INTERNATIONAL SYMPOSIUM ON MUSICAL AND ROOM ACOUSTICS

May 24-27, 2025

Loyola University
New Orleans, Louisiana

Thank you to our co-sponsor

and our meeting sponsor

May 24, 2025

Greetings to all participants of ISMRA2025, the third joint International Symposium of Musical and Room Acoustics. We are delighted to welcome you to New Orleans, a city that celebrates its many cultural influences.

We hope you are able to take advantage of the several distinct components to the Symposium:

- Two workshops on Saturday that provide an in-depth exploration, and hands-on experience, of interesting topics.
- An opening reception Saturday evening from 6-8pm in Miller 112.
- Joint technical sessions on Sunday with three keynote lectures.
- Parallel session tracks on Monday and Tuesday.
- We will visit the fantastic Music Box Village on Sunday evening, where you can play on custom musical instruments that are integrated into specific structures.
- Throughout the symposium, you can interact with a sonic art installation by Trimpin called the Kinetic Funk Contraption (or KFC, as you wil see).
- Other musical events include an outing to see a jazz band (playing in a typical jazz venue) and our own jam session, where participants can show off the instruments they made in the Saturday workshop! (There will be prizes.)
- Of course, many people come to New Orleans for the food - and we hope you will not be disappointed. Small local restaurants will be catering our various meals, providing fresh and distinctive versions of Louisiana cooking.

We hope you enjoy the symposium!

Andy Piacsek, Dave Woolworth
ISMRA Chairs

Scott McDermott
Local Coordinator

Thank you to the ISMA Technical Committee!

Jonas Braasch, Rensselaer Polytechnic Institute, USA

Murray Campbell, University of Edinburgh, Scotland

Vasileios Chatziioannou,
University of Music & Performing Arts Vienna, Austria

Claudia Fritz, Sorbonne University & CNRS, France

Nicholas Giordano, Purdue University, USA

Malte Kob, Detmold University, Germany

Andrew Morrison, Joliet J. College, USA

Montserrat Pàmies-Vilà,
University of Music & Performing Arts Vienna, Austria

Mark Rau, McGill University & MIT, Canada & US

Peter Rucsz,
Budapest University of Technology & Economics,
Hungary

Gary Scavone, McGill University, Canada

Henna Tahvanainen,
University of Bologna and Univ. of Arts Helsinki,
Italy & Finland

Thank you to the ISRA Technical Committee!

(indicates technical chair)*

Arianna Astolfi, Politecnico de Torino, Italy

Zackery Belanger, Arcgeometer, USA*

Kaitlyn Hunt, Kirkegaard Assoc., USA*

Ana Jaramillo, Olson Sound, USA*

Tapio Lokki, Aalto University School of EE, Finland*

Mélanie Nolan, DTU Electro, Denmark*

Thomas Scelo, Acoustics Research & Design, AECOM, New Zealand

Louena Shtrepi, Politecnico de Torino, Italy*

Michael Vorländer, RWTH Aachen University, Germany

Stefan Weinzierl, TU Berlin, Germany*

Ingo Witew, TU Berlin, Germany*

Ning Xiang, Rensselaer Polytechnic Institute, USA

Dana Hougland, Shen Milsom & Wilke*

Day 0: Saturday, May 24th

ISMA Workshops

Workshop 1: Design and Application of Listening Discrimination Tests

9:00am – 12:30pm in Monroe 251

- **Victor Salvador**: Discrimination tests in playing situation: Can players differentiate bows which vary slightly in terms of center of mass position and of moment of inertia? Discussion about players' bias
- Discrimination between instruments in listening situation: How to separate playing variations from differences between instruments:
  - **Corto Bastien**: The use of tetrad test (when the test is based on recordings)
  - **Claudia Fritz**: The use of CR-DT (when the test is live)
- **Stefan Weinzierl**: Discrimination tests used to evaluate the authenticity and plausibility of virtual environments
- **Tapio Lokki** and **Nils Meyer-Kahlen**: Testing auditory illusions in augmented reality: Plausibility, transfer-plausibility and authenticity
- **Tapio Lokki** and **Sergio de las Heras Pérez**: Auditory Memory for Room Acoustics

Workshop 2: Build Your Own Musical Instrument

1:30pm – 5:00pm

Each workshop will be offered in two 90-minute sessions: from 13:30 - 15:00 and 15:30-17:00. Participants can choose a different workshop for each session.

- Version A: Build a musical instrument using vegetables, led by **Malte Kob**. Location: Monroe 152
- Version B: Design and construction of distributed MIDI-controlled instruments, led by **Trimpin**. Location: Miller 112.
- Version C: Build a stringed instrument with a tin can resonator, led by **Henna Tahvanainen**. Location: Monreo 152.

Joint ISRA and ISMA sessions - Miller 114

Time	Author	Title
8:00	Pavel Zahorik*	Using psychoacoustic approaches to understand and predict perception of sound in rooms **Plenary Speaker - more details in back of program*
9:00	M. Zhang	Stage Response Through Choristers' Ears: Investigations

Choral singers may experience the stage acoustics of performance spaces differently from both listeners and instrumentalists. During the New Zealand Youth Choir's tour of Australia in late 2022, an opportunity arose to investigate how stage acoustic conditions influence singers' perceptions. Surveys of choristers were conducted after performances for ten venues, complemented by acoustic measurements in the stage areas of eight venues, including neo-Gothic churches, multipurpose auditoriums, and a Concert Hall. The results revealed that choral singers generally preferred spaces with lower levels of early and late stage support, contrasting with preferences reported by orchestral musicians. However, higher levels of stage support were found to enhance acoustic conditions in smaller spaces with lower reverberation times. These findings highlight singers' sensitivity to and preference for spaces with longer reverberation times, while also revealing a nuanced response to stage-specific conditions.

9:20	C. Fernandez, M. Lawless, D. Poirier-Quinot, and B. Katz	Preliminary Evaluation of a Virtual Acoustic Envirtonment for Rehearsal and Performance in Unknown Venues

This preliminary study introduces a prototype tool that enables musicians to rehearse within a virtual acoustic environment (VAE) and experience playback from an audience perspective. In a pilot evaluation, a small group of musicians—spanning various instruments and skill levels—participated in VAE rehearsals before performing on an unfamiliar stage. Early observations suggest that rehearsing in the VAE may help musicians better account for venue acoustics, potentially enhancing stage presence and playability. Participants rated the tool as comfortable, user-friendly, and offering good sound quality, with the virtual acoustics closely approximating those of the real performance space. These initial findings indicate that VAE-based rehearsal might be a valuable aid in performance preparation, warranting further investigation and refinement.

9:40	M. van Zyl, M. Wright and T. Fujioka	Virtual Acoustics, Real Adjustments: Leveraging virtual reality to investigate how room acoustics affect music performance.

Musicians perform in various venues with different acoustic properties. Research indicates that they adjust performance parameters, such as tempo and intensity, based on room acoustics or reverberation. However, it remains unclear whether these adjustments are individualistic or shared among musicians, and how specific musical score properties influence them. This study examines how room acoustics affect music performance. Nineteen musicians with over 10 years of experience performed two musical compositions on an electronic keyboard in virtual renderings of three real-world spaces: a rehearsal hall (small), a concert hall (medium), and a church (large). Each score was performed under two auditory conditions: dry (no acoustics) and wet (with room acoustics). Visual feedback was provided via a virtual reality headset. One score contained quarter and eighth

notes, while the other also included sixteenth notes. Results showed significant effects of score type and room size on tempo. Musicians chose slower tempos for the score with fewer subdivisions. Room-related tempo differences occurred only in reverberant conditions, with slower tempos as room size increased. Participants' playing intensity also became more uniform in reverberant conditions, indicating increased stability in articulation. Finally, it appears that score complexity influenced performance more than individual preference, yet shared approaches to performance in different reverberant spaces emerged.

Time	Author	Title
	Morning Break 10:00 - 10:30	
10:30	Joel Ward and Tapio Lokki	Church Acoustics: Ease and Difficulty in Choral Singing

Churches are common performance venues for choirs, offering unique acoustical environments that can influence the choir's performance. Choir members often have personal insights into which churches are easier or more challenging to sing in based on their experiences. To investigate these perceptions, we conducted an online survey targeting a cappella singers and conductors regarding their singing experiences in churches in Helsinki area. Based on the responses, we identified three churches where singing in a choir is perceived as easy and three churches where it is perceived as difficult. We then measured the spatial room impulse responses in these selected churches to provide objective acoustical data. This paper presents the results of our analysis of these impulse responses, offering quantitative insights into the acoustical characteristics that may contribute to the ease or difficulty of choral singing in these venues. Additionally, we performed a qualitative analysis of the choir members' written responses. This analysis aims to uncover specific reasons behind the perceived ease or difficulty of singing in particular churches, providing a deeper understanding of the subjective experiences of choir members. The findings from both the objective and subjective analyses are discussed in detail, highlighting the interplay between acoustical properties and singer perceptions in various church environments.

