ISMRA 2016

The International Symposium on Musical and Room Acoustics

SEPTEMBER 11-13, 2016 - La Plata, Argentina

PROCEEDINGS

FIA Federación Federação Iberoamericana de Acústica

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ISMRA
2016

The International Symposium on Musical and Room Acoustics

La Plata, September 11-13, 2016

Proceedings

Editor:

Federico Miyara

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ISMRA 2016 in La Plata

The ISMRA2016 Organizing Committee and the Asociación de Acústicos Argentinos welcome musical and room acoustics researchers and specialists from around the world to participate in the International Symposium on Musical and Room Acoustics ISMRA 2016, a Satellite Symposium of ICA 2016 in Buenos Aires. This time the Symposium merges the topics corresponding to musical and room acoustics, usually developed in specific symposia ISMA and ISRA.

We come from different countries and continents, with different experiences from the point of view of politics, economics, culture and music. But at the same time, we share at least two main features that define and interpellate our contemporary sound landscape: the widespread use of modern digital systems of sound reproduction and the extensive application of dynamical compression in music transmission and recording. Answering those issues is, among others, one of the main challenges to our discipline. We hope that in the symposium we can interchange knowledge, experiences and good moments on those topics and on the others included in it and distributed among the different sessions that cover a wide range of themes related to room and musical acoustics.

We are confident that you will find the Symposium rewarding and challenging, and hope you have the opportunity to meet friends and colleagues in a convivial atmosphere.

We think that in this symposium we all share the passion for sound and, through sound, the passion for music. Music is, in our opinion, the core of all the sessions that will be held in ISMRA 2016. We are lucky to be passionate for such a wonderful subject.

You are welcome to La Plata and to ISMRA 2016.

Gustavo Basso
General Chair
of ISMRA2016

Nilda Vechiatti
Asociación de Acústicos
Argentinos President

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Technical Program

Day 1: Sunday, 11 September Teatro Argentino, La Plata			
	Piazzolla Room	**Conference Room**	**Pettorutti Room**
08:20	**Opening and registration**		Exhibition
09:00 - 09:20	**Opening Ceremony**		
09:20 - 10:10	Keynote presentation Room Acoustics ISMRA2016-68		
10:10 - 11:30	Session on Room Acoustics ISMRA2016-39 ISMRA2016-56 ISMRA2016-41 ISMRA2016-05	Session on Musical Acoustics ISMRA2016-46 ISMRA2016-85 ISMRA2016-36 ISMRA2016-63	
11:30 - 11:50	**Coffee break**		
11:50 - 13:00	e-Poster Session ISMRA2016-29 ISMRA2016-40 ISMRA2016-32 ISMRA2016-06 ISMRA2016-80	e-Poster Session ISMRA2016-83 ISMRA2016-48 ISMRA2016-77 ISMRA2016-49 ISMRA2016-73	
13:00 - 15:00	**Break**		
15:00 - 15:50	Keynote presentation Musical Acoustics ISMRA2016-69		
15:50 - 17:10	Session on Musical Acoustics ISMRA0216-38 ISMRA2016-27 ISMRA2016-82 ISMRA2016-42	Session on Room Acoustics ISMRA2016-23 ISMRA2016-70 ISMRA2016-14 ISMRA2016-52	
17:10 - 17:30	**Coffee break**		
17:30 - 18:30	Session on Musical Acoustics ISMRA2016-10 ISMRA2016-81 ISMRA2016-86	Session on Room Acoustics ISMRA2016-45 ISMRA2016-08	
18:00 - 19:00	**Technical visit to Teatro Argentino**		
19:30 - 20:30	**Welcome cocktail + Tango Show**		

Day 2: Monday, 12 September Planetarium, La Plata	
09:00 - 10:20	Session on Room Acoustics ISMRA2016-66 ISMRA2016-43 ISMRA2016-28 ISMRA2016-30
10:20 - 11:10	Keynote presentation Room and Musical Acoustics ISMRA2016-72
11:10 - 11:30	**Coffee break**
11:30 - 13:00	Session on Musical Acoustics ISMRA2016-47 ISMRA2016-60 ISMRA2016-09 ISMRA2016-50
13:00 - 15:00	**Break**
15:00 - 16:20	Session on Room Acoustics ISMRA2016-59 ISMRA2016-58 ISMRA2016-15 ISMRA2016-13
16:20 - 16:40	**Coffee break**
16:40 - 18:20	Joint Session on Room and Musical Acoustics ISMRA2016-22 ISMRA2016-79 ISMRA2016-34 ISMRA2016-55 ISMRA2016-37
18:20 -18:40	**Closing ceremony**

Day 3: Tuesday, 13 September Buenos Aires	
	Technical Visits in Buenos Aires Teatro Colón Usina del Arte Centro Cultural Kirchner (Ballena Azul Auditorium)

ISMRA 2016
ABSTRACTS

Sunday, 11 September 2016

Sunday morning, 11 September 2016 **Piazzzolla Room**
09:00 - 09:20
Opening Ceremony

Sunday morning, 11 September 2016 **Piazzzolla Room**
09:20 - 10:10
Plenary Lecture
Musical Acoustics
MA-PH: Physics of Musical Instruments and the Voice

PLENARY LECTURE
Physics of Musical Instruments and the Voice:
Paper ISMRA2016-68

Acoustics of pianos: An historical perspective

Antoine Chaigne
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Abstract
The art of piano making shows a considerable evolution during the nineteenth century. Around 1800, the instruments were built almost in the same manner as harpsichords, whereas the pi- anos made at the end of the century are very similar to modern pianos.This evolution is of major interest for musical acousticians, since the pianos made at successive milestones provide us with clearly distinct tone qualities. The challenge is then to establish the links between these tonal properties and the main physical parameters of the instruments. Precise knowledge and understanding of these links pave the way for a predictive approach in piano making. The lecture will start with the presentation of some of the most important aspects of the evolution of piano making, in terms of hammers, strings, soundboard and case. Consequences of this evolution for the strings caling, hammer forces, rib design and modal properties of the soundboard will be discussed. With the help of dedicated simulations of some representative models of pianos, it will be shown to what extent the observed differences in physical parameters can affect the efficiency of string-sound board coupling, the spectral content of the transients, and the temporal evolution of the tones.

Measurement of Concert Halls / Opera Houses:

Paper ISMRA2016-39

Measurements of IACC during music performance in concert halls

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Abstract

Spatial aspects of the sound field at concert listeners' ears have for many decades been considered important for the experience of concert hall acoustics. Strangely enough, this knowledge has not led to development of direct measurement methods. Acousticians seems to have arrived at the consensus that two distinct aspects are important, namely Source Broadening or Apparent Source Width (ASW), and Listener Envelopment (LEV). The aspects are considered predictable from impulse response measurements, in terms of LF and 1-IACCE for ASW, and LLG and 1-IACCL for LEV. In order to explore cues of ASW and LEV directly at listeners' ears, this author has analyzed binaural recordings in concerts with symphony orchestras. Until otherwise proven, one would expect that any difference between two halls that can be perceived by our ears could also be measured as soon as the technical challenges are overcome. At least, one would like to test the common understanding that there are significant differences in IACC from hall to hall. This paper presents results from measurements of IACC(t) obtained from binaural recordings during symphony orchestra performances worldwide, including well-known halls and orchestras, with statistics from N=337989 correlation periods measured over 33799 seconds, i.e. >9 hours, from 10 big concert halls in Europe and the US. The hypothesis, "Binaural signals, i.e. signals at listeners' pair of ears, can exhibit statistically significant hall-to-hall differences in cross-correlation", is not rejected by the data. In further work, the issue of predicting ASW(t) and LEV(t) in terms of parallel streams will be pursued.

Measurement of Concert Halls / Opera Houses:

Paper ISMRA2016-56

Stage and pit acoustics in opera houses

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Abstract

Musicians and singers in opera houses work together in an extremely difficult acoustical environment. Due to the acoustic and visual aspects, the orchestra is traditionally situated in a pit before or partly below the stage. This lowering and partly covering the orchestra works positively on the balance between singers and orchestra. The partly covering is especially positive for large opera's; it enables a full symphony orchestra sound without losing the balance to the lower power of the singers. Bayreuth is an extreme example of such an orchestra pit that significantly reduces the loudness of the orchestra. However, the working environment for musicians and singers is a real challenge. As they usually can't see each other, they both heavily depend on the conductor, in the pit the loudness is high and the singers often stand between absorbing decorative elements and curtains. Although there are not much reflection paths left between musicians and singers, the few remaining possibilities for early energy sound transmission paths can cause large differences between opera houses. The differences are clearly noticeable in the acoustical interaction between musicians and singers as well as in the balance between the two at the listeners' positions. Measurements made in the Staatsoper Berlin, Festspielhaus Bayreuth, Oper Cologne and Komische Oper Berlin are used to analyze the differences, which can be used for the design of new opera houses as well as improvements for renovations.

