of inter-correlation functions of different sensors measuring at the same time the instrument vibration, is adapted to take into account the string as a particular excitation of the body. Experimentations are therefore performed while playing. The influence of the left hand holding the guitar neck, of the fingers pressing the string against the fingerboard, and of the right hand and the stomach touching the body are then quantified in terms of body modal parameters.

Thu 12:15 Conference room Player gesture

How does posture influence flute player's breathing and playing ? [000056]
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This study focuses on the influence of musical task and position on the preparatory gesture, respiratory patterns and the associated respiratory muscle recruitment used in flute playing. The study was triggered by the flute players and teachers claiming that the control of the playing starts during these preparatory phases. We present the experimental setup used to record simultaneously the lip positions, the activity of a few selected respiratory muscles, the chest wall compartment displacements and the associated volumes, the blowing pressure in the mouth of the player and finally, the radiated sound. Thus, the flautist plays two musical tasks, which present different complexities in two different postures (seated and standing position). The analysis of respiratory and hydrodynamical parameters show the strategy developed by the player in the case of different complex musical tasks. The data indicates a strong correlation between the duration of the musical phrase, the register at which it is played and the preparatory gesture. To play a demanding musical task, the flautist has to take into account all the difficulties

before playing. Furthermore, the flute player needs to adapt his respiratory strategy to the physiologic changes due to the position changes. However these respiratory control variations do not influence the hydrodynamical parameter control, which is thus independent of the change of position. Finally, our results on the respiratory control in the seated position are consistent with the observations in the literature on forced respiratory maneuvers.

Thu 14:00 Conference room Singing voice

Voice Source and Subglottal Pressure in Persian and Kurdish Singing [000046]

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Subglottal pressure (Psub) and voice source were analysed in singers representing traditional Persian and Kurdish singing styles, thereby complementing a previous study of stylistic formant-to-harmonics relationships as well as melodic ornaments in these traditions.
Audio and EGG signals were simultaneously recorded while the subjects sang excerpts from their traditional repertoires. The subjects either repeated the song, replacing each syllable of the lyrics with [pæ], or they sang diminuendo sequences of [pæ] on different pitches (with constant pitch in each sequence). Psub was recorded as the oral pressure during the occlusion for the consonant /p/.
Fundamental frequency F0 was measured from the EGG signal, and voice source parameters from inverse filtering of the audio signal by means of the custom made DeCap and S-naq software (Svante Granqvist). The relationships between Psub and voice source parameters, e.g., NAQ, MFDR, Closed Quotient and H1-H2 are compared between the two singing traditions and with some Western classical as well as non-classical singing styles (Zannger Borch & Sundberg 2011; Sundberg, Thalén & Popeil 2010; Björkner, Sundberg & Alku 2006; Björkner 2008).
The data indicate high adduction and high Psub as being characteristic for Persian and Kurdish singing; both styles use pressed phonation. This in combination with the strong second harmonic achieved by the formant tuning (as found in the previous study) seems to serve the purpose of producing a yelly sound in both styles.

Thu 14:15 Conference room Singing voice

Factors of the assessment of a vocal category in female singers - a preliminary study [000091]

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Recordings of 11 women of different voice type were evaluated using listening tests on examples of recitatives and coloraturas from Rossini's aria "Una voce poco fa". Seven voice teachers (trained group) and 7 musicians non-teachers (untrained group) evaluated the properties of the voice category, brightness, the degree of resonance, the position of vowels, suitability of vibrato, aesthetic expression, and vocal mobility. The results showed a significantly higher interjudge reliability (interclass correlation) in the trained group. The highest reliability was achieved at brightness and voice category evaluation, the least consistent was the evaluation of resonance. Factor analysis of assessment variability showed dependent rating of the voice category, brightness and vowel position for both groups in recitative. The trained group similarly evaluated the brightness a voice category in coloratura. Assessment of the voice category correlated with the reported categories of singers only in the trained group. LTA spectra differentiate the groups of mezzo-sopranos and sopranos in the region of 3.5-4 kHz in recitative and in the area of 1.5-2 and 3-3.5 kHz in coloratura. The singers, who were able to sing for a longer time in a higher position in coloratura and have lower values of the first formant amplification, were evaluated as a higher vocal category and brighter voice. The brightness was associated with a higher position of the center of gravity (COG) in the region of 2-5 kHz, the vocal category with an overall spectral width given by a higher position COG in 5-10 kHz.

Thu 14:30 Conference room Singing voice

Interplay between harmonics and formants in singing : when vowels become music [000119]

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In human speech, the production of vowels consists in strengthening some specific areas of the harmonic spectrum, known as formants, by adjusting vocal-tract acoustical resonances with articulators such as tongue, lips, velum, jaw, and larynx. In singing, a compromise is often sought between the frequency of harmonics and resonance frequencies, sometimes at the expense of vowel perception. In some vocal cultures, this link between harmonic frequency and

resonance frequency is skilfully adjusted. A melody is generated independently of the tonal melody related to vocal-fold vibrations. This is the case of harmonic singing, overtone singing or Xhoomij, practiced in Central Asia, but also of singing by Xhosa women in South Africa. In this paper, the adjustments between harmonics and formants are explored on a wide range of commercial singing recordings and experimental recordings in laboratory. Three main strategies are described from both acoustical and musical point of view. In a first case, the spectral melody is produced by a play on the first formant (F1). The first harmonic frequency is often kept constant and at low values due to period doubling induced by a ventricular vibration. In a second case, the spectral melody is produced by a play on the second formant (F2), with a higher frequency of the first harmonic. Complex spectral melody can also be developed by a vocal game on the first two formants. In particular, we will illustrate and discuss the cases where the two first formants evolve while remaining in an octave ratio (F2 = 2F1).

Thu 14:45 Conference room Singing voice

Positive Effect of Noise On Self-Perceived Vocal Control [000107]

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Good vocal control discriminates between the trained and untrained voice and critically contributes to the quality of singing. Achieving such high vocal control capabilities presents considerable challenges for professional western singers, especially at the high tessitura of their vocal range. While training and teaching classical singing one of the authors (T.M.) found a positive effect of running-water noise on vocal control. The effect was strongest in the more challenging aspects of singing. The purpose of the present study was therefore to examine this effect in a controlled experiment. In the initial phase described here, we set out to determine the effect of background noise on singers' perception of their own vocal control. Eleven soprano singers (students and professionals) performed 5 musical excerpts twice consecutively, with or without noise (administered though headphones). They were then asked to evaluate their performance according to nine criteria assessing key skills of vocal control. Statistical analysis showed that the noise condition was significantly preferred for the majority of the assessed criteria: "feeling comfortable about my singing" ($p<0.001$), "ease of singing high notes in terms of vocal effort" ($p<0.001$), "better ability to sing longer sustained notes" ($p<0.001$), "feeling that my singing was more correct" ($p=0.002$), "flexibility of voice in transition between notes" ($p=0.016$), "better vocal control" ($p=0.016$). In future stages of this study, the recorded excerpts will be analyzed acoustically and in addition these excerpts will be presented to experts for evaluation, in order to determine if the described effect is also perceptually discernible.