10:50	S. Mullins, E. Canfield-Dafilou and B. Katz	Choral Onset Synchronization in Historical Acoustics: Medieval Polyphony and Notre-Dame de Paris

This study examines the effect of recreated historical acoustics on choral synchronization when performing historical music. As part of a broader investigation into the acoustic heritage of Notre-Dame de Paris, the experiment evaluates how choirs specializing in early music performance adapt their singing in varying reverberation conditions. Two choirs of trained early music singers performed plainchant, School of Notre-Dame organum, and a late-medieval liturgical motet under different simulated acoustic conditions, corresponding to various architectural configurations of Notre-Dame. The recorded performances were analysed to quantify temporal deviations and synchronization across acoustic environments. The analysis results indicate that, like individual singers, the two choirs adapted to the acoustics in unique manners. However, no greater trends were found between the synchronisation of onsets and specific acoustical parameters, such as T30 or C80. These findings contribute to the understanding of musical adaptation in reverberant spaces and provide empirical support for the hypothesis that historical acoustic environments influenced medieval choral performance practice. They also highlight the continuing need to adapt existing methods of music performance analysis to ensemble performances, especially those belonging to genres outside of the canon typical to the field.

Joint ISRA and ISMA sessions - Miller 114

Time	Author	Title
11:10	L. Shtrepi, N. Somà, A. Guastamacchia, D. Sgro, G. Emma Puglisi, A. Carullo and A. Astolfi	Singers' likability of the acoustic environment and adaptation of singing in contemporary churches

Several studies have reported that singers' performances vary across different acoustic environments due to the perception variations of the space acoustic characteristics. This study investigated these relationships based on the feedback of six professional singers performing in four contemporary churches. The acoustic parameters according to ISO 3382-1 were measured and singing delivery parameters such as the Power Singing Ratio and Cepstral Peak Prominence Smoothed (CPPS) were analysed. In order to investigate the singers' likability of the acoustic environment, the study has been structured in two phases: 1) a preliminary subjective feedback of the singers has been collected immediately after the four venues performance, showing that they naturally adapted their singing to auditory feedback of each church, and 2) a subjective listening test with amateur singers has been conducted in the Audio Space Lab at the Department of Energy, Politecnico di Torino, Italy. This laboratory, equipped with a 16-loudspeaker spherical array system, enabled real-time auralization based on 3rd order Ambisonic impulse responses recorded in a single position within each church. The amateur singers were asked to evaluate their preferences after performing in each auralized environment, and their responses were compared to those of professional singers who had performed in the four churches.

11:30	E. Porcinai, S. Lepa, P. Klein, H. Talal Schaar and S. Weinzierl	Stage acoustics for chamber music ensembles: a laboratory study with auralised rooms

Ensemble preference for architectural and acoustic features on stage has mostly been investigated in field studies. While these provide optimal conditions in terms of ecological validity, they are limited in the number of halls that can be studied and challenged by the confounding effects of the unique features of the halls in which the experiment takes place. In a focus group discussion with experts in the field of performance space design, a set of six typical architectural features of the stage enclosure was identified. These features were then systematically varied to produce a set of 256 models of halls with balanced variations of these features. Binaural impulse responses were then simulated using the geometrical acoustic software RAVEN. A low-latency dynamic binaural synthesis was set up in anechoic conditions. This allowed up to five participants to perform simultaneously in the same virtual space. Interactions between ensemble type and architectural features, as well as the recently proposed directional room acoustic parameters TH (top-to-horizontal energy ratio) and TS (top-to-side energy ratio) were significantly correlated with perceived support.

11:50	S. Mullins and B. Katz	Listening to Medieval Polyphony in the Virtually Reconstructed Acoustics of Notre-Dame de Paris

This study presents the results of perceptual listening tests designed to evaluate the influence of historical acoustics on the perception of medieval polyphonic music. Using binaural auralization and acoustic modelling, the study simulates the acoustics of Notre-Dame de Paris across different historical periods to assess

the impact of architectural modifications on listener perception of reverberance and the acoustic suitability of the spaces for the different polyphonic eras under examination. Participants, including musicologists, professional musicians, and general listeners selected for their engagement in music, evaluated recorded performances of medieval polyphony presented within these simulated environments. Responses were collected on both the quantitative acoustic attribute of reverberance and the subjective assessment musical and acoustical suitability. The responses indicate that the earliest Gothic cathedrals were perceived as more favourable for polyphonic performance than the later cathedral conditions. However, listener expertise influenced perception, with responses from trained participants displaying an inverse trend of assessments compared to the general participant pool. Findings provide empirical data on the perceptual effects of historical acoustics on recreations of historical music. The study highlights the relevance of perceptual evaluation in validating acoustic simulations and offers insights into how changing room acoustics may have shaped medieval musical practices.

Time	Author	Title
		Lunch Break 12:10 - 13:10
13:00	Trimpin*	Engaging the room: Contraptions for Art and Sound **Plenary Speaker - more details in back of program*
14:10	V. Fraisse, N. Schütz, C. Vincent, M. Wanderley, C. Guastavino and N. Misdariis	Exploring sound installation reactivity: acoustic niches in public space

While the soundscape approach gains increased research attention, it remains underexplored in urban design and sound art. Sound installations in public spaces exist within dynamic acoustic environments, where the interplay between pre-existing sounds and introduced artistic elements influences the auditory experience in complex ways. Yet, there is a lack of tools and methods to evaluate their perceptual impact and inform artistic practice. The present work is part of a research-creation collaboration on Niches Acoustiques, a permanent sound installation designed by sound artist Nadine Schütz for a public square in Paris. The installation explores the acoustic niche concept by adapting its sonic content in reaction to fluctuations in the acoustic environment. We report on a laboratory study focusing on the installation's reactivity, following-up an initial study that linked composition strategies to soundscape perception. Specifically, we present the implementation of variations in the installation's responsiveness – such as amplifying, attenuating, or transforming its content – in reaction to the ambient conditions. These variations serve as a framework for evaluating the impact of reactivity across different listening scenarios. By comparing data-driven approaches with an artistic approach to reactivity, we seek to uncover how reactive sound installations can shape the auditory experience of public space users.

14:30	Elliot Canfield-Dafilou	Recording the Internal Soundfield of a Pipe Organ for Auralization

It is difficult to separate the sound of a pipe organ from the room where it is installed as these instruments are often custom-built and tuned to for the acoustic environments where they are located. In order to study or listen to the instrument and room independently, it is necessary to develop methods for capturing them

independently. The present work focuses on recording the internal soundfield of a pipe organ and proposes strategies for the placement of microphones inside the organ cabinet to capture an even level of sound across pitches and ranks of pipes. Four ranks of pipes of a small pipe organ were sampled with multiple microphones located inside and outside the instrument to investigate the effect of the internal geometry of the instrument on steady state sound production. An analysis of the SPL of prominent spectral peaks pipes as a function of microphone position is provided. Challenges related to the complexity of the instrument and issues of deploying multiple microphones are also discussed.

Time	Author	Title
14:50	I. Witew, M. Wiedemann and S. Weinzierl	Sound power dynamics of chamber ensembles under realistic performance conditions

The suitability of acoustic conditions in performance spaces and rehearsal rooms depends on achieving appropriate sound levels, which in turn requires accurate knowledge of the sound power radiated by musical ensembles. Previous studies have investigated the sound power of individual instruments under laboratory conditions, providing valuable insights that have found recognition in recent standards on the requirements for rehearsal rooms. However, it remains uncertain whether such conditions and the necessary extrapolation to ensembles fully capture the complexities of live performance scenarios. This study investigates the sound power of musical ensembles under realistic performance conditions, analyzing its variation during performances and the effects of instrumentation and musical pieces. The results show the range of radiated sound power and how often these levels occur during performances. These findings suggest opportunities for optimizing auditorium design by incorporating expected sound power levels into the planning process, better accommodating the dynamic nature of musical performances.

15:10	S. McDermott	Accuracy of Audio Attenuation in 3D Audio Libraries

Developers of 3D virtual environments have access to a wide variety of powerful tools and advanced programming interfaces (APIs) that allow the creation of impressive visual representations in their applications. On the other hand, significantly less attention has been paid to the audio aspect of 3D virtual environments. Currently the main and widely available audio programming library, OpenAL, provides limited spatialization and 3D audio. This paper analyzes the multiple models OpenAL uses for calculating attenuation and offers an efficient algorithm as an alternative to those of OpenAL. Specifically, we provide a robust and objective breakdown of the approximations and efficiencies of these models and chart how they compare to real-world physics-based approach.