Measurement of Concert Halls / Opera Houses:
[Paper ISMRA2016-41]

Recording of Italian Opera orchestra and soloists: The musicians point of view

Dario D'Orazio[(a)], Simona De Cesaris[(a)], Jacopo Rivani[(b)], Massimo Garai[(a)]
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[(b)] Orchestra Conductor, La Corelli, Ravenna

Abstract
Anechoic recordings of symphony orchestra have been proposed in the literature and have been used in a multitude of studies concerning both innovative measurements and psychoacoustic experiments. Using the same approach, the present work shows the results of a recording cam- paign focused on theItalian Opera. Different motifs fromI talian Operas have been played by professional musicians and soloists in the silent room of the Bologna University. The excerpts have been chosen because of their musical style characteristics and their acoustic properties (dynamics, timbre, vibrato). The chosen motifs come from scores of Donizetti, Verdi and Puccini, in order to consider various orchestrations and Opera styles.

Measurements of Concert Halls / Opera Houses:
[Paper ISMRA2016-05]

A New Chamber Hall in M. Karlowicz Philhamonic Orchestra in Szczecin Poland

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Abstract
This paper describes a new Chamber Hall inside of: "M.Karlowicz Philharmonic, in Szczecin". The acoustic design of the project was finished in 2009. It was built later and finally opened on 6nd September 2014. The acoustics of the two halls of new Philharmonic hall have been very well received by audience public. On this report, we outline several acoustic aspects of design which were developed, obtaining a very result excellent. Furthermore we show the acoustic results. In this design we have played with convex curves that are excellent diffusers of sound. This curves more tensed are seen also in the walls. "The Chamber hall, also known as "acoustical gem", may accommodate nearly 192≈200 people. All acoustic parameters of the Chamber hall are excellent. In this report, we outline several acoustic aspects of design which were developed, obtaining a good result.

Sunday morning, 11 September 2016 — **Conference Room**
10:10 - 11:30
Musical Acoustics
MA-PH: Physics of musical instruments and voice

Physics of Musical Instruments and the Voice:
[Paper ISMRA2016-46]

Modernization of traditional Asian free reed instruments: Comparing the sheng and the khaen

James Cottingham[(a)]
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Abstract
Two Asian free reed mouth organs operating on similar acoustical principles have had contrasting histories: the Chinese sheng and the Laotian khaen. Both are multiple-pipe mouth organs constructed from pipes with a free reed in each pipe. The sheng has a two thousand year recorded history in China, and in the last century modified versions have been developed and appeared in the Western concert hall style setting of the Chinese orchestra. The khaen, while remaining a strong cultural symbol of the Lao people, has not undergone similar developments as once prevalent traditional performance styles have almost disappeared. One common modification of the sheng is the attachment of cylindrical metal pipe resonators attached to most of the pipes. Of particular interest in the current study is a sheng in a traditional 17-pipe configuration, but with these resonators attached.

The resonators both amplify the radiated sound and alter the tone quality. Calculations of input impedance have been made for the pipes, with and without the resonators attached. These calculations are compared with the measured pipe impedances as well as the measured sounding frequencies and sound spectra. [Work partially supported by United States National Science Foundation Grant PHY-1004860]

Physics of Musical Instruments and the Voice:

Paper ISMRA2016-85

Non-stationary tones in reed instruments: A sequence of stationary states?

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[b] Université du Maine, France

Abstract

Self-sustained instruments, such as the reed family, are capable of producing sustained, periodic notes, as the energy is provided throughout the entire life of the note. If it is too stable, however, the note will sound mechanical and uninteresting. During the course of an isolated note or a musical phrase, an oboist adjusts the blowing pressure, lip force and even the mouth cavity configuration to produce a note or a musical phrase envelope that makes the timbre, loudness and pitch evolve during this note or phrase. Moreover, he or she might use an intended faster and regular fluctuation in some notes that is usually called vibrato, and in some cases tremolo. Achieving this evolution can make the difference between a good and an expert musician. When studying these fluctuations in the time scale of a vibrato or a note, it is interesting to ask whether they can be considered as a continuous succession of the stationary regimes corresponding to instantaneous values of playing parameters (mouth pressure and lip force for instance). By using simulations and real instruments played by an artificial mouth, we investigate this quasi-static hypothesis in carefully controlled and archetypal time-evolutions of these two parameters..

Physics of Musical Instruments and the Voice:

Paper ISMRA2016-36

Improving the stability of a hybrid wind instrument using two microphones

Kurijn Buys[a], **David Sharp**[b], **Robin Laney**[c]

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Abstract

A hybrid wind instrument is constructed by putting a theoretical excitation model (such as a real- time computed physical model of a clarinet embouchure) in interaction with a real wind instrument resonator. In previous work, the successful construction of a hybrid wind instrument has been demonstrated, with the interaction facilitated by a loudspeaker and a single microphone placed at the entrance of a clarinet-like tube.The prototype was evaluated using physical models of a single-reed, a lip-reed and a bow-string interaction. Musically relevant results wereobtained when the negative gradient of the nonlinear excitation function was limited to a certain threshold. When surpassed, erroneous noises appeared. In thepresent paper, a study of the open-loop system (the input-to-output response excluding the excitation model) reveals that this instability is caused by strong, high-frequency resonance peaks combined with an inverted phase response. The high frequency resonance peaks appear to result from non-planar air vibration modes in the small cavity in front of the loudspeaker. Hence, they are avoided by repositioning the microphone at the centre of the loudspeaker cavity. Mean- while, the inverted phase state occurs due tovarious phase lag sources such as the inevitable input-to-output latency of the computing system. This is accounted for by introducing a second microphone a distance $c{:}\Delta t$ along the tube (where c is the speed of sound and Δt the latency). The excitation models are implemented on a new digital real-time audio platform, “Bela”, supporting multiple audio inputs. A better stability is obtained and evaluation with a real clarinet gives musically relevant results.

Physics of Musical Instruments and the Voice:
[Paper ISMRA2016-63]

Trumpet mouthpiece equivalent lengths

Peter Hoekje[(a)], Hannah Hubbell[(b)]
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Abstract
The mouthpiece of a brass instrument serves two functions. On the one hand it provides a supportive interface to the player's lips. But it also controls the tuning of the instrument resonances, which should be harmonically related in order to give the best playing response. This acoustic effect of the mouthpiece is described by its frequency dependent equivalent length *Leq*, which can be defined as the shortest length of cylindrical tubing that could replace the mouthpiece and give the same boundary condition at the junction with the rest of the instrument. For most of the instrument resonances, *Leq* is shorter than 1/8 of the wavelength and the mouthpiece is well described by a two parameter model using the total volume and the frequency of its first or Helmholtz resonance. Any given mouthpiece may need to be tuned to its instrument in order to improve its playing characteristics, exemplified by a crescendo test and by an attack response test as well as by intonation of the various registers. Examples are given for a number of soprano brass instruments.

11:30 - 11:50
Coffee break

Sunday morning, 11 September 2016 **Piazzolla Room**
11:50 - 13:00
Room Acoustics
RA-SM: Simulation and Auralization of Concert Halls / Opera Houses

POSTER
Simulation and Auralization of Concert Halls / Opera Houses:
[Paper ISMRA2016-29]

Study of energy acoustical parameters at audience area in a simulated multi-purpose hall with an articulated orchestra shell

Gabriel Mello Silva[(a)], Alexandre Virginelli Maiorino[(b)], Stelamaris Rolla Bertoli[(c)]
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Abstract
The basic requirement for multi-purpose theaters is the adaptation to different musical styles that should be presented in the room. Orchestral shells provide better ensemble feeling to musicians, but also benefit listeners with closer first reflections. Nevertheless, there are few works devoted to study the acoustical influence of shells at the audience area. The Teatro Municipal de Paulinia, located in the countryside of São Paulo (Brazil), is a multi-purpose theater equipped with an articulated poly-cylindrical orchestral shell with a retractile ceiling. In previous works, the acoustic parameters TR, EDT and C80 were measured according to ISO 3382-1:2009 in two configurations of the unoccupied theater: in the presence and absence of the shell. However, energy related parameters (G, Gearly and Glate) and spatiality parameters (LF and GLL) were not studied. This paper aims to assess the computational model of the theater through the measurement data and calculate these other acoustical parameters to further analyze the resulting effect of the shell upon the audience area. First, the model is validated in the configuration of the theater where the shell is not mounted, so as to estimate the absorption and scattering coefficients of the room. Then, the model is validated in the presence of the shell to estimate its absorption coefficient. The parameters G, Gearly, Glate, LF and GLL are calculated in both configurations. The results indicated an improvement in the acoustical performance of listeners.