Thu 15:00 Conference room Singing voice

Sound Energy Measurement of Singing Voice on upper Parts of the Body: A Research in Classical, Pop, Soul and Musical Theatre Singing [000044]

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Most musical instruments exhibit complex patterns of sound radiation, which change with materials, pitches played and other factors. The same holds true for the body of a singer (regarded as an instrument) singing with her or his voice but activating also parts of the neck, face, etc. A topic addressed in this paper is whether there are differences of sound radiation energy between Classical and Popular including Soul and Musical Theatre singing. Five vowels /a/e/i/o/u/ at 250 Hz (approx. tone B3) were sung by seven trained singers (five females and two males of the four singing styles) and measured with a microphone array comprising 121 microphones. This method allows to measure in which body parts the energy of the singing voice is generally produced and its extent and strength. For this research, the energy of the singing voice was analyzed at fifteen body parts. The results show that the energy of singing voices is not only produced in the mouth but also in other body parts that can even become stronger in higher frequency range than from the mouth and the corners of the mouth. The non-mouth body parts are radiating relatively weak at the fundamental but radiate stronger in higher frequency range, so that the total of energy from the non-mouth parts can surpass not only the energy value from the mouth, but also that from the whole mouth region. However, this phenomenon depends not only on frequency range but also on the vocal technique and the vowel.

Thu 16:00 Conference room Perception

Pitch, Intensity, Duration and Spectrum - Psychoacoustic Thresholds of Musicians Compared to Non-Musicians [000030]

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Auditory performance of musicians is of interest because their exceptional listening abilities may serve as a reference for the limits of the human auditory system. Superior auditory performance of musicians has been reported primarily on tests that reflect specific facets of music, which may be the result of many years musical training. Only a few studies, however, attempted to compare the auditory abilities of musicians and non-musicians on basic psychoacoustic tasks. So far comparison between the two groups focused primarily on pitch discrimination abilities. The purpose of the present study was to compare the capabilities of musicians and non-musicians on different psychoacoustic abilities. Twelve musicians and 15 non-musicians, all with normal hearing, participated in this study. Each participant performed four psychoacoustic tests, obtaining thresholds for pitch, duration, intensity and spectral discrimination. For each test, five thresholds were obtained. Both groups improved thresholds on the pitch and intensity tasks only. On average musicians performed significantly better) on all but the intensity task. Their continued improvement within the study suggests that that the limits of the auditory system were not reached. Our findings that musicians performed better than non-musicians on tasks that they did not specifically train on may indicate the influence of top-down processing driven by music exposure and learning.

Thu 16:15 Conference room Perception

Old Italian versus new violins: the soloists' perspective [000036]

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Many researchers have sought explanations for the purported tonal superiority of Old Italian violins by investigating varnish and wood properties, plate tuning systems, and the spectral balance of the radiated sound. Nevertheless, the fundamental premise of tonal superiority has been investigated scientifically only once (1), and results showed a general preference for new violins, and that players were unable to reliably distinguish new violins from old. The study was however relatively small in terms of the number of violins tested (six), the time allotted to each player (an hour), and the size of the test space (a hotel room). In this study 10 renowned soloists each blind-tested six Old Italian violins (including five by Stradivari) and six new during two 1h15 sessions - the first in a rehearsal room, the second in a 300-seat concert hall. When asked to choose a violin to replace their own for a hypothetical concert tour, six of the ten soloists chose a new instrument. A single new violin was easily the most- preferred of the 12. On average, soloists rated their favorite new violins more highly than their favorite old for playability, articulation, and projection, and at least equal to old in terms of timbre. Soloists failed to distinguish new from old at better than chance levels. These results confirm and extend those of the earlier study, and present a striking challenge to near-canonical beliefs about Old Italian violins.

Thu 16:30 Conference room Perception

Perceptual Thresholds for String-Body Coupling in Plucked-String Instruments [000041]

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The coupling between the strings and body of a plucked-string instrument has a great influence on its tonal qualities. Strong coupling is advantageous to attain a responsive instrument but over-coupling can lead to unwanted effects and uneven tonal qualities from one note to another. An investigation has been carried out to evaluate the perceptual importance of different levels of string-body coupling in plucked-string instruments. Modal parameters consisting of effective masses, Q values and natural frequencies have been extracted from admittance measurements on a classical guitar and used in a pre-existing model that describes the interaction between body modes and nearby string modes. The model showed that over-coupling leads to fast string decays and significant frequency perturbations that can contribute greatly to an instruments' acoustic signature. Fourier analysis made on the radiated sound from the instrument enables characterisation of the components of the sound. This is useful to validate the coupling model as well as allowing re-synthesised tones to be generated for the use of psychoacoutical tests. Listening tests were carried out to assess the extent of even tonal qualities between notes by highlighting the

presence of wolf notes. Extending this work to include other instruments such as the steel-string guitar and banjo helps to clarify the quantitative relationships between the design of an instrument, its mechanical response and its perceived tonal qualities. Ultimately this work aids in understanding what structural changes lead to audible changes in the instrument's sound by considering string-body coupling.

Thu 16:45 Conference room Perception

A perceptual study on the effect of pad resonators on the saxophone [000064]
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There is a lot of controversy regarding the pad resonators of saxophones and their effect on the acoustical response of the instrument is not well known. The resonators, which are mounted in the middle of the pad, exist in different shapes (flat, domed, corrugated) and different materials (plastic, copper, brass, even gold!). A previous study [1] shows that pads without resonator tend to lower the impedance peaks of the saxophone, which may make the instrument more difficult to play. A perceptual study is performed with 13 musicians in order to characterize more precisely the influence of the resonators from the perspective of players. Four alto saxophones of the same model are given to the players and they are asked to blindly rate their brightness, ease of playing and evenness. Two saxophones are provided with domed plastic resonators, one with metal domed resonators and one without resonators. Results show that musicians perceive the saxophone without resonators as the least bright and least easy to play. As for the three other saxophones, they cannot distinguish them.
[1] P. Eveno, M. Curtit, J.-P. Dalmont, R. Caussé. Influence of pad "resonators" on saxophone. SMAC 2013, Stockholm, Sweden.

Thu 17:00 Conference room Perception

Comparison of perceived sound qualities of five clarinets of different makes [000130]
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In this paper, the perceived sound qualities of five clarinets from different manufacturers are compared. An attempt is made to relate differences in the timbres of the instruments to variations in their designs. A series of psychoacoustical listening tests is discussed. The listening tests are designed to investigate perceived differences between single notes played on the five clarinets. Recordings of four note pitches (E3, F3, F4 and B4 clarinet transposed notes), played at two different dynamic levels, are used to populate the tests. Each listening test is either made up of notes produced by a human player or notes produced by an artificial mouth. In the tests, participants are presented with 60 pairs of sounds and asked to rate the overall difference between the notes of each pair and also to indicate which has the brighter timbre. A selection of results from the listening tests is presented and analysed via comparison with geometrical, spectral centroid and input impedance measurements.

Thu 17:15 Conference room Perception

Modeling roughness perception for complex stimuli using a model of cochlear hydrodynamics [000092]
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A roughness model composed of a physiological auditory model and an algorithm calculating roughness from the envelope of the auditory model output signal is described in the study. The roughness model is sensitive to phase changes between the spectral components and to shape of the temporal waveform of the analyzed stimuli which limits most of the state of the art roughness models. Synthetic and real complex stimuli were used in this study to test the model performance. Amplitude modulated harmonic complexes and intervals in the chromatic scale composed of harmonic complexes were among the synthetic stimuli. Voice samples of a vowel /a/ extracted from the signal recorded during the scale signing were used as the real stimuli. Some of the samples were dysphonic (with roughness). Listening tests were conducted to obtain roughness ratings of the stimuli. The subjective roughness ratings correlated with the ratings predicted by the presented roughness model.