Time	Author	Title
15:30	J. Braasch	Auralizing music ensembles in concert venues using wave field synthesis

This paper proposes an efficient method to create auralizations of acoustical landmarks using a 2D ray-tracing algorithm and publicly available floor plans for a 128-channel wave field synthesis (WFS) system with 2.5D approximation. Late reverberation parameters are calculated using additional volumetric data. The approach allows the rapid sonic recreation of historical concert venues with adequate sound sources. The listeners can walk through these recreations over an extended user area 12x10 sqm, and the software suite can be used to calculate room acoustical parameters for various positions directly using a binaural rendering method or via the WFS simulation.

Day 1: Sunday, May 25th (continued)

Joint ISRA and ISMA sessions - Miller 114

Time	Author	Title
		Break 15:50 - 16:00
16:00	Anders Friberg*	Swing timing in a jazz ensemble: measurements and models **Plenary Speaker - more details in back of program*
18:30		Trip to Music Box Village (~3 hours) Public transport passes and directions will be provided. Alternate transportation can be provided for those that may have difficulty negotiating public transport.

Notes

Day 2: Monday, May 26th

Room Acoustics (ISRA) Sessions - Miller 114

Time	Author	Title
8:00	Margriet Lautenbach*	Room acoustics for classical halls: Practice, theory and music **Plenary Speaker - more details in back of program*
9:00	A. Szeląg, K. Baruch-Mazur, K. Brawata and A. Kłosak	The application of scale model reverberation rooms for testing acoustic properties of interior finishing materials

The paper presents possible applications of small reverberation rooms (with the volumes of about 1.4 m³) for testing acoustic properties of interior finishing materials and structures. The analyzed practical examples concern all three most important acoustic parameters of materials, i.e. sound absorption, diffusion and isolation. As regards the sound absorption, the research concerned the influence of the location of low-frequency absorption systems mounted on some furniture on their acoustic efficiency. Further, the diffusion of selected Schroeder diffuser was tested on a specially designed miniaturized rotary table. Finally, insulation measurements were performed for samples of different sizes using two small reverberation rooms in order to determine the influence of sample size on the insulation measurement result.

9:20	A. Klosak, A. Gade and A. Szelag	Application of Visually Appealing and Architecturally Preferred Materials - Concrete, Wood, Metal, and Fabric - in Modern Room Acoustic Design

This paper discusses the design, fabrication, installation, and acoustic performance of several unique surfaces individually created for concert halls and auditoriums, which the authors acoustically designed. Several design aspects are discussed: diffusion, absorption, the ability to alter absorption properties while maintaining a coherent visual appearance, ease of fabrication, installation constraints, as well as budget restrictions. The presented examples include wavy reinforced concrete walls, pyramidal-shaped plywood diffusers and tuned absorbers, flat wood wool finishes with enhanced low-frequency absorption, perforated metal roof panels incorporating both acoustic and thermal functions, upholstered auditorium chairs with woven fabric, as well as stretched metal surfaces used as wideband absorbers. Construction details of each material and their influence on the acoustics are also discussed.

9:40	V. Buggè, L. Shtrepi, G. Nocerino, M. Leone and S. Pone	Integrating design, acoustic performance and fabrication: the case of the acoustic optimization of a meeting room

The integration of design, performance and fabrication has been object of continuous research in contemporary architecture. However, this integration is rather limited for the acoustic performance, which is commonly introduced at later stages of the design process. This paper aims to present the integrated design and fabrication of an acoustic performance-driven wooden structure in an existing meeting room. A complex double curved structure has been considered for the general shape of the design concept. It has been based on a “two-way joist shell” (waffle structure) realised through the repetition of a single reference module, embedding different acoustic properties: absorptive, reflective and diffusive. The room clarity and reverberation time have been considered as key performance indicators throughout the existing conditions measurements phase, simulations and optimization workflow. The paper gives an overview of the conception and implementation of a digital workflow that is applied at a first level for the

Time	Author	Title
8:00	J-F. Petiot, G. Hamelin, V. Freour and K. Arimoto	Contribution of sound simulations by physical model and machine learning for the bore optimization of a brass instrument

This work consists in studying the contribution of sound simulations by physical model and machine learning (ML) methods for the optimization of the bore of a trumpet. A training set of virtual instruments is constituted by varying the internal geometry of the bore of a trumpet (the leadpipe). These instruments are then simulated using a physical model of the instrument-musician couple. For each instrument, two descriptors are calculated from the simulations: the EFP (equivalent fundamental pitch), representing the intonation of the notes created, and the threshold pressure (obtained by linear stability analysis), representing the ease of emission. A supervised learning using random forests is then performed on the training set, modeling each descriptor according to the geometric variables of the leadpipe. Thanks to the models, an optimization of the descriptors can finally be carried out to determine the leadpipe geometries that maximize the intonation and ease of emission (biobjective optimization with genetic algorithms). The results are presented in the form of maps, useful for visualizing the influence of the leadpipe geometry on intonation and ease of emission. Different optimal geometries are proposed, which could be tested by manufacturing a real prototype and confirm the validity of the approach.

8:20	V. Freour, Br. Cochelin, C. Vergez and K. Arimoto	Modelling the lips of an artificial trumpet player system

Developing accurate models of the {musican - instrument} dynamical system requires not only to accurately model the resonator but also the musician components involved in sound production. In brass instruments the musician can be considered, in its simplest form, as a set of lips that forms the excitation mechanism coupled to the resonator. Different lumped models of the lips have been proposed in the literature to represent the dynamics of this lip-reed valve. Although a simple one degree-of-freedom linear model is able to produce realistic sounds and behaviors, additional localized nonlinearities and degrees of freedom have been proposed in the literature in order to implement more advanced lip models. However, these improvements often come at the cost of uncertainties on the physical phenomena to be modelled and on the added parameters to be tuned. We present a study where the objective is to propose a lumped model of the lips inspired from the functioning of artificial lips developed in our laboratory to artificially play the trumpet. After presenting the experimental system and the artificial lips, we will detail the study where a finite element model of the lips is fitted on optical measurements performed on the experimental bench. Through a model-reduction approach, a one-degree of freedom model of the lips with a cubic stiffness is derived from a Von Karman plate model, along with analytical formulations for the elastic parameters. Some results of sound simulations and computations of bifurcation diagrams will be presented.

8:40	F. Soares, V. Freour, B. Cochelin, C. Vergez and K. Arimoto	Bifurcation diagrams of a brass instrument model including nonlinear acoustic propagation

Developing accurate models of the {musican - instrument} dynamical system

integration of the design and acoustic performance, and at second level for the integration of the design and digital fabrication of a full-scale prototype and its practical execution. Finally, the work highlights the advantages of a process that incorporates interdisciplinary techniques and innovations in the built environment.

Time	Author	Title
	Morning Break 10:00 - 10:30	
10:30	Z.Belanger, C. Newell and W. McGee	The Design and Assessment of a Glass Acoustic Surface

"Long Range" is a custom acoustic surface made of slumped auto-glass panels. It was designed to exhibit overlapping gradients of acoustic absorption, diffusion, specular reflection, and transmission. These gradients occur across aggregates of unique components, avoiding acoustic categorization of the behavior of any given panel. Shape was used as a guide in the design process, yielding a surface which is planar at one end and becomes increasingly complex toward the other. The use of shape as a guide allows the designer to access innumerable gradient combinations and layouts, all within the constraints of a notoriously "hard" material. However, the acoustic assessment and validation of such a surface poses challenges given that standards such as ISO 354 and ISO 17497 target specific categories of behavior, and tacitly assume that the components of testing samples are consistent across the sample. This paper describes the development process, presents the acoustic data gathered, and discusses what it tells us, and what it doesn't, about such surfaces.