POSTER

Simulation and Auralization of Concert Halls / Opera Houses:

Paper ISMRA2016-40

The choice of architectural materials and its influence in the acoustical performance of an opera house

Roberta Smiderle[a], Alexandre Maiorino[b], Rafaella Estevão da Rocha[c]

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Abstract

Several cultural buildings have the start of its project conception ruled by other issues than those concerning its future use of space. Architects have to follow laws, finances, culture, society and other aspects before get in to the architectural features. In addition, most of the projects developed in Brazil, follow the aesthetical parameters rather than the necessities of the project. For an Opera House, it is mandatory that the project strictly follows the acoustical demands in order to achieve the adequate behavior for its use. In this research, the aim was to analyze the acoustical aspects influenced by the choice of specific acoustical materials and their positioning inside the building. Quantitative analysis was done through computational simulation in an Opera House still in project stage. The virtual simulation considered four situations: (I) Acoustical materials specified on the original project; (II) Changing the materials inside the stage house; (III) Changing the materials in the audience area; (IV) Acoustical materials changing in all the theatre. Analyzed parameters were Reverberation Time, Early Decay Time, Clarity, Definition and Sound Strength, and compared to the literature. The results demonstrated that although the analyzed theater is considered as a project for an Opera House, it does not pursue the ideal criteria according to the directives found in the literature. The theatre does not have an appropriate acoustical performance, nor the stage or the orchestra pit follow proper architectural parameters. Changing in the material along the experiment improved the acoustical performance of the project.

POSTER

Simulation and Auralization of Concert Halls / Opera Houses:

Paper ISMRA2016-32

Double slope decay rooms: the influence of coupling aperture location on reverberation according to seat location

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Abstract

The construction of performance spaces with variable acoustics is part of a growing tendency among acousticians. One way of varying the acoustics of a room is using a coupled acoustic chamber that can be located around the stage area or along the sidewalls. The coupling area can substantially change the reverberation time of the hall, depending on volume and the ratio of absorption between the chamber and the main room. Coupled rooms are common for having a double slope decay curve. It is also common that the doors of the chamber are located in a balcony area where there are audience seats. Therefore, it is possible that with the same coupling area, different listener positions may have a different perception of spatialization due to proximity of the acoustic chamber. Also, if a room has several coupling doors, the location and sequence of opening may interfere in the acoustic perception of that space. The aim of this study is to compare the variation of reverberation time in a coupled volume concert hall in several seats location by changing the location of the coupling areas. A concert hall was simulated in Odeon with 12 different coupling areas by means of 136 doors. Two scenarios were analyzed: one, where the apertures are progressively opened close to the audience, another, where the openings are opened far from the audience seats. Results show that the location of the coupling areas promotes a variation in reverberation time in different seats positions and listeners may possibly perceive it.

POSTER

Evaluation of Concert Halls / Opera Houses:

Paper ISMRA2016-06

Acoustics for amplified music and a new, variable acoustics technology that includes low frequencies

Niels W. Adelman-Larsen
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Abstract

Surveys among professional musicians and sound engineers reveal that a long reverberation time at low frequencies in halls during concerts of reinforced music such as pop and rock, is a common cause for an unacceptable sounding event. Mid- and high-frequency sound is seldom a reason for lack of clarity and definition due to a 6 times higher absorption by audience compared to low frequencies, and a higher directivity of speakers at these frequencies. Lower frequency sounds are, within the genre of popular music, rhythmically very active and loud, and a long reverberation leads to a situation where the various notes and sounds including vocals cannot be clearly distinguished. This reverberant bass sound rumble often partially masks even the direct higher pitched sounds. A new technology of inflatable, thin plastic membranes presents a solution to this challenge of needed low-frequency control. It is equally suitable for multipurpose concert halls that need to adjust their acoustics by the push of a button and for halls and arenas that only occasionally present amplified music and need to be treated just for the event. The technology, permanently mounted, is being projected in various concert halls around the world and is being installed in the new Dubai Opera and the Sheik Jaber Al Ahmad Cultural Center, Kuwait during spring 2016. This paper presents the authors' research as well as the technology showing applications in dissimilarly sized venues, including on/off measurements of reverberation time versus frequency.

POSTER

Evaluation of Concert Halls/Opera Houses:

Paper ISMRA2016-80

The acoustical quality of rooms for music based on their architectural typologies

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Abstract

The acoustical quality of an auditorium for music is a complex cultural subject that involves, at least, the physics of waves, the auditory perception, the musical use of the space and the listeners' individual preferences. The scientific analysis of those questions requires the examination of the complex correspondence between the acoustical fields and the music perception of them. The main objective of this paper is to develop a methodology of acoustical analysis and design, which allows us to predict some aspects of the final acoustical quality of a hall based on its basic architectural shapes. From the selected acoustical data, four main architectural typologies were established as canonical shapes: shoebox, fan, vineyard and horseshoe. All of them have their own and particular acoustical behavior. The analysis carried out in several auditoriums and theatres within the Republic of Argentina allows us to conclude that the acoustic quality of a hall for music can be inferred from its architectural basic typology, if certain general conditions are met. On the other hand, it is possible to explain the behavior of some non-traditional acoustic fields by applying an analysis that combines various architectural typologies.

Sunday morning, 11 September 2016 **Conference Room**
11:50 - 13:00
Musical Acoustics
MA-PH: Physics of Musical Instruments and the Voice

POSTER

Physics of Musical Instruments and the Voice:

Paper ISMRA2016-83

A new method for high-speed line-scanning of brass players' vibrating lips using the examples of subcontra G-flat (tuba) and split tones (trombone)

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Abstract

This study aims to develop a device for observation of lip vibrations in brass musicians. To avoid motion artefacts, mouthpieces with probe holes for the endoscope were used. A standardised device with fixed coupling between endoscope and camera on the one hand and mouthpiece with instrument on the other hand was constructed. For localisation of the probe hole the endoscope was positioned opposite to the mouthpiece so that the outer rim of the mouthpiece was completely visible through the endoscope. The distance between endoscope tip and outer rim was measured and mirrored on a horizontal axis alongside the outer rim. The optimal position for the probe hole resulted and allowed a frontal view on the lips. Thus, lip vibrations were observed with a kymography camera in real-time. Two examples of high-speed line-scanning illustrate this technique: While playing a subcontra G-flat (approx. 23 Hz), each lip vibration correlates with a video frame (frame rate 25 Hz). Single sinusoidal lip vibrations can be distinguished. Split tones (e.g. "Keren" by Iannis Xenakis) are multiphonic effects on brass instruments. Two pitches with different frequencies are played. The pitches alternate so quickly that the human ear notices them simultaneously. Imaging methods like high-speed line-scanning can be used as biofeedback in order to bring these brass playing techniques to perfection.

Sunday morning, 11 September 2016 **Conference Room**
11:50 - 13:00
Musical Acoustics
MA-SP: Sound production – Sound synthesis

POSTER

Sound Production - Sound Synthesis:

Paper ISMRA2016-48

Eliminating aliasing caused by discontinuities using integrals of the sinc function

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Abstract

A study on the limits of band limited correction functions used to eliminate aliasing in audio signals with discontinuities is presented. Trivial sampling of signals with discontinuities in their waveform or their derivatives causes high levels of aliasing distortion due to the infinite bandwidth of these discontinuities.Geometrical oscillator waveforms used in subtractive synthesis are a common example of audio signals with these characteristics. However, discontinuities may also be introduced in arbitrary signals during operations such as signal clipping an drectification. Several existing techniques aim to increase the perceived quality of oscillators by attenuating aliasing sufficiently to be

inaudible. One family of these techniques consists on using the bandlimited step (BLEP) and ramp (BLAMP) functions to quasi-bandlimit discontinuities. Recent work on antialiasing clipped audio signals has demonstrated the suitability of the BLAMP method in this context. This work evaluates the performance of the BLEP, BLAMP,and integrated BLAMP functions by testing whether they can be used to fully band limit aliased signals. Of particular interest are cases where discontinuities appear past the first derivative of a signal, like in hardclipping. These cases require more than one correction function to be applied at every discontinuity. Results obtained show that if sufficiently many samples are corrected at each discontinuity, aliasing can be virtually eliminated whilepreserving the spectral envelope of the signal. This work extends the understanding of the BLEP, BLAMP, and integrated BLAMP functions as antialiasing tools.