Thu 17:30 Perception

Pitched Musical Instrument Sound Inter-conversion Through Extraction of Timbre Features [000052]
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Abstract: Timbre is an abstract quantity that is responsible for distinguishing two sounds of the same frequency and amplitude. Timbre cannot be quantified easily as it depends on various temporal and spectral parameters like the time-domain envelope, spectral envelope, spectral flux and additive noise components. The work is based on the analysis-synthesis approach [1] and we assume the source- filter model [2] of musical instruments for the analysis. The parameter dependencies are extracted such that the sound can be recreated using the additive synthesis technique. In our work, we extract these dependencies of timbre in a manner suitable to our model to facilitate mapping of these feature dependencies of one instrument model to another. In the timbre space, variation of either frequency or volume affects the timbre significantly, thereby changing the dependencies on the extracted features. Our work also includes these variations to effectively map the timbre features in all frequency and loudness ranges. To validate our proposed method, we have used flute and violin samples which were specifically recorded for this purpose and database available online. [3]
References: [1] Xavier Rodet, Musical Sound Signals Analysis/Synthesis: Sinusoidal+Residual and Waveform Models. In Proceedings of the IEEE Time-Frequency and Time-Scale Workshop (TFTS), August 1997. [2] Thierry Galas and Xavier Rodet. Generalized Functional Approximation for Source Filter Modelling. In Proc. Eurospeech, pages 1085-1088, Geneve, 1991. [3] University of Iowa, Electronic Music Studios, theremin.music.uiowa.edu

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Bringing traditional instruments of Africa into the 21th century: Presentation of the 'Mvet fou' (Crazy Mvet) by François Essindi [000095]

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We propose in this project to bring together traditional musical concepts of Cameroun, including both instruments and musical corpus, and modern ones from Occident, including engineering technologies and musical styles. François Essindi is an artist and instrument maker from Cameroun, with the ambition of moving the musical heritage of Cameroun beyond traditional boundaries and make it evolve towards original and fruitful ways. As a first step, we will present various instrument making techniques realized by François to the traditional Mvet (a zither with steel strings from Cameroun), such as the fixation of strings to the calabashes with pegheads inspired from acoustic guitars, and a new global shape of the instrument which also allows original methods of playing. As a second step, we describe experiments of implementing sensors on this instrument, drawing inspiration from the field of instrument augmentation (Lahdeoja, 2010). This protocol includes piezoelectric, electromagnetic and optical sensors. And the three applications considered here are : 1. automatic music transcription, as the selected multichannel sensors allow to record the sound of each string separately, and convert a polyphonic signal into monophonic ones which are much easier to analyse (Cazau et al., 2013). The analytical recordings obtained with the sensors should help in transcribing traditional tunes from Africa and consequently in providing precise musical characterization and in their preservation ; 2. timbre modification, which is the main preoccupation of instrument augmentation 3. Human-Machine musical interaction, through the OMAX improvisation IT environment. We used this environment with the MIDI data from our retrieval system.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Acoustical Analysis of the Mexican Vihuela [000054]

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This work studies the tonal generation of the *Mexican vihuela* , a 19th century guitar-like chordophone mostly played by Mariachi groups as a rhythmic accompanying instrument. It has five nylon strings attached to a simple wooden bridge, glued to the soundboard. The strings are fixed at the bridge with a sling-knot which results in different boundary conditions compared to the case of a regular guitar-like string termination. Two transverse polarizations of string motion are measured with a high speed camera. Radiated tones are recorded with a dummy head in an anechoic chamber. Finally, radiation patterns are measured with an array of 11 x 11 microphones. All measurements are performed with the vihuela string termination and with a guitar-like bridge applied to the instrument for comparison. The strong beating is found to be caused by the specific string termination. The sling acts as a rigid termination for the perpendicular polarized part of the transverse string motion, but moves freely in the parallel direction. Comparable to effects found in the finish *kantele* , this leads to two different virtual lengths of the string. Spectra of the radiated tone show string modes of both string lengths resulting in a vivid, chorus-like

effect.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

A Bowed Bamboo Tube Zither from Southeast Asia [000043]

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The group of musical instruments generally classified as bamboo tube zithers can be considered typical for the Malayo-Polynesian linguistic area, frequently to be found, often with ethnic minorities, over a geographical space extending from Mindanao in the East to Madagascar in the West. Tube zithers are commonly considered to be very early representatives in the developmental history of the chordophone family [1]. An unusual type of bamboo tube zither, called the kating-gá-ùn, is the only continuous pitch instrument used by the Moken, a group of maritime nomad hunter- gatherers living, until comparatively recently in relative isolation, in the Mergui archipelago off the western coasts of Burma (Myanmar) and Thailand. The kating is of great significance in the context of the spiritual worldview of the Moken, the instrument's two heterochordic strings representing archetypal ancestral couples, a dichotomic dyad central to Moken mythology and ethnic identity. While the overwhelming majority of tube zithers are either plucked or beaten, the Moken kating is bowed, it thus belongs to the very rare category of bowed tube zithers (Hornbostel-Sachs classification: 312.121-71). A 30.000 fps high-speed camera point-tracking analysis of the string's transversal motion shows considerable differences compared to the behaviour of more elaborate types of bowed chordophones (i.e. the modern Violin). Also, the influence of the instrument's body's material properties (bamboo being anisotropic and inhomogeneous, as well as orthotropic) and morphology (being, in good approximation, an elongated hollow right circular cylinder) on sound production are to be discussed.

[1] See e.g. Norlind, T. (1939): Systematik der Saiteninstrumente, Bd.1. Stockholm. Musikhistoriska Museet. 69-70.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Acoustic characteristics of the Stroh-violin [000122]

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In 1899, the engineer Augustus Stroh invented the Stroh-violin (A. Stroh, Improvements in Violins and other Stringed Instrument, patent No. 9418 , 4th May 1899). This instrument has a solid body instrument, in which the soundbox has been suppressed. The bridge is mounted in a rocking whose vibrations are transmitted to a circular diaphragm, put at the entrance of a horn. The acoustic behaviour of hybrid instrument has two characteristics : Firstly, the directivity is strong and directly linked to the properties of the horn. Secondly, the spectral analysis of sounds produced by the instrument shows a filtering effect induced by strong resonances of the coupled bridge-diaphragm-horn system. A detailed experimental study of these two characteristics is performed on a modern Stroh instrument. Complementary investigations are also provided on historical Stroh-violin and Stroh-cello. A physical model of the instrument is done : the horn acoustic input impedance of the horn and the bridge admittance are modelled using a lumped element model, permitting an interpretation of the instrument response. The resonant behavior of the bridge has similar features with the one encountered in some classical violins and known as Bridge Hill. A discussion on the importance of the resulting filtering effect is made.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Vibroacoustics of the Guqin [000018]