10:50	M. Patel	Tailored Acoustics: Enhancing Acoustic Performance with Customized 3D-Printed Textures

Architectural design is inherently a multi-sensory experience, yet the role of acoustics is often overlooked outside of sound-focused spaces. Technological advancements have enhanced spatial design precision, however, acoustic considerations are frequently addressed late in the design process or post-construction, limiting their effectiveness. Most acoustic simulation tools are computationally expensive and provide only standard material data, and off-the-shelf acoustic products, such as panels, offer generic solutions that lack contextual specificity. Given the scale of these impacts, the research utilizes advanced additive manufacturing to enhance acoustic performance through material customization. Departing from conventional slicer-based workflows commonly used in 3D printing, this study investigates the potential of custom tool pathing and material property manipulation. The paper presents prototypical studies created using the same amount of material utilizing 3D-printed polylactic acid (PLA) to explore distinct acoustic properties. The prototypes are evaluated and validated using ASTM E1050-12, a standardized test method for measuring impedance and absorption characteristics. Furthermore, this approach emphasizes the potential of integrating both local and global surface textures to create an acoustic continuum capable of reflection, diffusion, and absorption. The findings emphasize digital fabrication's ability to integrate acoustics into architectural design, offering a precise, adaptable alternative for crafting tailored aural properties.

11:10	L. Brill, C. Giegold, R. Glosemeyer Petrone, M. Mayell and D. Schuette	From Computation to Construction: Optimizing and Validating Innovative Acoustic Surfaces

The integration of innovative acoustic surfaces into architecture requires a balance between aesthetic intent and acoustic performance. This work explores the

requires not only to accurately model the resonator but also the musician components involved in sound production. In brass instruments the musician can be considered, in its simplest form, as a set of lips that forms the excitation mechanism coupled to the resonator. Different lumped models of the lips have been proposed in the literature to represent the dynamics of this lip-reed valve. Although a simple one degree-of-freedom linear model is able to produce realistic sounds and behaviors, additional localized nonlinearities and degrees of freedom have been proposed in the literature in order to implement more advanced lip models. However, these improvements often come at the cost of uncertainties on the physical phenomena to be modelled and on the added parameters to be tuned. We present a study where the objective is to propose a lumped model of the lips inspired from the functioning of artificial lips developed in our laboratory to artificially play the trumpet. After presenting the experimental system and the artificial lips, we will detail the study where a finite element model of the lips is fitted on optical measurements performed on the experimental bench. Through a model-reduction approach, a one-degree of freedom model of the lips with a cubic stiffness is derived from a Von Karman plate model, along with analytical formulations for the elastic parameters. Some results of sound simulations and computations of bifurcation diagrams will be presented.

Time	Author	Title
9:00	M. Jackson and G. Scavone	A study of brass instrument impedance

The input impedance of a brass instrument can be analyzed to infer some aspects of playability. The input impedance can be calculated from the instrument geometry, with various parts such as the mouthpiece, bell, pistons and main bore. However, because the geometries of the parts are not always precisely known or measurable, the overall impedance are not straightforward to calculate. In order to work toward a method for calculating the impedance of a full brass instrument from only its geometry, it is necessary to isolate each component of the instrument, such as mouthpiece, bell, curved pipes, valves, and mutes. A study has been performed to compare the impedances calculated using the transfer matrix and finite element methods to the measured impedances of individual instrument components, with a focus on the trumpet. The results of this study will be presented.

9:20	M. Aragó Bishop, A. Myers, M. Campbell and S. McGrattan	Optimising intonation and playability in a vented trumpet: Acoustical behaviour and performer insights

Sound is produced in a brass instrument by the vibration of the player's lips at the input end and radiates through the bell at the exit. Typically, these are the only two openings in brass instruments. In a vented trumpet, additional holes are drilled into the sides of the tube. The player can open or close these holes to improve the instrument's intonation and stability, particularly in baroque performances. This paper studies the acoustical behaviour of the vent holes in a four-hole vented trumpet. The input impedance is measured using the BIAS system for two frequently used venting fingerings. These experimental results are compared with numerical simulations using the Openwind framework, with input data derived from mechanical measurements of the bore profile of the trumpet. An optimisation method based on the input impedance is proposed for the trumpet, varying the physical size and position of the holes. A new tube with holes is built based on these modifications. A professional player of the vented trumpet has provided feedback on the effect of the modifications on the intonation and playability of the trumpet.

application of computational optimization techniques, specifically the use of genetic algorithms (GA) and finite-difference time-domain (FDTD) analysis, to develop high-performing, architecturally expressive acoustic surfaces. Through two case studies, we examine how aesthetic goals were translated into geometric parameters that informed the GA optimization process, ensuring the desired acoustic diffusion performance. FDTD simulations were employed to evaluate impulse responses and frequency behavior, utilizing cloud-based GPU computing clusters to efficiently analyze thousands of design iterations. To validate computational predictions, full-scale prototypes were fabricated and subjected to experimental acoustic testing, providing critical insights into real-world performance and potential fabrication constraints. The findings demonstrate how these computational workflows enable architects and acousticians to integrate acoustic performance as an active design parameter while expanding the possibilities for customized, performance-driven surfaces. The discussion will highlight lessons learned in design, fabrication, and validation, as well as the broader implications of integrating advanced computational tools into architectural practice.

Time	Author	Title
		Lunch Break 11:50 - 12:50
12:50	A. Klosak, An. Gade, K. Piotrowski and A. Szelag	Subjective evaluation of differences in concert hall shape using a multisource orchestra anechoic recordings auralized in 3d computer models

The current trends in concert hall design seem to concentrate on two basic hall shapes, either 1) the rectangular “shoe box” with one or more balconies or 2) an arena shape with vineyard terraces (and sometimes balconies). By means of auralizations created by the ODEON software, the present study aims towards testing whether such auralizations are capable of revealing systematic subjective differences between these two topologies. The procedure was to create 3D model auralizations in each of three classical shoeboxes and three modern “vineyard” halls. Anechoic multisource orchestra recordings were used as signal input in the models and fifty subjects with and without musical background evaluated the halls with respect to general preference in paired comparisons tests. The paper discusses the results regarding the subjects’ detection of differences in room shape, and whether these are accompanied by corresponding differences in objective parameter values.

13:10	A. van der Harten	Open Source Numerical Tools for Evaluating Unique Finish Designs

The process of designing new and unique bespoke finishes often has the unintended consequence of yielding new and unique questions. Does this geometry create more absorption than intended, or can this color the sound? In many applications the concern is not serious, but in some cases, it may be necessary to understand the consequences of a design decision. Unusual design scenarios require flexible simulation solutions that only an open-source tool can provide. Pachyderm includes numerical tools such as the Transfer Matrix for Materials, Finite Volume Method, and Boundary Element Method, which can be used to develop estimates of performance for fine-scale geometry, not only in isolation, but also as installed to some degree. This presentation will discuss the open-source numerical tools in Pachyderm Acoustic that may apply in these instances, and provide examples of how the simulation methods can be applied to perform standardized test simulations for performance estimation, as well as customized simulations that can help to understand the actual performance in a given installation configuration, and the consequences of your design decisions.

Musical Acoustics (ISMA) Sessions - Miller 204

Time	Author	Title
9:00	David Gillespie	Quantitative Comparison of Various Cajon Models

Cajons are simple percussion instruments originally designed to hide an instrument as a crate. Since cajons have been gaining popularity, novel designs have been developed for different applications, sounds, and styles. In this investigation, three different designs are quantitatively compared in the frequency domain to investigate their spectral differences. Basic theories were also used to calculate expected resonances based on each cajon's internal volume, port size, playing surface dimensions, and wood types. Theoretical values were compared to experimental recordings and showed good agreement with expectations. The theories were especially good at following the expected trends as predicted frequencies decreased with increased cajon size. The cajons were also compared to each other to show how different designs can result in different frequency responses. Calibration signals were generated and used to determine potential effects of room modes and the overall recording setup and signal chain. Overall, this investigation showed that simple theories can be used to determine approximated sounds of novel cajon designs. It also showed that validating measurements can be performed with basic and relatively inexpensive recording equipment without the need for an anechoic chamber as long as the additional coloration of these imprecise techniques can be accounted for or analyzed.

Morning Break 10:00 - 10:30

10:30	E. Canfield-Dafilou, S. Yusuf and M. Rau	Acoustics of Sympathetic Strings in a Sarangi

The sarangi, a bowed North Indian viol, is renowned for its rich tonal quality and expressivity. Its characteristic sound is largely attributed to its unique construction with its body carved from a single block of hardwood and partially covered by a goatskin membrane typically hosting 3 main strings and up to 40 sympathetic strings. The sympathetic strings are divided into 4 choirs: chromatic and diatonic sets mounted close to the body and two additional sets of longer strings, mounted above and tuned to important notes of the raga (Indian melodic systems). The present work uses vibration and acoustic measurements to investigate how these distinct sets of sympathetic strings contribute to the resonant sound of the instrument.