Sunday morning, 11 September 2016 **Conference Room**
11:50 - 13:00
Musical Acoustics
MA-IM: Instrument making

POSTER

Instrument Making:

Paper ISMRA2016-77

Tunable sonic crystals as an extension of acoustical musical instruments

Valeria Sol Gomez[a], Alejo Alberti[b], Ignacio Spiousas[c] , Leonardo Salzano[d], Oscar Edelstein [e] , Manuel Eguia [f]

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Abstract

Sonic crystals are made by the periodic arrangement of hard scatterers in a host medium, such as air, and are efficient devices for controlling the propagation of sound. There is a vast literature that shows many of their extraordinary capacities like forbidden frequency bands, hyperfocusing, self collimation or negative refraction, and potential applications such as sound barriers, acoustic switches or acoustic diodes.In this work we describe the first application of a sonic crystal to the domain of musical acoustics. We constructed a tunable sonic crystal that when placed between the sound source and the audience, it is able to greatly modify the timbre and directivity pattern of the source during the performance, acting as an acoustical extension of the musical instrument. The sonic crystal can be dynamically tuned by changing its internal geometrical configuration. Different configurations of the sonic crystal and their possible effect on the localization of two instruments from the woodwind family were evaluated by analyzing a transverse section of the sound field and binaural recordings.

POSTER

Instrument Making:

Paper ISMRA2016-49

Design and development of active ribbon microphone with variable polar pattern

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Abstract

A prototype of a top level ribbon studio microphone was designed and is being constructed. In order to improve efficiency and enlarge the applicability of the transducer, a cardioid polar pattern configuration was achieved through acoustical design in addition to the typical bidirectional polar pattern for this types of microphones. In this paper, a system to calibrate the ribbon was developed. Contrary to most of this type of microphones, the current prototype includes the design of a phantom powered preamplifier, which implements a low noise JFet to obtain a 40 dB output gain. Due to its harmonic characteristics, the JFet mic preamplifier acquires a unique sound which emulates valvular circuits. To compare in a representative manner the performance of the microphone, technical specifications were measured according to international Standard.

POSTER

Music Perception:

Paper ISMRA2016-73

The effect of entropy and duration in the temporal perception of a sequence of sound events

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Abstract

Entropy has become important as a phenomenon of contemporaneity in art practice and theory. Since the composer Karlheinz Stockhausen stated the problem in his essay Structure and Experiential Time (1955), several authors focused their studies on the influence of the rate of auditory information in the perception of elapsed time. In this article the influence of physical duration and some aspects of entropy on perceived duration of a sound stimulus of about 35 s is studied. Dispersion of time interval between onset of events and the temporal density of events are aspects possibly related to the entropy. An experiment is conducted and preliminary results about the influence of entropy on the perception of duration are discussed.

13:00 - 15:00
Break

Sunday afternoon, 11 September 2016 **Piazzzolla Room**
15:00 - 15:50
Plenary Lecture
Room Acoustics
RA-EV: Evaluation of Concert Halls / Opera Houses

Evaluation of Concert Halls / Opera Houses:

Paper ISMRA2016-69

Big halls for music in Argentine

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Abstract

In recent decades several large rooms for music have been built or reconditioned in Argentine. Among them is the well-known *Teatro Colon* of Buenos Aires, the *Teatro Argentino* of La Plata, the *Usina del Arte* Symphony Hall, the *Blue Whale Auditorium* of the CCK in Buenos Aires and el *Centro del Conocimiento* in Posadas, Misiones. And there are under construction or in its development stage some more, such as the *Teatro del Bicentenario* of San Juan and the *Polo Cultural Ambiental de Arte* of Tierra del Fuego. This paper describes briefly their physical, architectural and acoustic features. In each case it is highlighted the particular needs of each project and the strategies developed for their acoustical design.

Sunday afternoon, 11 September 2016 **Piazzzolla Room**
15:50 - 16:30
Musical Acoustics
MA-PH: Physics of musical instruments and voice

Physics of Musical Instruments and the Voice:

Paper ISMRA0216-38

Optimisation techniques for finite order viscothermal loss modeling in acoustic tubes

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Abstract

Viscothermal losses for models of one-dimensional wave propagation in ducts are usually expressed, in the frequency domain, in terms of a series impedance/shunt admittance pair. A well-known model is that of Zwikker and Kosten, for which the immittances are not expressed in terms of rational functions of the frequency variable—andthusadifficultmatchtotimedomainsimula- tion methods. One approach to finite order rational approximation is based on a high-frequency approximation, leading to a representation in terms of fractional powers of the frequency variable, which can then be further approximated in terms of a rational function using standard techniques. Another is to approximate the Zwikker-Kosten model directly, and a major design consideration is to ensure positive realness under a finite order approximation, leading to a passive or dissipative representation. Though closed-form solutions based on continued fraction expansion are avail- able, another approach is to make use of optimisation over a parameter is definite order rational function for which the positive realness property is inbuilt. This paper focuses on the optimisation problem, using standard iterative techniques such as gradient descent and its extensions, particularly with regard to model order, and extensions to the case of optimisation in a discrete time setting are also discussed. Optimisation results, for a variety of model orders and frequency optimisation ranges, are presented.

Physics of Musical Instruments and the Voice:
[Paper ISMRA2016-27]

Coupling of a one-dimensional acoustic tube to a three-dimensional acoustic space using finite-difference time-domain methods

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Abstract
In this paper a simple coupling mechanism between a one-dimensional acoustic tube and a three-dimensional acoustic space is proposed to model the radiation behavior of an open tube. This mechanism is derived from energy conserving principles: the energy leaving the acoustic tube is equal to the energy injected into the acoustic space, and viceversa. The tube-room system is modeled using finite-difference time-domain methods for a box terminated using absorbing boundary conditions. Input impedances are calculated and compared against a frequency domain model terminated using the classic Levine and Schwinger radiation impedance.

Sunday afternoon, 11 September 2016 **Piazzzolla Room**
16:30 - 17:10
Musical Acoustics
MA-SP: Sound production – Sound synthesis

Sound Production - Sound Synthesis:
[Paper ISMRA2016-82]

Development of a modal Udwadia-Kalaba formulation for guitar modelling

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Abstract
Most musical instruments consist in a set of dynamical subsystems connected at a number of constraining points through which energy flows or tuning is achieved. For any physical sound synthesis, one important difficulty deals with the manner to enforce these coupling constraints. While standard techniques include the use of Lagrange multipliers or penalty methods, we explore in this paper a different approach, the Udwadia-Kalaba (U-K) formulation, which is rooted on analytical dynamics but avoids the use of Lagrange multipliers. Up to now, this general and very elegant formulation has been nearly exclusively used for conceptual systems of discrete masses or articulated rigid bodies, namely in robotics. Despite its natural extension to deal with flexible systems modelled through their unconstrained modes, such an approach is surprisingly absent from the literature. Here, we show the potential of combining the U-K equations forconstrained systems with the modal description, in order to simulate musica linstruments. Our objectives are twofold:(1) to develop the U-K equations for constrained flexible systems in which subsystems are modelled through unconstrained modes,and (2) to apply this framework to compute the coupled dynamics of the string/body vibration. This example complements ourwork on guitar string modelling using penalty methods, and enables to compare results obtained from different approaches. Simulations show that the proposed technique provides results of comparable quality with a significant improvement in computational efficiency.

Sound Production - Sound Synthesis:

Paper ISMRA2016-42

Bow control and playability of a two-polarisation time domain physical model of a bowed string

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Abstract

Many studies have explored bowed string control, first in theory, and later through experiments and simulations. Bowing control is most commonly described in terms of 3 parameters: downward bow force, bow position, and transverse bow velocity. The correlation between these parameters and the production of a note is generally referred to as the playability of the instrument. The musically-useful region within this parameter space where Helmholtz motion is achieved has been extensively researched. The coordination of these player-controlled parameters is crucial for the existence of steady-state oscillations, but also for their behaviour during note onset. Time domain models of bowed strings require the dynamic input of these physical control parameters. A detailed exploration of this parameter space is therefore of importance for playable physical models. In this work, a two-polarisation bowed string is coupled to a fully dynamic nonlinear lumped bow model. A finite difference scheme is used to solve the discretised equations of motion in the time domain. The bow-controlled input to the model is based on a two-dimensional force vector applied to the bow itself, coupling the two string polarisations. One force component is applied downwards, and the other orthogonally across the string axis, in contrast to the common convention of imposing a downward bow force and transverse bow velocity. The new model has the potential to allow for more realistic and dynamic gesture control. This study explores the parameter space implied by the model, relating it to the playability of the virtual instrument. Analysis of the steady state bow-string dynamics leads to classification of the playing regime, and a graphical representation inspired by the well known Schelleng diagram. The resulting playability-force diagrams may be used as an aid to control of the sound synthesis algorithm.