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The guqin (or qin) is a plucked seven-string Chinese zither tuned pentatonically (typically C2-D3), with dimensions approximately 120 cm long, 20 cm wide and 5 cm deep, and 1.7-3.2 kg in mass. The guqin is played with the strings horizontal, and the soundbox is made in two shaped halves, the top usually being of tung wood and the base catalpa, each piece approximately 1 cm thick. There are two tone holes in the base, and one or two soundposts placed on the central axis inside. Our four examples, of widely varying quality, have been measured and modelled

in terms of wood and cavity modes, and of radiativity. At low frequencies our guqins display bending mode spectra, and associated radiativity, characteristic of a tapered beam, with a fundamental around 120 Hz. Above 600 Hz the radiation is stronger and dominated by the cavity modes radiating from the tone holes, which fills in the gaps between the bending modes. With holes blocked, the cavity modes have a fundamental frequency of about 150 Hz, and opening the holes largely silences modes below 600 Hz, with those above having a spectral density of around seven per kHz. The cavity modes are broad, owing to the rough finish of the interior and the constrictions ("absorbers") placed at the entrances to the tone holes, further smoothing the radiativity spectrum. The most obvious differences between our best and worst quality guqins are mass and radiativity; the best guqin is the heaviest and quietest instrument.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Acoustical study of the Carnyx of Tintignac [000048]

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The carnyx is an instrument which was used by Celtic peoples in various parts of Europe around 2000 years ago. In September 2004 an excavation at Tintignac (Naves, Corrèze district of France) revealed a buried horde of bronze instruments, including a lot of parts of several different carnyxes. Some of the parts have been put together to make an almost complete carnyx which has been exposed in Paris in 2012.
In 2011, a brass copy of this carnyx has been made by Jean Boisserie. This paper discusses some acoustical aspects of the carnyx brass copy, and presents measurements made on it. The measurements are mainly input impedance, vibrations measurements, and playing frequencies estimations. The question of the bore profile and its influence on the resonance frequencies inharmonicity are particularly discussed. In order to minimize the inharmonicity, it is suggested that the carnyx should be slightly extended. A specificity of the Tintignac carnyx is the presence of thin large ears on its head, their possible influence on the radiated sound is discussed.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Acoustical Impedance of the Xiao [000047]

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The xiao is a Chinese end-blown flute with a history of over a millennium, traditionally made of bamboo, notched at the blowing end, with six or eight finger holes. The tone range of the xiao is two to three octaves. Tones starting from the second octave come from over-blowing, and cross-fingerings have to be used for the third octave. Currently most xiaos have difficulties in sounding the higher notes, which also have serious intonation problems. This paper aims at explaining and solving the xiao's problems by studying its input impedance. As an air-reed instrument, the xiao plays at its input impedance minima. We use the transmission-matrix method to model the instrument, and experimentally measure the input impedance to validate the model. For finger hole configurations of 24 tones in the two and a half octaves under test, the model has a maximum deviation of 8 cents from measurements. Then the player's effects are taken into account, and the model is able to predict the tuning of a xiao with any tone hole positions, sizes, and arbitrary bore shape along the symmetry axis. Based on this model, numerical optimizations were applied to find the best configurations. A xiao made of PVC pipe with optimized tone holes shows tuning results as predicted. Modifying the bore shape shifts the frequencies of the impedance minima and can be used for controlling the brightness and volume of the instrument. Our optimizations of the bore shape are ongoing.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Persian Ney Headjoint for Modern Boehm Flute [000129]

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The Persian ney is an end-blown conical flute with a cylindrical bore at its entrance. The musician places the ney mouthpiece against the teeth and the tongue is used to form an air jet that impinges on the edge of the flute tube. The result of this unique interdental embouchure is a distinctive rich, airy timbre over which the player has a great deal of control using both tongue and upper lip. It also allows control of the pitch by a whole tone up and down,

accommodating the microtonal pitch demands of Persian music. The traditional Persian ney has six tone holes and a range of about two octaves, with five different playing registers. By contrast, the modern Boehm flute has a cylindrical body and a tapered headjoint that is side-blown, with a chromatic scale over two and a half octaves. A new mouthpiece-headjoint has been designed that uses the embouchure of the Persian ney but fits the body of the Boehm flute. To achieve good playability in the low register, a headjoint taper sets the ratio of the first two mode frequencies 30 to 50 cents wider than an octave. Tuning in the third octave is improved by a sudden expansion in the mouthpiece, the equivalent of the embouchure-to-cork shunt volume of the Boehm headjoint. The resulting instrument has the sound and flexibility of the ney but the chromatic scale and range of the Boehm flute.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Sound synthesis of Siku and closed pipe flutes [000131]

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Sound synthesis by physical modeling of flute-like instruments has been developed in various contexts and development environments, from acoustical research to musical applications. The models used have mostly been discussed and partially validated in comparison with recorders, open organ pipes and Boehm flute. Latin American flutes from the Andean region show some specific features that are distinctive from the instruments cited above, from the physical point of view as from the sounding aesthetics. The present study focuses on closed pipes used in open air playing of traditional music on indigenous instruments, like the sikú and antara. Both the power and the more "timbral" aesthetics of the sound are challenging for physical modeling. Apart from the approximately odd relation of resonant frequencies, the closed pipe induces a recirculation of the portion of the air flux that gets into the pipe, affecting the hydrodynamics of the jet. The high jet fluxes requested to play the instruments results in flow structures that are rapidly turbulent, as can be verified from a Reynolds number estimation. Models for sound synthesis including specific aeroacoustic features of these instruments will be discussed.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Maurice Martenot:From past to present [000141]

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In 1928 Maurice Martenot presented the first ondes Martenot at the Paris Opera. He created seven different models of this instrument between 1928 and 1975. Each successive model is an improvement on the previous one. The replacement of the tube amplifiers by transistors is among the most important organological and technical changes introduced. Today few musicians remember the first generation ondes Martenot, which were based on tube amplifiers. Though the functional qualities of ondes Martenot based on tube amplifiers account for the initial success of the instrument, the description of such functional qualities is a complex question. We present a tentative description of the functional qualities of a tube-based ondes Martenot. This description is based on the study of an instrument designed in 1932. This ondes Martenot is among the oldest that can still be preserved in its original state. Our work is a unique document on the art of making an ondes Martenot. The general design of the ondes Martenot studied here is consistent with the descriptions patented by M. Martenot. The ondes Martenot is based on a frequency mixer of the type found in superheterodyne radio receivers. The type of components found in this ondes Martenot are dated between 1920 and 1928. The functional analysis of the electrical and electronical components allows us to highlight the musical choices of the inventor. In this light, Maurice Martenot appears to be an "electronic luthier". This tube-based instrument is compared to transistor-based instrument of the last generation. This allows us to phenomenologically identify the technical improvements made by the inventor to his first models.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Acoustic Pots in Ancient Buildings: State of Art and Historical Questions [000142]

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From the 10th to 16th centuries and even later, the practice of using acoustical pots as a common feature in church architecture spread throughout Europe. Three questions could be addressed at their purpose; their efficiency, their origin and the intention of those who inserted them in the buildings.
More than efficiency, we pay attention on the intention of the builders. Behind this question, we attemptd to undertand the actual knowledge concerning acoustics and "architectural acoustics" at these periods. Particularly, the pots seems to have been inserted using rules related to the practice of musics (pots are often tuned) of, more surprisingly, also related to the volume of the edifice.
Furthermore, their insertion seems also follow symbolic considerations which is not in contradiction with acoustic interpretation. Indeed, at these time, practice and symbolism are deeply linked in a large part of societal and religious questions.
The poster will present, through further points of view (archeology, history of art, linguistics, acoustics), the state of the art of the knowledge of this old acoustical technics and the questions still opened.
The question of their origin which quickly emerged as a crucial one in our research, is also presented. The common idea of a direct filiation from antiquity is discused but evidences of a renewal (or an emergence) in the 9th century are given.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Effect of the shape of mouth pressure variation on dynamic oscillation threshold of a clarinet model [000073]