10:50	M. Rau and G. Scavone	Vibration Measurements Comparing the Contrabass and Octobass

The octobass is the largest and lowest member of the stringed instrument family. First developed in the 1850s by French luthier Jean-Baptiste Vuillaume, the octobass has three strings and measures close to 3.5 meters tall. There are fewer than 10 known octobasses in the world, with most examples being housed in museum collections. However, the Orchestre Symphonique de Montréal (OSM) possesses three octobasses built by French luthier Jean-Jacques Pagès, unique in that they are regularly used in performances. We present recorded bowed notes and bridge admittance measurements of the three OSM octobassses and three contemporary contrabasses. The lowest mode frequencies of the contrabasses are 51, 52, and 68 Hz, while the lowest mode frequencies of the octobasses are significantly lower at 34, 35, and 39 Hz. The octobass and contrabass measurements are compared to better understand the advantages and disadvantages of such a colossal instrument.

Room Acoustics (ISRA) Sessions - Miller 114

Time	Author	Title
13:30	S. Kartub, N. Dulworth, M. Mayell, C. Springthorpe, J. Strong, C.Giegold and S. Pfeiffer	Auralizing Curved Reflector Arrays for Onstage Listeners

Auralizations have been beneficial to Threshold Acoustics' process for decision-making with design teams and end users alike, improving confidence in choices made. To date, auralizations have originated in ODEON, a Geometric Acoustics (GA) modeling software. Previous critical listening scenarios have exposed limitations in listening among musicians on stage due to the size of the auralized sphere in the listening room. Necessary approximations required of GA also lead to unpredictability of expected reflections from reflector arrays. Pachyderm was used to generate auralizations of these challenging conditions in two recent projects: the first, a semi-outdoor performance space renovation and the second, upgrades to a church-turned-orchestral rehearsal space. These efforts sought to enhance the resulting aural environments by modeling true curves instead of faceting or flattening them, better bridging the gaps between individual reflector elements. Professional musicians were brought in to evaluate changing room conditions. Through their and the consultants' subjective listening, it was determined that modeling using Pachyderm produced believable musician-to-musician auralization scenarios and nuanced audible differences between varying source and receiver placements in relation to reflector arrays. However, directional realism remained difficult to capture in believable ways, especially with closely spaced sources and receivers, and should be refined with future study.

13:50	W. Ahnert and S. Feistel	Complex acoustic simulations in real time

Statistical calculations in acoustic simulation programs are fast but deliver correct results only for simple room structures. Raytracing calculations are significantly more accurate but for complicated room structures they often require long calculation times. In either case, when considering sound systems and room acoustics combined, the positioning and aiming of loudspeakers is an important first step for an effective acoustic environment. In the new approach presented here, direct SPL mappings are calculated in real time and allow for interactive model changes with immediate visual feedback, including loudspeaker configuration, signal processing, and environmental parameters. Calculations are performed at a frequency resolution of at least 1/24th octaves. The full bandwidth from 20 Hz to 20 kHz is supported allowing to investigate low-frequency interaction. A regular, contemporary PC is sufficient to take full advantage of the performance of the highly optimized, hybrid CPU/GPU simulation engine. Its real-time ability offers new ways of investigating or teaching the physical properties of sound fields. It also facilitates new forms of collaboration with clients and partners. The presentation uses examples to illustrate the calculation speed for complicated room structures and changing parameters. It demonstrates how the performance and coverage of a sound system is optimized time-efficiently.

14:10	T. Jüterbock, U. Finnendahl, M. Worchel and S. Weinzierl	misuka: An Open-Source Extension to Mitsuba 3 for Efficient Differentiable Room Acoustic Rendering

Geometric room acoustic simulations are widely used in architectural acoustics.

Musical Acoustics (ISMA) Sessions - Miller 204

Time	Author	Title
11:10	A. Piacsek and C. Fritz	Preliminary results of a survey of musicians and luthiers regarding beliefs about playing-in

The phenomenon of "playing-in," whereby the tonal characteristics of a stringed instrument are improved by it being played, is anecdotally reported by many musicians, with sufficient acceptance to support commercial products designed to accelerate or enhance the process. To guide us in the design of laboratory experiments and perceptual tests for investigating the efficacy of playing-in, we developed a survey of specific views held by performers and luthiers about this phenomenon. Questions were carefully worded to provide a clear and consistent definition of terms, for example, distinguishing between "playing-in" and "seasoning". As a baseline for sensitivity to both tonal changes and playability, respondents were asked to compare the effects of playing-in with the effects of humidity changes. The survey also asked about changes in tone and playability associated with phenomena related to playing-in, such as aging, warming up, or letting an instrument go dormant for a long time. Preliminary results indicate that the phenomenon of playing-in is widely accepted, although there is less support for the efficacy of mechanical devices. There is also a diversity of opinion about which attributes are affected the most by playing-in. Implications for future experiments will be discussed.

11:30	H. Tahvanainen	Coupling of higher-order air modes and structural modes in string instruments

Typically, the effect of the air cavity in string instruments is summarized by the first air cavity mode, also called the Helmholtz resonance. However, there are also other significant effects. In this research, the effect of higher-order air cavity modes on the vibroacoustic response of the classical guitars, archtop guitar and violin are investigated with the help of finite element modelling. The results confirm some of the previous speculations and findings and shows that some of the higher-order air cavity modes have a significant effect.

Lunch Break 11:50 - 12:50

12:50	P. Cillo, P. Ziegler and P. Eberhard	Reducing tonal variability in guitars: An efficient framework for soundboard shape optimization

The tonal quality of guitars is inherently affected by the natural variability of wood's mechanical properties, a challenge traditionally addressed by luthiers through nuanced, experience-driven adjustments. This study presents a systematic method for mitigating material variability in guitar soundboards by implementing precise geometric modifications. A parametric finite element model is combined with optimization techniques that minimize discrepancies in eigenfrequencies and mode shapes, ensuring consistent vibrational behavior. To manage the significant computational costs associated with repeated model evaluations, a parametric model order reduction strategy is adopted. To achieve this, we leverage an affine parametric representation of the system matrices, accomplished through a custom finite element implementation of shell and volume elements. This methodology enables a substantial reduction in computational time while maintaining accuracy withing 0.5% across the modes. The methodology is validated through a numerical case study, where the modal parameters of a cedar soundboard are closely replicated by an optimized spruce soundboard, reducing average frequency deviation from 10% to 1%, with closely aligned mode shapes. This framework offers a robust and reproducible strategy for reducing tonal variability in instrument production. It also opens new possibilities for using alternative and more sustainable materials while preserving the desired acoustic characteristics of traditional tonewoods.

Room Acoustics (ISRA) Sessions - Miller 114

While ray tracing and path tracing algorithms offer computationally efficient alternatives to wave-theoretic models, most existing acoustic implementations rely on CPU-based rendering, limiting their scalability. Furthermore, improvements to an acoustic scene are only possible through iterative simulations. In this paper, we present misuka, an open-source software for differentiable room acoustic rendering. Built as an extension to the differentiable light transport renderer Mitsuba 3, misuka enables efficient acoustic path tracing on both the CPU and GPU, while supporting automatic gradient tracking through Mitsuba 3's interface and its underlying differentiable just-in-time compiler. With misuka, scene parameters such as material properties and geometry can be optimized based on target properties like spatial or temporal sound energy distributions. We validate misuka against an established simulation tool and demonstrate its applications in material and geometry optimization.

Afternoon Break 14:30 - 15:00

15:00	Panel discussion	Simulation Techniques in Room Acoustics

Break 16:30 - 17:30

17:30 - 18:30	JAM SESSION MILLER 114
20:00 - 21:30	Trip to Cafe Istanbul - Jazz Trio James SIngleton And Friends Showtime 20:00-21:30 cash bar, no food provided, small restaurant on premises

Time	Author	Title
13:10	T. Yudasaka, G. Scavone, M. Rau and K. Ishizaka	Measurement and analysis of electric guitar neck admittance for digital waveguide models

This paper examines the implementation of neck admittance in digital waveguide (DWG) models for guitars. We explore whether neck admittance varies significantly from fret to fret and might necessitate modeling adjustments based on fingering. Measurements of horizontal, vertical, and coupling admittances across all frets revealed significant differences in decay. Finite element method calculations of admittance were performed on a 3D model of the measured guitar and found to closely match the measurements. The measured admittances were used in a DWG synthesis model of string vibrations, confirming that string decay differences due to neck admittance variations were present in the resulting sounds. Comparisons between the synthesized and measured string vibrations showed consistent decay differences at the frets, validating the accuracy of the model. This study highlights the importance of real-time neck admittance adjustments in improving the realism of DWG guitar models.