Sunday afternoon, 11 September 2016 **Conference Room**
15:50 - 17:10
Room Acoustics
RA-SM: Simulation and Auralization of Concert Halls / Opera Houses

Simulation and Auralization of Concert Halls / Opera Houses:

Paper ISMRA2016-23

Acquisition of boundary conditions for a room acoustics simulation comparison

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Abstract

Room acoustics simulations are often validated by comparing the simulation results with measurement results of an existing room. The results obtained with the simulations, however, strongly depend on the input data, in particular the boundary conditions. For geometrical acoustics simulations, it is generally sufficient to describe the acoustical properties of walls and surfaces by absorption coefficients. These can be determined by classical methods, such as impedance tube measurements or by conducting a reverberation chamber measurement. For existing rooms however, it is preferred to acquire the boundary conditions by in-situ measurements or look up the data in absorption coefficient databases. Another option is to determine the absorption coefficient by an inverse calculation based on the measured room impulse responses of the investigated room. This work presents and compares the boundary conditions determined by the different mentioned methods and their impact on the simulation results in case of a practical scenario.

Simulation and Auralization of Concert Halls / Opera Houses:
Paper ISMRA2016-70

Interactive multi-source sound propagation and auralization for dynamic scenes

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Abstract
We present a sound propagation and auralization system designed for interactive simulation of complex dynamic environments with many sound sources. Our approach builds on previous work in geometric acoustics using ray tracing. A key component of our technique is the use of temporal coherence in the computation of the sound on each simulation update. Previous ray-tracing methods recompute the impulse response for each source and listener pair on every update. However, this can lead to auralization artifacts because the result at each time step is slightly different. We leverage this variation using a cache of results from previous time steps, including early reflection paths and late impulse responses, to improve the quality and performance of the simulation. We also apply a psychoacoustic metric based on the human threshold of hearing to the resulting impulse responses in order to determine how far to propagate rays on the next frame. This feedback mechanism allows dynamically-changing reverb times and both quiet and loud sound sources without expending computation for inaudible parts of the impulse response. To handle the case of large environments with tens or hundreds of sound sources, we introduce a method for clustering sources into representative clusters based on their relative visibility and distance from the listener. The result is that the number of simulated source and listener pairs is reduced. We demonstrate the results of our technique on a variety of indoor and outdoor benchmarks with up to 200 sound sources and show that it can achieve interactive performance on consumer computer hardware.

Simulation and Auralization of Concert Halls / Opera Houses:
Paper ISMRA2016-14

Augmented auralization: Complementing auralizations with immersive virtual reality technologies

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Abstract
A framework conceived and designed to enable ecological assessments of theater, concert hall, and auditorium acoustics is presented. Coupling real-time convolution based auralization and 3D visualization with the inclusion of a 3D audio-visual (3D-AV) recorded performance provides for an animated visual anchor, allowing for appropriate orientation and distance variations perception, improving the sense of presence in the simulation. Auralizations are rendered either via an Ambisonic speaker array or binaural head phones usinga Max/MSP audio engine. The 3D visualization is handled by Blender VR,an open-source framework for Virtual Reality (VR). The framework is designed to facilitate multi-platform operation and seamles sporting of the ren-dering over Head-Mounted Display (HMD), a portable one-projector CAVE system, or anyother VR architecture. A use-case is presented with the historic Théâtre del'Athénée in Paris. The acoustics from various seats are auralized using High-Order Ambisonic room impulse responses calculate dusing the Geometrical Acoustics (GA) software CATT-Acoustic on a GA model of the theater validated in a previou sstudy. A 3D-AV theatrical performance is filmed with a depth sensor (Kinect2), the resulting volumetric video is encrusted on the virtual stage all owing the same performance to be played in different roomcon figurations withoute need to construct and animate CGI avatars. Diverse application scenarios are discussed. The tools developed to support this framework are Open Source to promote research and development in augmented auralization.

Simulation and Auralization of Concert Halls / Opera Houses:
Paper ISMRA2016-52

Finite difference room acoustics simulation with general impedance boundaries and viscothermal losses in air: Parallel implementation on multiple GPUs

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Abstract
Room acoustics modelling requires numerical methods that can simulate the wave behaviour of sound across a wide band of frequencies while taking into account the frequency-dependent characteristics of absorption in air and at walls, but the accurate and stable numerical modelling of complex room geometries under frequency-dependent boundary conditions has remained an elusive problem. Recently, boundary conditions for finite difference / volume time-domain methods have been proposed to simulate frequency-dependen twall impedances in provably-stable numerical schemes based on the viscothermal wave equation over complex room geometries. The purpose of this paper is to investigate these new frequency-dependent boundary conditions in parallel implementations on graphics processing unit (GPU) devices. An efficient implementation of general impedance boundaries combined with the simplest Cartesian viscothermalscheme is presented and shown to be nearly as fast as simpler frequency-independent boundaries in acoustic simulations of a grid-aligned box domain with six frequency-dependent materials and of the Goldener Saal, Musikvere in Vienna concert hall, running on up to four Nvidia K20GPU devices.

17:10 - 17:30
Coffee break

Sunday afternoon, 11 September 2016 **Piazzolla Room**
17:30 - 18:30
Musical Acoustics
MA-PH: Physics of Musical Instruments and the Voice

Physics of Musical Instruments and the Voice:
Paper ISMRA2016-10

Mode switching in a n air-jet instrument

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Abstract
It is well known that air-jet instruments, such as the recorder, undergo transitions between oscillation modes as a function of the blowing pressure. For example, the recorder undergoes a transition from its fundamental mode of frequency *f* to the mode an octave higher (2*f*) as the blowing pressure is increased. In theoretical studies of the recorder the interaction of the air jet with the labium and feedback from the resonator tube to the air jet play central roles in creating a stable oscillation and in determining the blowing pressure at which this transition occurs. However, the details of these interactions, especially the feedback from the resonator tube, are not completely understood. We use Navier-Stokes-based simulations of the recorder to study these interactions for the recorder. We find, in accord with reports of musicians, that the transition blowing pressure is reduced when the resonator tube cross-section is reduced. Movies of the air jet dynamics are used to probe the origin of this effect. By studying a hypothetical recorder with a square resonator tube, we are able to separate the effects of the air jet Reynolds number and sound pressure amplitude.

Physics of Musical Instruments and the Voice:

Paper ISMRA2016-81

Lip vibrations in brass musicians

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Abstract

This experimental study investigates lip vibrations in brass musicians. Lip vibrations were observed with high-speed line-scanning and stroboscopic video sequences. Therefore mouthpieces with probe holes for the endoscope were used. In a preliminary survey three devices for stroboscopic examination of lip vibrations were compared. For online analysis of lip vibrations a standardised device with fixed coupling between endoscope and camera on the one hand and mouthpiece with instrument on the other hand was most suitable. In the main study this standardised device for observation of brass players' vibrating lips was validated and implemented. Typical values for the amplitudes of lip vibrations in different kinds of brass instruments and diverse playing techniques were measured and compared. The lip vibration cycle was scaled in different phases both with high-speed line-scanning and stroboscopy. In all subjects lip vibrations showed an increase in amplitude when lower or louder notes were played (and vice versa). In brass musicians occupational lip injuries and overuse syndromes are relevant for health economics: Often it takes long-term rehabilitation programmes to restore the ability to play the instrument. In serious cases even an occupational disability can arise. It is useful and necessary to establish video-based imaging devices for functional and morphological assessment of these patients' lips.

Physics of Musical Instruments and the Voice:

Paper ISMRA2016-86

Controlling the transients and timbre on single reed instruments

Weicong Li[(a)], André Almeida[(a)], John Smith[(a)], Joe Wolfe[(a)]

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Abstract

A beautiful note should have appropriate pitch, loudness and timbre, and be elegantly articulated. On the clarinet and saxophone, the frequency, sound level, spectral envelope and articulation can be controlled using a learned coordination of breath pressure, lip force, tongue motion and vocal tract shape. But how do players achieve this and how do these control parameters affect the sound? Here, the acoustical impedance spectrum of the player's vocal tract, the blowing pressure and its time variation, the tongue-reed contact and their coordination were measured while players played notes of different pitch, loudness, timbre and articulations such as accent, *sforzando*, *staccato etc*. The effects of blowing pressure, lip force and tongue motion on the initial and final transients were studied independently using a clarinet-playing machine. To start a note, players vary the blowing pressure (P) over time and adjust the timing of tongue release from the reed to produce different articulations with rates of exponential increase in amplitude (of order 1000 $dB \cdot s^{-1}$) in the initial transient. In the sustained part of a note, advanced players can use the vocal tract to vary the spectral envelope whilst keeping the pitch and sound level constant. The harmonics in the radiated sound are enhanced when the magnitude of the player's vocal tract impedance is increased sufficiently to become comparable with that of the instrument bore at nearby frequencies. Notes can be terminated either by decreasing P below a threshold or by tongue contact with the reed: both produce exponential decreases in sound pressure, often dominated by energy losses in the bore.