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Simple models of clarinet instruments based on iterated maps have been used in the past to successfully estimate the threshold of oscillation of this instrument as a function of a constant blowing pressure. However, when the blowing pressure gradually increases through time, the oscillations appear at a much higher value, called dynamic oscillation threshold, than what is predicted in the static case.
This is known as bifurcation delay, a phenomenon studied in [1,2] for a clarinet model. In particular the dynamic oscillation is predicted analytically when the blowing pressure is linearly increased. However, the mouth pressure cannot grow indefinitely. During a note attack, after an increasing phase, the musician stabilizes the mouth pressure.
In the present work, the analytical prediction of the dynamic oscillation threshold is extended to more complex situations in which the mouth pressure approaches a steady state pressure PM according to different non-linear time profiles. The predictions still show a good agreement with simulations of the simple clarinet-model. The different ways of stabilizing the pressure are compared in terms of bifurcation.
[1] Bergeot, B., Almeida, A., Vergez, C., & Gazengel, B. (2013). Prediction of the dynamic oscillation threshold in a clarinet model with a linearly increasing blowing pressure. Nonlinear Dynamics, 73(1-2), 521-534. doi:10.1007/s11071-013-0806-y.
[2] Bergeot, B., Almeida, A., Vergez, C., & Gazengel, B. (2013). Prediction of the dynamic oscillation threshold in a clarinet model with a linearly increasing blowing pressure: influence of noise. Nonlinear Dynamics, 74(3), 591-605. doi:10.1007/s11071-013-0991-8.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Tongue Control and Its Coordination with Blowing Pressure in Clarinet Playing [000067]

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Articulation is one of the most important techniques of playing wind instruments, and it requires skilful control of the tongue. Clarinettists use their tongues in coordination with rapid mouth pressure changes to initiate transients. An expert player studied here produces accented and *sforzando* notes with the fastest increases in pressure, starting by releasing the tongue from the reed while the mouth pressure is low, and reaching the highest levels of mouth pressure. For *staccato* notes, the tongue was used to stop the reed vibration and thus the sound. For all others, decreasing mouth pressure terminated the note. An experiment using a playing machine investigated another use of the (mechanical) tongue under controlled conditions. Without using the tongue, the threshold mouth pressure at which notes begin with gradually rising mouth pressure is higher than that at which the notes cease under slowly

falling pressures. For pressures lying in the hysteresis region between these two thresholds, transient displacement of the reed by the tongue initiates sustained notes.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

On the control of respiratory muscles in trombone performance [000078]

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From the physiological point of view, instrumental gesture in brass instrument performance can be presented as the action of respiratory muscles and adjustments of respiratory airway geometry, leading to a fine control of the quasi-static mouth pressure driving lip auto-oscillations. Among the different views and conceptions on how the respiratory system works or should work during playing, the roles of certain anatomical components such as the diaphragm or the abdominal musculature are important subjects of debate among musicians.

Today, new experimental tools such as optoelectronic plethysmography allow monitoring of chest-wall volumes with a low degree of invasiveness, hence making measurements during music performance easier to conduct. Along with recording of the quasi-static pressure at different locations within the respiratory system, the pressure developed by the different groups of respiratory muscles can be precisely quantified and the respiratory "gesture" of a music performer characterized. In this paper, we report experiments conducted on a trombone player. After describing the experimental setup, the net pressure developed by the diaphragm, as well as abdominal and rib cage muscles are extracted and their relationship to the mouth pressure, playing frequency and sound loudness assessed during basic playing tasks. The main results reveal a similar and almost linear variation of the actions of abdominal and rib-cage muscles when the playing frequency is varied, resulting into a sequential and coordinated variations of rib-cage and abdominal volumes. In addition, the diaphragm remains relaxed during playing, hence allowing an optimal coupling between the abdominal and rib-cage compartments.

Thu 11:00 Cool instruments, Impact excitation and Player gesture

Sound Radiation Characteristic of a Shakuhachi with different Playing Techniques [000121]

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The shakuhachi, a Japanese flute, is a rather small instrument with a simple geometry. Still, it appears to have a complicated spatial sound radiation characteristic. This effect results from interference of sound emanating from finger holes and the blowing hole as well as diffraction around and acoustic shadow behind the instrumentalist. Even in absence of room reflections, the pure direct sound of musical instruments already creates the impression of a certain extent of the source. This perceived extent is especially large for listeners close to the instrument and decreases with dinstance. This effect is investigated in more detail on the shakuhachi.

The sound of a shakuhachi is recorded in an anechoic chamber by a circular microphone array consisting of 128 microphones. Amplitude and phase per frequency and angle around the instrument are measured. Interaural phase- and amplitude differences as well as the correleation of the signals arriving at the two ears are calculated for several listening positions at various angles and distances. These parameters are compared between different playing techniques.

It is discussed how far the parameters are suitable to explain the perception of the spatial source extent.

Thu 16:00 Singing voice and Perception

Perception of Different Types of Roughness of Violin Tones [000102]

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The presented psychoacoustic experiment was focused on perception of roughness in violin tones. The research suggests a possible multi-dimensionality of perceived roughness linked to both the processes of sound generation influenced by irregularities in string oscillation and psychoacoustic roughness perception principles. The sounds of free violin G string, played with different bow speed and force (built-up of differing rough tones) were recorded with microphone. Simultaneously, the recordings of the violin string movement were done with high speed video camera. Nine standardized audio records were used as stimuli in listening tests with 18 subjects. Their roughness measure was obtained in ranking and rating test. The ratings of dissimilarity in roughness and verbal attributes descriptions were received in a pair comparison test. The resulting perception spaces were analyzed on space

dimensionality. Different kinds of roughness described with different verbal descriptions were joined with stimuli positions in perception space and also with form of string motion near the violin bridge. The obtained perception space had at least 3 dimensions and it was possible to recognize minimally the same number of roughness types in separate sectors of the space. The results will be presented also in 3D graphs and string movement documentation.

Thu 16:00 Singing voice and Perception

Perception of bass with some musical instruments in concert halls [000077]

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The perception of many orchestral instruments with their fundamental frequencies in the low frequency region may suffer from a lack of the bass in concert halls. In particular, the perception may be affected by the seat-dip attenuation which occurs typically between 80-1000 Hz due to the direct sound propagating across the audience area at near-grazing angles. This paper presents studies on the perception of bass with some musical instruments in four existing concert halls. In a paired comparison listening test, the assessors compared the amount of bass and overall clarity (articulation) in the concert halls with three musical excerpts. The excerpts are obtained by convolving anechoic recordings of cello, double bass, and tuba with room impulse responses of four European concert halls measured with a calibrated loudspeaker orchestra. The results show that perceived amount of bass is clearly stronger in the shoebox-shaped halls with wideband seat-dip attenuation than in the vineyard halls with narrowband seat-dip attenuation. Clarity, on the other hand, depends on the musical context.