13:30	R. Mores and S. Zimmer	Preserving the art of sound design in Spanish guitars - archiving, modeling, and replication with model-based modifications

In 2019 the acoustical properties of some 60 valuable acoustical guitars were archived for purposes of preservation and research. Among these guitars is an outstanding exemplar from Conde. This guitar served as a reference for generating an analytical model. The model identifies relevant factors to achieve a multiplicity of main resonances in the low frequency range. This supports the fundamental tone over a wide range. While the construction of the reference guitar is unusual to some extend the derived model is rather universal and has proved to be applicable for diverse concepts of top plate bracing. The guitar construction and the explanatory model raised interest among guitar makers in Granada, Madrid, and Markneukirchen. Luthiers now explore the construction's potential. A replica of the reference guitar was built and predictions for minor construction modifications came true. This approach of preserving the culture of sound design is encouraging. The project report comes along with supporting material and tools.

13:50	S. Linke, P. Kuchenbecker, R. Mores and R. Bader	The influence of single-coil pickup height on string vibration and intonation in electric guitars

On some electric guitars, the height of a single-coil pickup can significantly influence string vibration and, thus, the instrument's intonation. Due to the nature of the pickup's magnetic field, string vibrations parallel to the field (orthogonal to the guitar's top plate) are affected more strongly than those in the orthogonal direction. This results in two different fundamental frequencies depending on the polarization direction, leading from beating sounds to rough and ring-modulator-like behavior. This effect is examined through experimental measurements with varying pickup heights. Additionally, a simplified numerical model is developed to reproduce these observations by capturing the core dynamics of the interaction. Further, this process is dynamically modeled using the Impulse Pattern Formulation (IPF). This general nonlinear modeling approach describes musical instruments by the interaction of individually propagating and exponentially damped impulse trains. Thus, the coupling of different instrument parts (here, mainly magnetic pickup and string) relies on a single recursive equation suitable for real-time simulation, which also allows the application of the model as an audio effect for electric guitars that emulates the sounds of different pickup heights.

Notes

Musical Acoustics (ISMA) Sessions - Miller 204

Time	Author	Title
		Afternoon Break 14:10 - 14:40
14:40	E. Matusiak, V. Chatziioannou and M. van Walstijn	A refined bow string interaction model considering hysteresis

In order to accurately model the bow-string interaction, a friction model is necessary that will correctly predict the friction force during stick-slip phases. This force has been estimated from experimental measurements. It appears to be at its highest at the start of slipping, and it decreases as the slipping speed increases. On the way back towards the sticking phase, the force is lower than on the way towards the slipping phase. It has been hypothesised that the temperature fluctuations of rosin are responsible for this hysteretic behaviour [Smith, J. and Woodhouse, J., The tribology of rosin. J. Mech. Phys. Solids, 48(8), 2000]. In this work, a model is proposed that directly incorporates the temperature changes of rosin during bowing. It is shown that the friction force resembles the one estimated from the measurements.

15:00	A. Lampis, V. Chatziioannou and G. Scavone	Experimental analysis of playability and tonal quality of cello strings using Schelleng diagrams

In this study, we used a robotic arm as bowing device and a custom monochord to evaluate the playability and tonal quality of eight custom-made G cello string types. Each string type is defined by a unique combination of core material, winding, and operating tension. Several repeated measurements of individual strings were also performed to assess experimental variability. We constructed high-resolution Schelleng diagrams that revealed relationships between string response and bowing parameters, and analyzed bow force limits and spectral feature trends. String vibrations were measured under controlled conditions, varying bow force and bow-bridge distance. Analysis of steady-state signals revealed typical vibration regimes and tonal color features—pitch flattening, spectral centroid, and anomalous low frequencies—as functions of bowing parameters. Minimal differences in playability and tonal color were observed between string types. Correlations between these features and measured mechanical properties were explored, although results remain preliminary due to the limited sample size. This research was funded in whole or in part by the Austrian Science Fund (FWF) [P34852-N].

15:20	H. Pauget Ballesteros, P. Lalitte and C. Fritz	Influence of Bowed String Control Parameters on Audio Descriptors in Real Playing Conditions

Traditional models of the bowed string rely on three main parameters: bow speed, bow force, and the distance of the bow to the bridge. In the article “The Violinist’s Sound Palette: Spectral Centroid, Pitch Flattening and Anomalous Low Frequencies,” Schoonderwaldt et al. investigate the influence of these parameters on the spectral centroid using a monochord and a bowing machine. However, this study is limited to experimental conditions that are far from real playing conditions and focuses only on the analysis of the steady-state portions of the sounds. To address these limitations, we analyzed recordings made by violinists playing different violins and exploring various playing parameter configurations. Several audio descriptors were computed, and statistical tests were used to identify those most sensitive to parameter variations. We examined both the steady-state portions and the notes in their entirety. Our results confirm that, in the steady-state portions, bow force has the greatest influence on the spectral centroid, followed by bow speed, while the distance to the bridge plays a minor role. In contrast, the analysis of the notes in their entirety reveals a dominant influence of bow speed on the studied descriptors.

Notes

Musical Acoustics (ISMA) Sessions - Miller 204

Time	Author	Title
15:40	C. Fritz, C. Bisserie, A. Cagnetta, Mj Kwan and S. Zygmuntowicz	Sound differences between Stradivari and del Gesu violin models

The models created by the two Cremonese masters Stradivari and Guarneri del Gesù are frequently reproduced by contemporary violin makers. While variations in the model can influence the sound and response of the instruments, so too can differences in materials such as wood, glue, varnish, ... Furthermore, neither Stradivari nor del Gesù have a single, definitive model, but rather multiple variations. However, it is generally believed that instruments based on del Gesu models have distinct characteristics when compared to those based on Stradivari models. We take the opportunity of the large database of acoustical measurements taken by the last author on the violins of his production to investigate whether there are significant spectral differences and how they are linked to perceived sound qualities via a listening test. The same short excerpt, recorded via piezo sensors on the bridge of a violin, was convoluted by the radiated response of different Zygmuntowicz violins, built either on a Stradivarius or del Gesu model. These synthesized stimuli were then used in a free categorisation test, taken by about thirty participants. While violins of the same model were not systematically grouped together, the collected verbal data and spectral analyses may shed light on the perceptual groups.

16:00	V. Salvador Castrillo, F. Ablitzer and C. Fritz	Investigating the Role of Bow Rotational Inertia in Violin Bowing Mechanics

Violinists are particularly sensitive to the moment of inertia of the bow, especially during bouncing bow strokes like sautillé and spiccato. This study examines how variations in bow inertia affect the execution of these bowing techniques. Sixteen violinists, ranging from students and advanced amateurs to professionals, performed bouncing strokes on the same violin using a bow with an adjustable moment of inertia. The experiment controlled for factors such as string choice, dynamic level, and bow inertia, while a metronome ensured rhythmic consistency across participants. Bowing movements were recorded using optical motion capture and analyzed with linear mixed models to assess the effects of the experimental conditions. The results indicate that increasing the bow's moment of inertia significantly reduces the amplitude of rotational oscillations around axes perpendicular to its longitudinal axis. Additionally, increasing inertia shifts the bouncing point toward the tip. These findings underscore the influence of bow inertia on bowing mechanics and demonstrate the impact of bow design on bowing technique.

Break 16:20 - 17:30

17:30 - 18:30	JAM SESSION MILLER 114
20:00 - 21:30	Trip to Cafe Istanbul - Jazz Trio James SIngleton And Friends Showtime 20:00-21:30 cash bar, no food provided, small restaurant on premises

Day 3: Tuesday, May 27th

Room Acoustics (ISRA) Sessions - Miller 114

Time	Author	Title
8:00	Stefan Weinzierl*	Generative design as a solution for room acoustic problems **Plenary Speaker - more details in back of program*
9:00	C. Hough	High frequency sound in concert hall design - balancing the spatial, tonal and frequency domains

High frequency (≥1 kHz) sound strongly influences clarity, spatial impression, engagement and timbre, including both desirable (e.g. engagement and spaciousness) and undesirable ("dullness", "harshness" or image shift) effects. Due to binaural hearing mechanisms some of these effects can be level-dependent and predicting whether a particular reflection is going to have positive or negative consequences to the overall sound quality is complicated. A key design decision is whether early reflection surfaces are specularly-reflecting or are diffuse. The importance of "information-preserving" early reflections is agreed on in the literature, but with opposed views as to what is an "information preserving" reflection. Is diffusion on early reflection surfaces desirable (and if so: at which frequencies?). Research has often considered only one of the temporal, spatial or frequency domains when approaching the problem. We do not have a full understanding of the consequences of the surface finish of early reflection surfaces. Are the positive spatial and proximity effects of strong early reflections necessarily accompanied by a timbral penalty? It possible to design for both spatial excitement and tonal beauty? Further research is needed to unpick the tangled threads of spatial, temporal and frequency domain characteristics of early reflections and guide designers in their decisions.