Sunday afternoon, 11 September 2016 Conference Room
17:30 - 17:50
Room Acoustics
RA-SM: Simulation and auralization of concert halls / opera houses

Simulation and Auralization of Concert Halls / Opera Houses:
Paper ISMRA2016-45

Acoustical design of Izmir Opera House

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Abstract
İzmir Opera House in Mavişehir, İzmir, designed by Teğet Architecture of İstanbul, faces the Aegean coastline in a high-rise residential suburban area. The project was awarded with the 1st price in the national design competition held in 2010 and is planned to be tendered in the third quarter of 2016. Over a construction area of 56.000 m2 the opera house will be the largest opera venue in Turkey. The project aims to re-organize the relations between urban areas and the coast in terms of programmatic and morphological sense. The complex accommodates a main hall with seating capacity of 1368, a black box with a capacity of 450 and a multipurpose open-air courtyard for 400 persons, rehearsal rooms for orchestra, ballet and opera, ateliers, offices and storage areas. This paper basically introduces the acoustical design process of main hall. Sightline analysis for the main hall has been performed as the first step in acoustical design. Number of balconies, floor rakes, and wall inclinations are studied accordingly. Surface modulations are specifically designed to provide enough scattering on relevant surfaces. Resonators, suspending under the ceiling in the main hall are specifically designed to control excessive bass sound. While tuning architectural parameters as of orchestra pit and room dimensions, surface forms and textures; rigorous acoustical simulations are held for the main hall until acoustical design criteria are satisfied in accordance with the functions.

Sunday afternoon, 11 September 2016 Conference Room
17:50 - 18:10
Musical Acoustics
MA-PH: Physics of Musical Instruments and the Voice

Physics of Musical Acoustics and the Voice:
Paper ISMRA2016-08

Design of a measurement methodology to characterize acoustic parameters and sound directivity of string instruments in a real acoustic environment

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Abstract
The directivity specifications and sound characteristics of an acoustic instrument are essential for a general use into the musical field. With this information, the musicians can select the adequate instrument for a specific purpose and the manufacturers can improve and advance in their designs. The study in this area also provides knowledge for virtual simulations and recording techniques. This research aims to disseminate a measuring methodology to characterize the acoustic parameters and sound directivity of a string instruments in a real acoustic environment. The design and development of a software capable to process data considering the ICE 61260 standard is promoted. It is exposed a method developed for an Amati model violin, using a continuous musical program touched with two different intensities by an experienced musician. The polar pattern results in both intensities are exposed with the sound characterization of the instrument through a spectral analysis.

Sunday afternoon, 11 September 2016 **Pettoruti Hall**
18:30 - 19:30
Piazzolla Room
Technical visit to Teatro Argentino

Sunday afternoon, 11 September 2016 **Pettoruti Hall**
19:30 - 20:30
Welcome cocktail + Tango Show

Monday, 12 September 2016

Monday morning, 12 September 2016 **Planetarium**
09:00 - 09:20
Room Acoustics
RA-EV: Evaluation of concert halls / opera houses

Evaluation of concert halls / opera houses

Paper ISMRA2016-66

Acoustical design of the new canopy for the Ginastera Hall of the Teatro Argentino of La Plata

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Abstract
After its inauguration in 1999, the opinions of musicians, critics and general audience about the acoustical quality of the Ginastera Hall were diverse. The sound was round and well balanced at the upper levels, but some problems appeared in the main floor: lack of bass frequencies, low sensation of envelopment, plain and distant sound, poor instrumental balance and the inaudibility of certain sections of the orchestra. In opera representations, the singers' voices were overpassed by the sound in the pit. In order to discover the reasons of such behaviour, we carried out a lot of acoustical measurements, some based on ISO 3382, and developed a digital model of the Hall. From the results of the analysis of the collected data, we detected at the main floor level a lack of acoustical energy in the first 100 ms after the direct sound, insufficient lateral energy and a strong seat dip effect caused by the small angle of arrival to the audience and the particular design of the seats. By means of that diagnosis, we decided to work mainly in the temporal and spatial structure of the early reflections focused towards the audience. A new canopy to be placed over the pit was designed. Its main objective was to fix the problems detected in the main floor without changing the acoustical quality at the upper levels. In this paper the design process of the acoustical reflector, made with a distributed array of rectangular panels with cylindrical curvature and based on the works of Rindel and Skålevik, is described. The final measurements carried out to analyze the results of the work and the opinions of some specialists about the musical outcomes of the intervention are showed.

Monday morning, 12 September 2016 **Planetarium**
09:20 - 09:40
Room Acoustics
RA-ST: Stage acoustics

Stage Acoustics:

Paper ISMRA2016-43

Methods to know and preserve a heritage of the Italian historical theatres: the wooden stage

Massimo Garai[(a)], **Dario D'Orazio**[(a)], **Simona DeCesaris**[(a)]
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Abstract
The work treats the refurbishment of a critical part of an historical theatre:the wooden stage. An opera house is characterized by the consistent use of perishable materials, such as the wooden floor, which is at the sametime structural and acoustic element. On the one hand the theatre geometry and materials are thecharacteristic heritage of each theatre, on the other hand the utilization of theatres changes over time and therefore modifications are unavoidable. An Italian opera house has been used as a cases tudy:the Alighieri theatre in Ravenna, designed by Tomaso Meduna and his brother (theformer architect of La Fenice theatre in Venice). In 2015 the theatre wooden stage was replaced and the authors of this work were asked to study the influence of the wood ageing. A sample of the

stage wood has been analyzed using vibro–acoustic techniques in laboratory and the stageh as been qualified using musical instruments (cellos,doublebasses) and measurements. Finally, a model has been proposed in order to quantify the stage radiation.

Monday morning, 12 September 2016 **Planetarium**
09:40 - 10:20
Room Acoustics
RA-EV: Evaluation of concert halls / opera houses

Evaluation of Concert Halls / Opera Houses:
Paper ISMRA2016-28

The effects of room acoustics on the physics and neurology that enable us to separate information in sonically complex environments

David Griesinger
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Abstract
Humans can tell instantly, independent of timbre or loudness, if a sound is close to us. We are also able in a crowded room to switch attention at will between at least three simultaneous conversations, and involuntarily switch to one of them if our name is spoken. These are the abilities that allow musicians to hear on stage, and the audience to hear music as composers intended. But these feats are only possible if individual voices can be separated into independent neural streams. We will present data showing that the ability to do this relies on the phase relationships between the harmonics above 1000 Hz that encode speech and music information, and the neurology of the inner ear that has evolved to detect them. Once in each fundamental period harmonic phases align to create massive peaks in the sound pressure at the fundamental frequency. Pitch-sensitive filters can detect and separate these peaks from each other and from noise with amazing acuity. But reflections and sound systems randomize phases, with serious effects on attention, source separation, and intelligibility. We will show how ears and speech co-evolved, and present recent work on the importance of phase in acoustics and sound design.

Evaluation of Concert Halls / Opera Houses:
Paper ISMRA2016-30

Accurate reproduction of non-individual binaural recordings without head tracking through individual headphone equalization

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Abstract
Acoustic research of all kinds desperately needs methods that allow accurate and instant comparisons of the sound in different seats and different venues. Binaural recording could provide such a reference if it can be made accurate enough. Early work by Schroeder and others showed that recording at the eardrums of a listener, and playing back with individual eardrum equalization, captures sound accurately without head tracking. But their methods were cumbersome. We show that the major problems with binaural reproduction do not lie with individual pinna functions, but with the highly individual resonances in the concha and ear canals. The eardrum response of different individuals with the same headphones varies by +- 8dB in the vital frequency range of 500Hz to 6000Hz. This talk describes the physics responsible for these variations and how headphones affect them. We have developed a software application that can quickly and simply equalize these variations through an equal-loudness technique. Once equalized for an individual music of all types, especially binaural recordings, can be perceived as frontally localized and startlingly beautiful.

Monday morning, 12 September 2016 **Planetarium**
10:20 - 11:10
Plenary Lecture
RA-EV: Evaluation of concert halls / opera houses

Evaluation of Concert Halls / Opera Houses:

[Paper ISMRA2016-72]

Why do some concert halls render music more expressive and impressive than others?