Thu 16:00 Singing voice and Perception

Study of perceived differences between simulated and real trumpets sounds [000132]

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This paper addresses the perception of differences between sounds of trumpets, played by a musician or simulated by physical modeling. The harmonic balance technique is used to simulate trumpet sounds in permanent regime. The input parameter of the simulations is the input impedance of the trumpet (resonator), the control parameters are the characteristics of the virtual musician (excitator), and the outputs of the simulations are the playing frequency and the magnitude of the 6 first harmonics of the notes. Three different trumpets, obtained by small geometrical variations of the leadpipe, are first simulated using several virtual musicians, and second played by a "real" musician. The objective of this paper is to define to which extent differences between sounds are noticeable by a panel of listeners. The factors of the experiment are the type of instrument used (type of trumpet), the playing dynamics of the sounds (pressure in the mouth for the simulated sounds), and the virtual musician (characterized by the control parameters of the simulations). For the two populations of sounds (simulated or real), a two alternatives forced choice hearing test was designed, with a panel of 26 participants. The analysis of the results of the tests with the signal detection theory allows the determination of the influence of the different factors on the noticeable differences between the sounds. The agreement between the results concerning the simulated sounds and the real sounds is assessed, to open the door to sound simulations for instrument design.

Thu 16:00 Singing voice and Perception

The Research of Controlling Loudness in the Timbre Subjective Perception Experiment of Sheng [000076]

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Timbre is the attribute of sound that allows humans to distinguish among different sound sources. How to map the objective properties of timbre with its subjective properties of timbre perception has been a core issue of timbre research. It is known that when the objective properties of timbre are changed to study the mapping relationship, its loudness will be influenced, which may affect the subject perception on timbre. To remove such effect, the sound whose objective properties have been changed should be properly adjusted. The general experimental method is to adopt the additive synthesis model with a variety of sound synthesis experiments and subjective perception experiments. This approach has two problems. One is that the study only is on one note from different instruments, and it cannot represent the adjustment methods of entire range, especially for the loudness, which is significantly

influenced by frequency. The other is that the study ignores the impact on the synthesis model. To solve the above two problems, we adopted both the additive synthesis model and the filter separation method to synthesis sound and considered the influence on the entire range of loudness with one traditional Chinese instrument called " Sheng ". The effects on experimental results of the sound synthesized by these two different synthetic models were investigated and the corresponding loudness adjustment curves were obtained. The necessity of adjusting the corresponding loudness between the timbre property relationships is verified through the multi-dimensional scale model.

Thu 16:00 Singing voice and Perception

Assessing the perceived strike notes and tuning properties of two historical carillons based on the identified modes and empirical psychoacoustic pitch criteria [000111]

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Assessing the strike pitch of carillon bells is a difficult task, as this topic is connected with physical and subjective aspects, which cannot be easily departed. The perceived notes may pertain to actual modal frequencies but, as is well known, they often arise as virtual pitches. Furthermore, even if definite trends can be extracted from the results of subjective panel tests for evaluating the importance of the bell partials on the perceived pitches, results obtained along the carillon tessiture often display a significant dispersion. Therefore, criteria for assessing the bell tuning properties rely mostly on empirical data and are still a matter of debate.

We here address some of these issues, following our recent quantitative analysis of the two carillons of the Mafra National Palace (Debut et al., An objective approach for assessing the tuning properties of historical carillons, SMAC 2013). Using a polyreference modal identification technique, we extend our previous modal identification results to include the bells higher frequency modes. Hence, for each carillon bell which plays a separate note of the instrument, we obtain extensive charts displaying the frequency relationships between a set of its most significant partials.

Then, the topic of estimating the perceived pitch and tuning features of these musical instruments is addressed. We develop an optimization strategy for weighting the sets of identified modal frequencies with respect to several popular empirical criteria for strike notes, thus obtaining optimal estimations of the (virtual or otherwise) perceived bell pitches along the instruments tessiture. Following this evaluation, the perceived tuning features of the carillons are presented.

Thu 16:00 Singing voice and Perception

Enhanced music performing environment for persons with cochlear implants (CI) [000058]

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A cochlear implant (CI) user is able to participate in music sessions and even professional music making. Contemporary CIs have improved speech perception abilities, but they are still challenged with music perception (McDermott, 2004). In a CI, the frequency range and spectral resolution of normal hearing is substituted with 14-24 channels (Ojala, 2012; Patel, 2013).

During music-making, the limitations in auditory feedback require some extra effort from the performer, e.g. position in the room to get a satisfactory soundscape (Palmer, Lahtinen, Ojala, 2012). When performing with a microphone and a PA system, the monitor loudspeaker is an important asset.

The primary scope of this study is in finding purely acoustical ways of supporting the performers. Field tests with musicians have showed that support is often welcomed even with normal hearing performers (Tuominen et al., 2013). This study replicates those tests with hearing and sight-impaired people.

One CI user has found that a felt-brimmed hat enables him to perceive his own voice clearer. The hat acts primarily as an extension of outer ear by giving more directivity: attenuation to unwanted environmental sounds and enhanced perception of own voice.

Methods of the study include tests in an anechoic chamber with and without added early reflection (20-80ms) employing quantitative measurements of musical synchronization (pitch and attack) in simulated ensemble situations. The researchers firmly believe that studies with special need groups, such as CI users, reveal something hidden but useful, which may not be apparent for normal hearing performers.

Thu 16:00 Singing voice and Perception

A New Experimental Approach for Urban Soundscape Characterization Based on Sound Manipulation : A Pilot Study [000108]

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In this paper, we aim at better understanding how human mental representations are structured in the special case of the perception of urban soundscapes. This task is traditionally studied using questionnaires, surveys or categorization tasks followed by a lexical analysis. In contrast, we propose a new experimental approach to tackle this work. In this approach, the subject is asked to manipulate sound events and textures within a dedicated computer environment in order to recreate two complex urban soundscapes, one "ideal" and the other "not ideal". Subjects have access to a sound data set which has been designed and structured based upon perceptual considerations, and may alter the physical parameters of the selected sound samples. In order to achieve this, we use an audio-digital environment and a web audio interface for sound mining developed for the purposes of this study. The latter allows subjects to explore a sound database without resorting to text.
By focusing on the auditory modality during the experimental process, this new paradigm potentially allows us to better put the subject in context and gives us a more detailed description of the actual mental representations. In the light of the results presented in this paper, it seems that it also reduces the potential bias of only using verbalization during the experiment. After a brief presentation of the computer environment, we detail the results obtained during a pilot study achieved with ten subjects. We stress the differences between using this paradigm and one based on questionnaires.

Fri 8:45 Conference room Keynote lecture

The Changing Picture of Nonlinearity in Musical Instruments: Modeling and Simulation [000148]

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The standard model of the functioning of a musical instrument, namely that of a linear resonator (such as a string, acoustic tube, bar, membrane or plate) subject to a nonlinear excitation mechanism (such as a hammer, bow, or lip/reed) is a powerful one indeed. Such a formalism, through the application of the apparatus of linear system theory to the resonator, leads not only to ease in terms of analysis of the instrument as a whole, but also to efficient simulation designs, where the resonator may be modelled in terms of modes, or travelling waves, or in an input-output sense. In the past 20 or so years a more detailed picture of the resonator has emerged, involving nonlinear refinements to the model of the resonator, and leading to various perceptual effects: pitch glides in strings and membranes, phantom partial generation in strings, crashes in plate/shell based percussion instruments, brassiness in high-amplitude brass instrument playing, and finally, effects due to distributed collision as in the case of the sitar and snare drum. The range of phenomena to be investigated is thus greatly increased—and yet simulation becomes a much more challenging undertaking. In this talk, unifying features of (and distinctions among) such nonlinearities are discussed, particularly with regard to the problem of simulation, in the context of both model validation and physically-based sound synthesis.