9:20	M.Vercammen and M. Lautenbach	Scattering, surround sound and perceived loudness in smaller concert halls

Several studies have reported that singers' performances vary across different acoustic environments due to the perception variations of the space acoustic characteristics. This study investigated these relationships based on the feedback of six professional singers performing in four contemporary churches. The acoustic parameters according to ISO 3382-1 were measured and singing delivery parameters such as the Power Singing Ratio and Cepstral Peak Prominence Smoothed (CPPS) were analysed. In order to investigate the singers' likability of the acoustic environment, the study has been structured in two phases: 1) a preliminary subjective feedback of the singers has been collected immediately after the four venues performance, showing that they naturally adapted their singing to auditory feedback of each church, and 2) a subjective listening test with amateur singers has been conducted in the Audio Space Lab at the Department of Energy, Politecnico di Torino, Italy. This laboratory, equipped with a 16-loudspeaker spherical array system, enabled real-time auralization based on 3rd order Ambisonic impulse responses recorded in a single position within each church. The amateur singers were asked to evaluate their preferences after performing in each auralized environment, and their responses were compared to those of professional singers who had performed in the four churches.

9:40	J.Heck, J. Llorca-Bofí, H. Park, N. Meyer-Kahlen, T. Lokki and M. Vorländer	Comparison of the auditory and auditory-visual perception in four concert halls

An interesting research question is still to what extent the visual impression of

Musical Acoustics (ISMA) Sessions - Miller 204

Time	Author	Title
8:00	K. Saenger and N. Giordano	Half-integer harmonics in the soprano recorder and new clues about their origins

The musical notes produced by recorders and other flue instruments consist primarily of spectral components with frequencies given approximately by nf1, where n is an integer and f1 is the fundamental frequency. However, spectral analysis clearly shows the presence of half-integer harmonic tones at frequencies (n ± ½)f1 in certain well-defined ranges of steady state blowing pressure [1]. We will review previous observations about half harmonics in the soprano recorder and describe new experimental and computational results that tie the presence of the half harmonics to cross flow patterns and geometric features the window region. [1] N. Giordano and K.L. Saenger, J. Acoust. Soc. Am. 154 (5) 2917-2927 (2023) * Work supported by U.S. National Science Foundation grant PHY-2306035

8:20	R. Tabata, K. Okada, T. Shoji, K. Arimoto and Y. Hattori	Shape optimization of an air-jet instrument using the continuous adjoint method

In this paper, we report the results of shape optimization for an air-jet (flue) instrument using the adjoint method. Direct aeroacoustic simulations were conducted using 2D compressible fluid analysis with the volume penalization method, and sensitivity analysis was carried out using the continuous adjoint method. We explored the optimization of the edge (labium) shape of the air-jet instrument, which maximizes a target function based on the acoustic power radiated from the instrument. The results demonstrate that this method effectively optimizes the edge shape, thereby maximizing acoustic power and consequently increasing the jet's amplitude. The optimization results were validated through experiments, confirming that the relative difference in the simulation results could be reproduced using artificial blowing experiments.

8:40	T. Lasickas, G.C. Alp Caridi, A. Soldati and V. Chatziioannou	The Influence of Side Hole Undercutting on Vorticity

Vortices in musical instruments form in a non-uniform flow, where air currents of different velocities or directions mix. Non-uniform flow, in the case of flutes or recorders, occurs at the labium, at the open end and at the side holes. Side hole undercutting has been shown to minimise vortex formation. Previous numerical simulations have visualised airflow velocity influence on vorticity. In experimental studies, where a tube with a side hole was excited by a loudspeaker, it was observed that speaker loudness and hole geometry influenced the vorticity. Recent simulations [1] explore the effect of undercutting on the transient and show detailed results on the vortex formation. In this study, we aim to compare vortex formation between 6 different side hole geometries with a significant undercut and another 6 without undercutting, under realistic input conditions. Using the same geometry as in [1] we employ time-resolved Particle Image Velocimetry to measure flow velocity at a sampling rate of 10 kHz. The recorder is excited utilising a commercial recorder mouthpiece with constant input conditions maintained at 100 Pa. [1] N.Giordano (2025), "Structure of air flow near a woodwind tone hole", ISMRA 2025, to be published.

9:00	N. Giordano	Structure of air flow near a woodwind tone hole

Recent experimental work by Lasickas et al. has used particle image velocimetry

a room influences the auditory perception. Subjective evaluations have been collected for four concert halls based on Individual Vocabulary Profiling (IVP) and MUSHRA-like ratings. The experiment was conducted with two groups, each comprising 20 participants. One group performed the auditory-visual experiment (AV) with 360-degree photographs of the halls being presented in a head-mounted display. The other group performed a blind test (B) evaluating the stimuli purely auditorily without seeing the hall. The acoustic stimuli were identical and reproduced over headphones for both groups. The stimuli consisted of anechoic orchestra recordings that have been convolved with measured spatial impulse responses from the concert halls under study. The aggregated comparative ratings allow to study the differences induced by the type of presentation, i.e. auditory versus auditory-visual. For this purpose, a multiple factor analysis has been performed that highlights the dominant perceptual dimensions. The results show that differences between the two presentation types can be mainly seen in the timbre, intimacy, reverberation and spatial perception.

Time	Author	Title
	Morning Break 10:00 - 10:30	
10:30	G. Atay, J. Llorca-Bofí and M. Vorländer	Visual Distance Influence on Apparent Source Width in Concert Halls

The degree of lateral energy, one of the key elements that contributes to the spatial impression of a hall, is found to be correlated with the subjective measurements of apparent source width (ASW) in concert halls. The present-study aims to investigate the relationship of the spatial impression of a concert hall with the changing source-receiver distances through a listening experiment conducted in VR environments. For the experiment, auralizations of the loudspeaker orchestra (Pätynen et al.) are produced for Gasteig Concert Hall. This pilot study is a part of future research aiming to assess the auditory-visual perception of loudness and ASW based on visual distance information. The initial results of the study are presented.

10:50	M. Yang and N.Xiang	Directional Perception of Reverberance in an Acoustically Coupled Volume System

In architectural acoustics practice, many performing arts venues have implemented reverberation chambers coupled to the main floor. In a coupled volume system, reverberant energy manifests multiple-slope decay features. This phenomenon facilitates an audible and localizable reverberance from the secondary volume, stimulating this investigation on the directional perception of reverberance within the coupled volume system. This paper discusses the angular perception sensitivity of directional reverberance under various conditions, based on binaural auralization tests. Binaural impulse responses are measured with different orientations. The results underscore the resolution of directional perception in coupled volume space and limitations including its relationship with signal type. This paper discusses some preliminary results of the perceptual evaluations.

11:10	J. Salesin, T. Lokki and T. Méndez Echenagucia	Seat Sublime: Focusing on the Totality of the Concertgoer Experience – Acoustical, Visual, and Physical

It is axiomatic that not all seats in a concert hall are created equal. The specific acoustical, visual, and physical conditions of seats within the hall will vary and will represent a set of compromises, yielding different experiences depending on where one is seated in the hall. The 3382 ISO standard for performance spaces identifies certain key acoustical metrics for a hall calculated by averaging. But

to obtain detailed results for air flow near a tone hole in a model recorder while the instrument was blown to produce a musical tone. We report a complementary simulation study of the same instrument geometry under similar blowing conditions. Detailed results for the flow of air through the tone hole have been obtained, and for vortex creation at both the inlet and outlet of the tone hole. We have observed the effect of undercutting on vortex creation and find that undercutting can have a profound effect on the behavior during the initiation of a tone.

Time	Author	Title
9:20	S. Adachi and Z. Qian	Comparison between the actual and simulated mode transition diagrams of a recorder for evaluating the jet oscillation model allowing overall deflection

In research on the sound production mechanism of flute-like instruments, a jet oscillation model allowing overall jet deflection has recently been proposed. This model can explain well the results of Price's measurements of the reflection coefficient of a recorder's head. A time-domain simulation using this model also reproduces various regimes of oscillation, normal, overblowing and underblowing (whistle tone) by changing the blowing pressure. To evaluate the simulation results, an artificial blowing experiment was performed under the same conditions as the simulation and the sound pressure level in the instrument was measured. As a result, it was found that the simulated sound frequencies of the normal and overblowing regimes were a few percent lower than the actual sound frequencies. It was also found that the sound pressure levels were estimated to be 6 to 8 dB lower than the actual levels. In order to develop a better model of the flute-like instruments, the causes of these differences were briefly discussed.