Tapio Lokki
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Abstract
Research on musical acoustics and room acoustics is very seldom performed together. This is quite strange, as it is well known that musical instruments sound unpleasant in anechoic spaces. A musical instrument needs reverberation to sound enjoyable, and therefore room acoustics is an essential part of music. Room acoustics not only reverberate the sound, but also change the timbre of musical sounds. Moreover, reverberation is an integral component of music that binds together individual notes, helps to form phrases, and carries on the harmony between phrases. This paper ties together musical and room acoustics. The directivity of musical instruments and the spectral changes according to played dynamics are reviewed. These issues are linked to the basics of concert hall acoustics to explain why room acousticians who design concert halls should also understand these fundamental aspects of musical instruments and their sounds. In addition, recent findings in concert hall acoustics are explained in light of the acoustics and concert halls that best support the music. In other words, what room acoustics features convey the important spectral changes to the audience as well as possible?

11:10 - 11:30
Coffee break

Monday morning, 12 September 2016 **Planetarium**
11:30 - 11:50
Musical Acoustics
MA-IM: Instrument making

Instrument Making:

[Paper ISMRA2016-47]

The violin: Studying the influence of the model by means of a free sorting task

Claudia Fritz[(a)], Joseph Curtin[(b)], Danièle Dubois[(a)], Julien Verschoore[(a)]
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Abstract
In the last few years, various blindfolded playing tests have been conducted in order to better understand how violinists evaluate violins. They mostly involved preference rankings and evaluation of different criteria using scales. These tests have shown a large intra-individual consistency but generally a rather low agreement between players, regardless of the age, the make, the price and the mechanical properties of the violins used in the studies, making the correlation between the perceptual and the physical (mechanical and geometrical) properties of the violins difficult. Another approach has been used here, based on categorization in order to identify the unknown properties on which the global judgments of violinists could rely : 21 violinists had to sort freely nine violins, i.e. they had to arrange the violins into categories by putting together the ones that they judged similar and in different groups the ones that they judged dissimilar, without any constraint on the number of categories. Six of the nine violins were Stradivarius models (two genuine, seven recent copies), while the other three were del Gesu models (one genuine, two recent copies). The additive tree resulting from the statistical

analysis of the data (similarity matrix) shows an interesting differentiation between the Strad and the del Gesu models, even if none of the participants mentioned being aware of such a difference. The analysis of the verbal comments that the participants made on their categories shows a large disagreement between players and seem to challenge the common belief of specific properties to Strad and del Gesu models.

Monday morning, 12 September 2016 **Planetarium**
11:50 - 12:10
Musical Acoustics
MA-PH: Physics of musical instruments and voice

Physics of Musical Instruments and the Voice:
Paper ISMRA2016-60
When singing bowls don't sing: A numerical and experimental investigation on the subtle dynamics of Tibetan bowls
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Abstract
Tibetan bowls have been traditionally used for ceremonial or meditation purposes, but also in contemporary music-making. They are handcrafted and produce different tones depending on their shape, size, mass and their alloy composition. Most important is the sound producing technique by impacting and/or rubbing, as well as the excitation location, the hardness and friction characteristics of the excitation stick. In aprevious paper, we developed a physically-based method for nonlinear time-domain simulation of Tibetan bowls. Our computational approach, based on a compact modal formulation, produces realistic dynamical responses. In the present paper we focus on an interesting feature of Tibetan bowls: in order to produce self-excited responses, the stick must rub the bowl against the *external* side of the rim, e.g. radially pressing outwards the bowl center. Indeed, experimenting with many bowls showed that they do not sing when rubbed internally. West art documenting this claim with experimental results from representative bowls, and then exploit our computational model in order to reproduce the observed behavior qualitatively. Our results are in good agreement with experiments, thereby demonstrating that internally excited bowls are dissipative and hence unable to sing.

Monday morning, 12 September 2016 **Planetarium**
12:10 - 13:00
Musical Acoustics
MA-MP: Music perception

Music Perception:
Paper ISMRA2016-09
Assessing the acoustic similarity of different pianos using an instrument-in-noise test
Alejandro Osses Vecchi[a], Antoine Chaigne[b], Armin Kohlrausch[a;c]
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Abstract
Speech-in-noise tests are a way to evaluate the perception of one or more aspects of phonetic elements. When varying the amount of noise, i.e., the signal-to-noise ratio (SNR), the target condition at which correct answers are given 50% of the times is of special interest. The obtained SNR is called

speech reception threshold (SRT). In order to quantify how close two (non-speech) sounds are in terms of their acoustic properties, we hypothesise that a similar procedure can be followed. If we let subjects distinguish two sounds presented together with a background noise, and measure the SNR at which the two can no longer be distinguished, we expect a strong correlation between SNR and similarity: high similarity needs only little noise (high SNR) to make the sounds indistinguishable, whereas in a decreasing similarity an increasing amount of noise is needed (lower SNR). For a given pair of sounds, we can establish thus similarity by measuring the SNR at which they become indistinguishable. In this paper we present an example of such a method, applied to recorded Viennese piano sounds. As in every speech-in-noise test, the noise to be used has to be carefully chosen. We chose a set of noises that are shaped according to the spectro-temporal properties of each note and instrument. Such a set was generated in a similar way as the so-called ICRA noises in speech, but being adapted to provide a more suitable "piano weighting". Results for similarity scores for one piano note (C#5) and 7 test pianos are presented and discussed.

Music perception:

Paper ISMRA2016-50

Harpsichord voicing: The player's auditive and tactile perception

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Abstract

When a harpsichord player presses a key with his/her finger, a jack is raised toward the string, and a plectrum, which is attached to the jack, plucks a string. The string/plectrum interaction depends on the mechanical and geometrical properties of the plectrum, which are thus expected to have an influence on a) the initial conditions of the string vibration, therefore the sound; b) the mechanical reaction of the key, therefore the haptic feedback. Players and makers have a thorough but quite informal knowledge of these relationships and accordingly attach a great deal of importance to the "voicing process", during which the plectra are selected and shaped in order to provide the instrument with interesting sound features while preserving a homogeneity of timbre and touch over the whole tessitura. A perceptual test was designed in order to investigate the relationship between the characteristics of the plectra and the way they are perceived. During semi-directed interviews, experienced harpsichord players played and evaluated two different sets of plectra (made by professional makers). Subjective evaluations were obtained from the verbalisation data and analysed with a psycho-linguistical method, focusing on the auditive and tactile aspects, as well as on their interaction. A perception-based characterisation of the sets of plectra is proposed, resulting from the comparison of the multimodal psychological measurements with the geometrical and mechanical measurements.

13:00 - 15:00
Break

Stage Acoustics:
[Paper ISMRA2016-59]

Transforming a rehearsal stage into an experimental music venue using active acoustics

Steve Ellison[a], Roger Schwenke[b]
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Abstract
In 2014 the San Francisco Symphony launched a new venue and concert series in which to program a wide range of repertoire, drawing upon a variety of ensembles comprised of musicians from the symphony. They envisioned a venue more intimate and flexible than the 2,743 seat Davies Symphony Hall, able to support both pre-Baroque choral music as well as contemporary works for percussion ensemble. The symphony created “SoundBox” by utilizing San Francisco’s “Zellerbach A,” which has been the rehearsal room for the San Francisco Opera since 1981. This 700 square meter space accommodates 500 people, and has a nominal reverberation time of only 0.9 seconds, lower than preferred for the repertoire presented. An active acoustic system was installed both to increase the room’s reverberation time and strength and to create early reflection patterns from the two performer locations both back to the performers as well as to the audience. Acoustic settings are selected for each piece during rehearsals. Music has been performed that utilize both musicians as well as pre-recorded elements spatialized by the acoustic system’s loudspeakers and integrated signal processing. The design, acoustic performance, and subjective impressions of the resulting acoustics from the point of view of the music directors, musicians, and press will be described.

Stage acoustics:
[Paper ISMRA2016-58]

Stage acoustic requirements extended to orchestra rehearsal rooms

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Abstract
In the last 8 years a lot of research has been carried out in the field of stage acoustics. The inducement for the investigations originally was initiated by the direct question concerning the improvement of the stage acoustics for a renovation. But the topic continually had our attention for new concert halls, other renovations and not at least: orchestra rehearsal halls. In order to rehearse on sound quality, balance and playing in time, the acoustical conditions in the rehearsal hall should not differ too much from the conditions on stage in a concert hall. This means that the rehearsal halls should not be too loud, have a decent frequency response, early reflections and reverberation time. The best place to have the rehearsal is mostly the concert hall. But the purpose of a separate rehearsal room is usually to have the maximum possibility to exploit the concert hall, and the economics desire a cheap and therefore small rehearsal room. With a lot of small (ca 2000 m^3) orchestra rehearsal rooms as a reference, the acoustical reasons for investing in a much larger orchestra rehearsal room should be very strong. In this paper the demands for good stage acoustics and the European requirements on sound exposure are extended to orchestra rehearsal rooms. Measurements in several (and very different) orchestra rehearsal rooms are provided to substantiate the maximum allowed differences between the performance environment and the rehearsal environment.