Fri 9:30 Conference room Numerical simulation of musical sound

Sound Synthesis for Contact-Driven Musical Instruments via Discretisation of Hamilton's Equations [000027]

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Physical modelling of musical instruments involves studying nonlinear interactions between parts of the instrument. These can pose several difficulties concerning the accuracy and stability of numerical algorithms. In particular, when the underlying forces are non-analytic functions of the phase-space variables, a stability proof can only be obtained in limited cases. An approach, leading to unconditionally stable simulations, has recently been presented in the case of lumped collisions [V. Chatziioannou and M. van Walstijn, An Energy Conserving Finite Difference Scheme for Simulation of Collisions, SMAC-SMC 2013, pp. 584-591]. In that study, discretisation of Hamilton's equations, instead of the usual Newton's equations of motion, yields a numerical scheme that can be proven to be energy conserving.

In this paper, the above approach is extended to collisions of distributed objects. Namely, the interaction of an ideal string with a flat barrier is considered. The problem is formulated within the Hamiltonian framework and subsequently discretised. The resulting nonlinear Matrix equation can be shown to possess a unique solution, that enables the update of the algorithm. Energy conservation and thus numerical stability follows in a way similar to the lumped collision model. The existence of an analytic description of this interaction allows the validation of the presented model. The proposed methodology can be applied to sound synthesis applications involving musical instruments where collisions occur either in a confined (e.g. hammer-string interaction, mallet impact) or in a distributed region (e.g. string-bridge or reed-mouthpiece interaction).

Fri 9:45 Conference room Numerical simulation of musical sound

Numerical Simulation of Tanpura String Vibrations [000014]

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The Tanpura is a fretless string instrument producing lively sounding drones typical of the musical cultures of the Indian subcontinent. Like various other Eastern string instruments, its specific overtone-rich sound results from the strings interacting with a curved bridge, but with the additional feature of a thin thread placed between the string and the bridge, which effectively creates a "two-point bridge" [C. Valette, C. Cuesta, M. Castellengo, and C. Besnainou, *The Tampura Bridge as a Precursive Wave Generator*, ACUSTICA (74), pp 201- -208 (1991)].

Modelling of the vibrations of a string with a one-sided constraint has been studied in several previous works, but attempts to numerically simulate the string-bridge interactions as elastic or semi-elastic collisions are extremely rare. Part of the challenge stems from the difficulty in deriving stable numerical schemes for modelling the distributed elastic collisions.

This paper describes such a numerical model of the Tanpura, based on a recently developed energy method for simulation of musical instrument contact dynamics, and defining the end positions of the string at the tuning bead and the nut. Simulations starting from several types of initial conditions demonstrate that the model reproduces the main characteristic feature of Tanpura string vibrations, namely the sustained appearance of a precursor in the bridge force waveform, carrying a band of overtones which decrease in frequency as the string vibrations decay.

Simulations are used to illuminate, through comparison, the roles played by the string stiffness and the impact damping. The model is further demonstrated through several sound examples derived from the bridge force signal.

Fri 10:00 Conference room Numerical simulation of musical sound

Numerical Simulation of Whistles Using Lattice Boltzmann Methods [000051]

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The aeroacoustics of a whistle have been investigated using a physical model based on the lattice Boltzmann methods (LBM) in two dimensions. The geometric data has been measured directly from a real whistle and converted to a straightforward curved boundary in the LBM scheme with a relatively high resolution. A multiple relaxation time (MRT) technique has been employed to maintain the numerical stability and consequently a more realistic low viscosity can be used in the simulation. An absorbing boundary condition (ABC) has been used on the four outside boundaries to simulate an open space. The exciting jet is generated from a rectangular jet channel attached to the mouth of the whistle, where the velocity boundary is implemented by an ABC scheme with a non-zero target velocity. The computation has been carried out efficiently using parallel computing based on GPU devices with a speedup factor of about 20. The vortex motion in the regions around the labium that is essential for sound production has been qualitatively observed in the simulations. These images are similar to those reported in previous works based on experimental visualization and numerical simulations. Further, the sound spectrum and frequency shift phenomenon under various blowing speeds has been presented.

Fri 10:15 Conference room Numerical simulation of musical sound

Design of Algebraic Observers for Brass Instruments [000024]

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Physical high-fidelity models of brass instruments are available in the literature, but controlling them to obtain a proper musical restitution is still a challenge. The inversion of the model from a unique observation, namely the sound produced by the instrument, is therefore a natural way to deal with this situation. The observer design problem consisting in an estimation of the vibro-acoustic state of the system is essential for that purpose.
The observer design problem was addressed in [AN10] for an elementary brass system using elastic player lips and straight pipe models. A neutral system representation of the system and Lyapunov methods were used ; a proof of the observer stability was obtained and simulations have demonstrated that the estimation method is robust in the presence of noisy measurements.
However no adaptation to the noise power was performed, leading to a rate of convergence of the observer that was suboptimal. Moreover, as the observer dynamics was related to the uncoupled lips dynamics, the response could be slow and oscillatory.
Using a representation of the same brass model as a delay-differential algebraic system, together with a sensitivity analysis and Kalman filter theory, we address these limitations through a new observer design resulting in a substantial improvement of the observer rate of convergence.
[AN10]: D'Andréa-Novel, Brigitte, Jean-Michel Coron, and Thomas Hélie. 2010. "Asymptotic Observers for a Simplified Brass Instrument Model." Acta Acustica United with Acustica 96.

Fri 11:00 Conference room Experimental methods

Application of High-Speed Line Scan Camera for String Vibration Measurements [000033]
D. Kartofelev[a], M. Mustonen[a], A. Stulov[a] and V. Välimäki[b]
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A novel high accuracy experimental equipment for acoustical measurements of vibrating objects has been designed and built. This set-up consists of a high frame rate line scan camera and a custom-built optical lens system. The optical tube is designed to capture maximum amount of light, as well as to provide sufficient magnification. The experimental set-up gives possibility to perform accurate non-invasive measurements of vibration of various parts of musical instruments, such as the strings, bridges, necks, etc. The set-up has been calibrated and successfully used to capture the piano and bass guitar string motion. In addition, the captured video data are presented and explained. A robust method of the vibration data extraction from the recorded video file is presented.

Fri 11:15 Conference room Experimental methods

A study of acoustic wavefronts radiated from trombones and trumpets through Schlieren imaging and direct measurements [000104]
P. Rendon[a], T. Vázquez[a], R. Velasco[a], C. Echeverría[b], D. Porta[b], A. Pérez-López[a] and C. Stern[b]
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The flaring bell section of modern trombones and trumpets is known to be critical in determining a wide variety of properties associated with the sound radiated by these instruments. We are particularly interested in the shape of the radiated wavefront, which is not exactly plane nor spherical, and clearly depends on the bell profile. The outlines of both a trombone and a trumpet bell have been traced, and these instruments have then been used to measure the radiated sound pressure field directly. The radiated wavefronts have also been visualised using Schlieren imaging. We observe shock formation, and we are able to estimate from our results both the shock velocity and the shock rise time.