Stage Acoustics:
Paper ISMRA2016-15

Overview and preliminary results from a study of stage acoustics for chamber orchestras

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Abstract
This paper describes an ongoing project that examines the on-stage acoustic conditions of major Australia purpose-built concert halls in relation to their use for chamber music performance. During a national tour in 2015, members of the Australian Chamber Orchestra made subjective assessments. Acoustic measurements in these auditoria are being undertaken using the same stage configuration as the performances, with both a traditional omnidirectional receiver and with a 32-channel spherical microphone array (Eigenmike). At the time of writing, measurements have been completed in six halls. This paper presents these initial results and considers both traditional omnidirectional parameters and also the spatial response on stage in the auditoria. The results of the subjective study have been previously reported, but are summarized briefly and then discussed in this paper in relation to the objective measurements. Further auditorium measurements are planned; nevertheless, these early results indicate some notable and interesting relationships between the objective measurements and subjective musician assessments.

Stage Acoustics:
Paper ISMRA2016-13

Live performance adjustments of solo trumpet players due to acoustics

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Abstract
Previous studies on musicians' adjustments to room acoustics have demonstrated an influence of room acoustics on live solo music performance. Musicians adjust different aspects of the performance, such as tempo, articulation, dynamics or level. However, this effect seems to be highly dependent on individual musicians, musical pieces and instruments. This paper studies the influence of acoustics on solo trumpet players under different acoustical conditions. By means of virtual acoustics different rooms are auralized in real-time and five trumpet students are recorded playing a set of pieces of their choice repeatedly. After the experiment the musicians are interviewed to gather their personal impression on the adjustments performed, the quality of different acoustical conditions and their personal preferences. Performance aspects such as tempo, level, articulation, and timbre are analyzed by evaluation of objective audio features i.e. length of the performance, RMS value, average-to-silence ratio, and spectral centroid, respectively. The correlation analysis of acoustic and performance parameters confirm that individualized strategies of performance adaption and the chosen repertoire seem to have an important effect on the performance adjustments. Although the effect of acoustics on tempo cannot be generalized, general trends can be observed: the RMS of the performance and the timbre brightness present a moderate inverse correlation with the strength and reverberation time of the room, while features related to articulation show a weak positive correlation with those room parameters.

16:20 - 16:40
Coffee break

Monday afternoon, 12 September 2016 **Planetarium**
16:40 - 17:00
Musical Acoustics
MA-PH: Physics of musical instruments and voice

Physics of Musical Instruments and the Voice:

Paper ISMRA2016-22

Proposed metrics for understanding how directional characteristics of assorted musical instruments change across musical passages

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Abstract

In room acoustic computer modeling, directional characteristics of sound sources are often modeled based on the static directivity measured in each octave band. In reality, though, the directional characteristics of sources like musical instruments can change dramatically across a musical passage, and such changes may not be adequately captured in the current common computer modeling practice. This paper reviews proposed metrics developed to quantify how directional characteristics of musical instruments change in real-time. Application of these metrics to multi-channel recordings of a number of different musical instruments are described to indicate how these metrics can show differences in instrument behavior. Do violins demonstrate greater directional tone color than other instruments? Do these directional characteristics change across different musical excerpts? How do the proposed metrics vary based on the number of channels used for the recording? Findings and recommendations on using these metrics for quantifying time-varying directivity are presented.

Monday afternoon, 12 September 2016 **Planetarium**
17:00 - 17:20
Room Acoustics
RA-EV: Evaluation of concert halls / opera houses

Evaluation of Concert Halls/Opera Houses:

Paper ISMRA2016-79

Acoustic feedback for performers on stage – return from experience

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Abstract

When working with musicians on the acoustics of concert stages, the commonly used set of acoustic criteria is insufficient to describe all aspects and problems. Orchestra musicians have clear requirements: hearing themselves, hearing others and hearing the room. While some commonly used acoustic criteria like ST1, Reverberation Time T and Glate (measuring late room response) can be helpful in understanding some of the problems encountered, other aspects like loudness and directions of arrival (of early sound as well as late sound) also need to be taken into consideration. Experiences from recent projects concerning optimization of stage acoustics will be given. In addition, findings from these experiences can help in setting rooms with coupled reverberation chambers as well as acoustic reflectors above the stage. Another aspect that often tends to be neglected is the question of orchestral balance (for audience members but equally for musicians on stage) that can strongly be influenced by acoustic design decisions.

Monday afternoon, 12 September 2016 **Planetarium**
17:20 - 17:40
Room Acoustics
RA-ST: Stage acoustics

Stage acoustics:
Paper ISMRA2016-34

Three-dimensional sound field simulation using the immersive auditory display system "Sound Cask" for stage acoustics

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Abstract
A three-dimensional (3D) sound field simulation system using the immersive auditory display system, "sound cask," has been developed for creating a virtual environment that would reproduce the 3D acoustics of concert halls for musicians. The simulation system is based on the boundary surface control principle. The original sound field was measured using a microphone array consisting of 80 omnidirectional microphones (DPA 4060BM) installed at the nodes of the C80 fullerene structure. The virtual sound field was then constructed in a cask-shaped space (approx. 2 x 2 m), with 96 channel full-range loudspeakers (FOSTEX FE103EN) installed in the space. The 3D acoustic waves of music, including the acoustic condition on the stage, were created virtually inside the sound cask. For this, the first step was to design inverse filters of the MIMO (Multi-Input Multi-Output) system between the 96 loudspeakers and 80 microphones located in the sound cask. Next, the inverse filters, and the impulse responses measured in actual concert halls and signals from instruments played by musicians, were convolved. Room acoustic indices between the actual and virtual conditions were compared to test the validity of the simulation results. Furthermore, subjective experiments involving professional musicians were performed, and the subjects' impressions of the sound quality, spatial size, and effect of reverberation were investigated. This paper presents the features of the sound field simulation system based on the results of objective and subjective experiments.

Monday afternoon, 12 September 2016 **Planetarium**
17:40 - 18:00
Musical Acoustics
MA-PH: Physics of musical instruments and voice

Physics of Musical Instruments and the Voice:
Paper ISMRA2016-55

The influence of bore profile on spectral enrichement due to nonlinear sound propagation in brass instruments

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Abstract
One of the characteristic features of the sound of a brass instrument is the way in which the timbre becomes brighter duringa crescendo. The spectrum of a quiet note on any brass instrument is dominated by the lowest three or four harmonic components; as the loudness is increased upper harmonics become relatively more significant. In instruments with a large proportion of cylindrical tubing the spectral enrichment is particularly dramatic, leading to the "brassy" timbre of a fortissimo

note on atrombone. An important contributing factor in the generation of very high frequency spectral components is nonlinear soundpropagation in the bore of the instrument. This paper presents the results of recent experimental studies of the propagation of high amplitude wave packets in cylindrical tubes with dimensions similar to those in trumpets and trombones, and discusses the significance of the results for predictions of the rate of spectral enrichment based on measurements of the bore profile of such instruments.

Monday afternoon, 12 September 2016 **Planetarium**
18:00 - 18:20
Room Acoustics
RA-EV: Evaluation of Concert Halls / Opera Houses

Evaluation of Concert Halls / Opera Houses:

Paper ISMRA2016-37

Acoustics in the restoration of Italian historical opera houses: Lessons learned

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Abstract
Dealing with the restoration of an historical opera house (OH) involves many specialties in the fields of architecture, engineering and fine arts. Acoustics is one of the most important since its mission is crucial for several reasons, aside those obviously connected with the vocation of the space. First, restoring the OH even with the best possible architectural practice by means of a “blind” copying of the original materials, which was done in the past at some places, can be risky without a control of single items and an accurate check of production processes. Second, an occasion to valorize the sound in the whole theatre and to enhance listening attributes in the hall in particular cannot be missed. Third, the close control of the acoustics in the stagehouse, where latest technologies are often installed, is mandatory. Based mostly on direct experience, this work discusses some of the problems that arise in the management of acoustics during restorations. In particular the approach proposed is a blend of respect for the heritage value of acoustics and of technical improvements, consisting in the inclusion of devices and solutions to optimize the listening for public and performers.

Monday afternoon, 11 September 2016 **Planetarium**
18:20 - 18:40
Closing Ceremony

ISMRA 2016 - Author index

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