Fri 11:30 Conference room Experimental methods

Analysis of the attack phase of a guitar sound using high speed digital holography [000134]
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In the transient phase of a guitar sound, the spectral components associated with the string modes are superimposed to the contributions due to the structural modes of soundbox. Such contributions are strongly damped and allow

us to define the attack phase, which is likely to play an important role in the perception of the instrument. In this paper, we propose to study the vibration of a guitar soundboard during the attack phase using high speed digital holography : Optical holography is a non-intrusive technique based on the interference between a reference beam and the field diffracted by the studied object . The computation of the optical phase difference provides the out of plane vibration field with a very high spatial resolution. The recording of a sequence of holograms is performed using a high-speed camera, which permits to get a high resolution in the time domain. The noise present on the displacement field reconstructed at each time step depends on many parameters. A full numerical simulation of the measurement set up allows us to analyze and minimize this measurement noise. For the experiment presented in the paper, the excitation of the string is done using a wire-breaking technique in order to control precisely the string polarization at the beginning of the motion. The analysis of the motion is performed using a projection over the soundboard modes, and leads to a discussion on the structure of the attack phase.

Fri 11:45 Conference room Experimental methods

Impact of Excitation and Acoustic Conditions on the Accuracy of Directivity Measurements [000120]

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Directivity measurements of music instruments produce qualitative and quantitative information about the spatial distribution of sound energy. This information can be used for improved microphone placement during recording sessions but also serves as radiation characteristics for virtual instrument synthesis. Many directivity measurements have been performed in anechoic rooms, using a human or artificial player. However, the perceived sound of an instrument strongly depends on the playing technique, the room acoustics, the distance from the instrument and other conditions. This contribution points out potential consequences of different excitation techniques, microphone distance and acoustic boundary conditions on the accuracy of directivity measurements.

Fri 12:00 Conference room Experimental methods

Attack transient exploration on sopranino recorder with time-domain Near-Field Acoustic Holography method [000075]

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Directivity of musical instruments have been studied for a long time. In the last decades, there has been a growing interest in imaging methods for the characterization and localization of sound sources. These developments are of great help to study the stationary and transient radiation behaviour of woodwind instruments.
The time-domain Near-Field Acoustic Holography is one of these powerful imaging methods. NAH allows to separate the sources contributions from the different parts of an instrument. One of the advantage of the time-domain holography is to observe acoustic phenomena during transitory states. Most studies on recorder acoustic radiation were conducted during steady state, yet none of them focus on the attack transients. In order to investigate the acoustic radiation of the sopranino recorder, we use a semi-cylindrical microphone array, thus taking advantage of the geometrical symmetry of the recorder. In this study, the imaging method is used for the localization and the characterization of radiating sources on a sopranino recorder played by a performer. The array consists in a 4 angular and 11 longitudinal microphone arrangement. Taking into account the symmetry, the number of measurements points is $2 \times 11 \times 4 = 88$. The recorder is located at the center of the cylindrical array. This study aims at highlighting an acoustic coupling between finger holes, labium and bell during the attack transient. This experiment allows us to validate the experimental protocol: semi-cylindrical array and time domain acoustic holography method for woodwind instruments radiation investigations.

Fri 12:15 Conference room Experimental methods

Experimental Verification of Pickup Nonlinearity [000032]

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In this study the nonlinear mapping between the string displacement and a resulting magnetic pickup signal (magnetic flux) is studied experimentally. The presented experimental results are obtained by using a novel optical measuring technique based on the application of the line scan camera. The measurements of the string

vibrations are carried out both for the vertical and horizontal planes relative to the pickup, and for different initial plucking conditions. This allows to reconstruct the vibrational motion of a single point of the string in a plane that is perpendicular to the direction of the string at rest. It is confirmed that the mapping between the string displacement and a pickup signal is nonlinear indeed, and it is responsible for enhancement of the high frequency harmonic content of the produced timbre. Also, the difference of the nonlinear mapping between the string position and a pickup signal for the vertical and horizontal string displacements is discussed.

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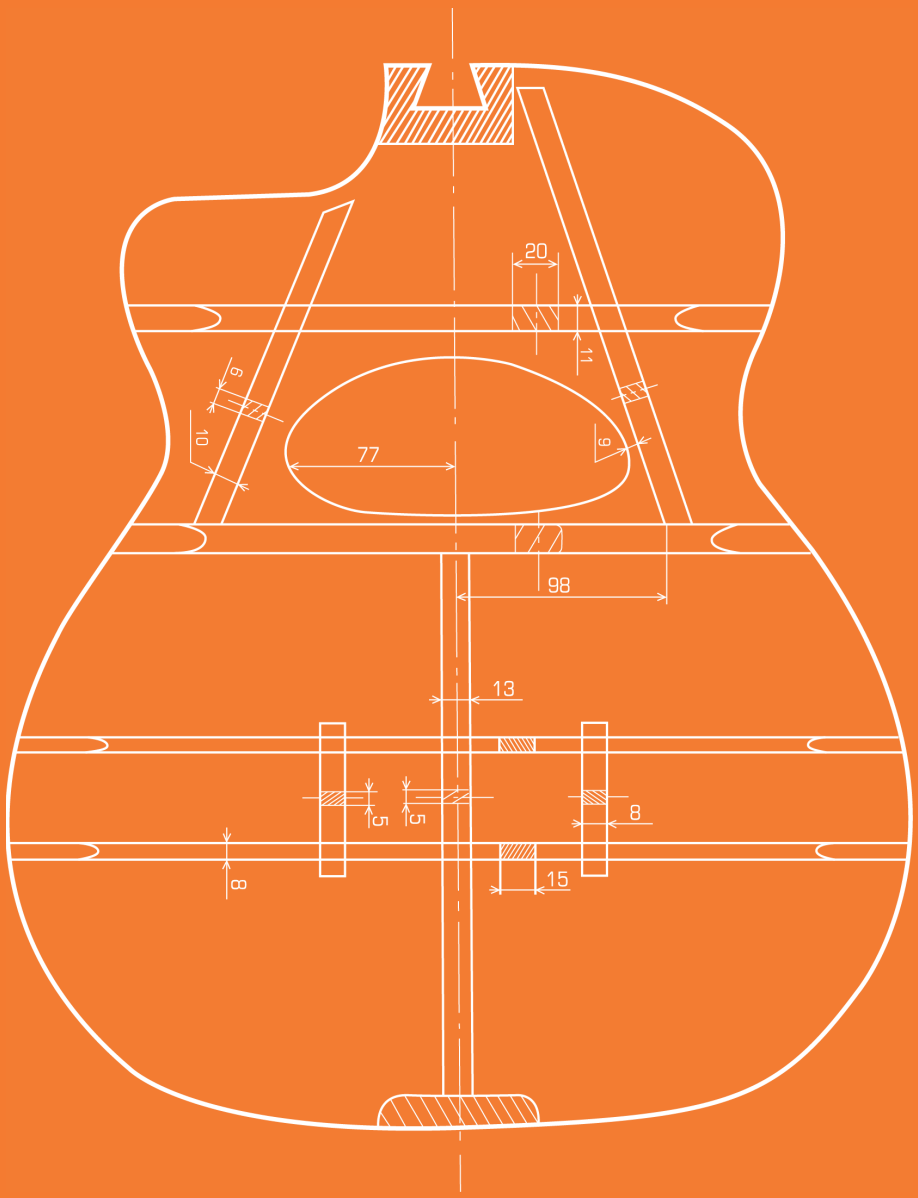
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