9:40	C. Bastien, C. Fritz and A. Ernoult	Modeling the intonation profile of a recorder and predicting its sensitivity to small tone hole variations

Musical acoustics continues to face challenges in supporting the design of wind instruments. For side-hole instruments like the recorder, the primary difficulty lies in predicting the absolute pitch of a given fingering. To address this, we propose an approach based on the intonation profile, which represents the relative pitch deviations between fingerings, regardless of the diapason and the temperament. The profile is determined from geometrical data of the bore and the fingerholes via acoustical models that integrate impedance simulations, sound synthesis, and linear stability analysis. Predicted profiles are then validated through impedance measurements and experimental bifurcation diagrams obtained with an artificial mouth. This method allows the investigation of how small geometric modifications, similar to those made by the instrument-makers, affect the intonation profile of an instrument. Future work will explore how the intonation profile relate to musician evaluations during playing tests. Ultimately, this study aims to provide a quantifiable understanding of the influence of geometric and acoustic parameters on the pitch accuracy and stability of recorders.

Morning Break 10:00 - 10:30

10:30	K. Saenger and D. Walkup	Using pulsed and steady speaker tones to probe note transitions in a soprano recorder

The behavior of a forced harmonic oscillator with damping is a classic example found in many acoustics textbooks. We reproduced this behavior in a soprano recorder driven with on-resonance and off-resonance tones from an electric speaker (instead of the typical air jet). Time-resolved spectral analysis of signals recorded by an internal microphone showed, for example, that speaker tone

these "average" acoustical measures do not describe the musical concert-going experience for the individual attendee, and do not capture the total experience in the hall. Individuals differ in their preferred acoustics, so acoustical variation in the hall could be a benefit if seat selection could be matched to individual preference. Research also shows that the emotional experience of attending a concert may be derived at least as much from the visual aspects of the performance as the acoustical. This paper suggests that the concertgoer experience could be improved if the acoustical, visual, and physical seating experiences in the hall are aligned to the individual concertgoer's preferences, and describes a seat selection system implemented to achieve this objective. It also suggests the potential benefits to designers, arts organizations, and concertgoers of utilizing such a system.

Time	Author	Title
11:30	B. Masiero, J. Nivaldo Sarinho Filho and R. Thomazelli	Optimizing Low-Frequency Reverberation in a Critical Listening Room

To evaluate subtle nuances in different audio reproduction systems or conduct auditory perceptual studies, international standards, such as the ITU-R BS.1116-3, indicate the need for a space with minimal residual noise and very low reverberation in all frequencies of interest. We constructed a Critical Listening Room (CLR) designed to meet these stringent requirements. The first construction phase employed a "box-in-a-box" design, featuring external walls made of cement blocks and internal walls built with a light steel frame and triple-layered gypsum boards, all resting on a floating floor. This design achieved outstanding sound isolation, surpassing the NR10 criterion, with residual noise levels of less than 6 dBA. The second construction phase focuses on installing internal wall treatments to address the room's reverberation time, which remains notably high at lower frequencies (e.g., 7 seconds at 50 Hz). To mitigate this, mineral wool and membrane absorbers are commonly used. In this study, we evaluate the effectiveness of various absorber configurations in controlling low-frequency reverberation, presenting results from detailed acoustic measurements conducted in the CLR.

11:50	A. van der Harten and D. Kahn	Recent Practice in the Design of Rehearsal Rooms

The design of music rehearsal rooms for large ensembles with attention to loudness has been a topic of interest for more than a decade. In this time, some acousticians have made strides in implementing the new thinking into their practice. Despite the new wisdom, there is often a clear tension between the need for control of loudness, and the preference for reverberation. This session will discuss the design of several recent rehearsal facilities with challenges related to available volume, loudness, and the need for the room to sound appropriate (not too dead) for its programming. The authors will discuss the various standards and practices for rehearsal room design, and will then share, based on end-user feedback, what has worked well, and what has proven challenging.

Lunch Break 12:10 - 13:10

13:10	J. Alvarez Chaia, R. Graus and H. Martin-Nieva	Two contributions of physicist Higini Arau-Puchades to Architectural Acoustics: On the boundary between scientific theory and consulting practice

The tonal quality of guitars is inherently affected by the natural variability of wood's mechanical properties, a challenge traditionally addressed by luthiers through nuanced, experience-driven adjustments. This study presents a systematic

pulses at D5 applied to a recorder configured to play C5 produced transient sound power at the recorder's C5 resonance frequency at the beginning and end of the speaker pulse. Next, motivated by an interest in the sound fields in a played recorder during a note transition, we examined the case of a steady speaker tone being applied to a recorder during a fingering change. It was found that an abrupt change in fingering from C5 to D5 In the presence of a steady C5 speaker tone produced transient sound power at D5. Our results provide a pedagogically useful illustration of the harmonic oscillator equations, insights into the complicated wave forms seen during note changes in a blown instrument, and a path to a possible diagnostic tool for studying tonehole open/close times. * Work supported by U.S. National Science Foundation grant PHY-2306035

Time	Author	Title
10:50	N. Giordano	An Approach to Describing Sound Production at the Mouth of a Wind Instrument

The problem of how an air jet interacts with the labium of a flue instrument to produce a musical tone has been studied for more than a century, using a wide variety of experiments, theories, models and simulation methods. In general terms, it is believed that vorticity in the flow field generated near the labium plays a central role in sound production. Applying or testing first principles descriptions of how the vorticity creates and interacts with the acoustic field are very difficult due to the challenges involved in extracting the acoustic field from the total pressure and velocity fields obtained in either experiments or simulations. We describe how results for the pressure and fluid velocity, as derived from Navier-Stokes-based simulations, can be used to calculate the spatial locations and times during each acoustic cycle at which acoustic energy is produced or dissipated. Our analysis also yields results for the "flow" of acoustic energy along the flue pipe and does not rely on any assumptions about the role of vorticity in sound production.

11:10	J. Hyrkas and T. Smyth	Vibrato Suppression by Time-Varying Delay and Spectral Magnitude Demodulation

A time-varying delay line (TVDL) may be used to apply vibrato to a pitched sound by modulating the frequency of its harmonics with a low-frequency oscillator. Vibrato removal by the same method is less straightforward because it does not handle the amplitude modulation (AM) that also accompanies vibrato and, possibly, because the delay function derived by the estimated frequency contour of the fundamental frequency does not completely cancel the frequency modulation (FM) of upper harmonics. In this work, we examine the use of a TVDL with a recursive delay function for better attenuation of FM in both the fundamental and harmonics, coupled with either a filter bank or spectrogram smoothing to attenuate AM. This work includes analysis of in-house recordings of instrumental/vocal vibrato to reveal harmonics having frequency contours consistent with that of the fundamental (at integer multiples), suggesting a single delay function is sufficient for their attenuation and effective removal. Results are compared to sinusoidal modeling, the current standard for vibrato suppression. Vibrato suppression using a delay line and spectrogram smoothing is found to be comparable in quality to sinusoidal resynthesis and less prone to loss of fidelity due to analysis error or poor parameterization.

11:30	C.Kemp, S. Wang and G. Scavone	Comparison of alto saxophone reed fatigue between natural cane and synthetic reeds

A study of alto saxophone reeds was conducted to evaluate and compare both natural cane and synthetic reed fatigue using a mechanical blowing system. Sixteen different natural cane reeds and four different synthetic reeds were investigated, corresponding to manufacturer labeled reed strengths from 2.5 to 3, depending on

method for mitigating material variability in guitar soundboards by implementing precise geometric modifications. A parametric finite element model is combined with optimization techniques that minimize discrepancies in eigenfrequencies and mode shapes, ensuring consistent vibrational behavior. To manage the significant computational costs associated with repeated model evaluations, a parametric model order reduction strategy is adopted. To achieve this, we leverage an affine parametric representation of the system matrices, accomplished through a custom finite element implementation of shell and volume elements. This methodology enables a substantial reduction in computational time while maintaining accuracy withing 0.5% across the modes. The methodology is validated through a numerical case study, where the modal parameters of a cedar soundboard are closely replicated by an optimized spruce soundboard, reducing average frequency deviation from 10% to 1%, with closely aligned mode shapes. This framework offers a robust and reproducible strategy for reducing tonal variability in instrument production. It also opens new possibilities for using alternative and more sustainable materials while preserving the desired acoustic characteristics of traditional tonewoods.

Time	Author	Title
13:30	An.Klosak, A. Szelag and B.Ziarko	Polish National Television production studios: acoustic design and performance

This paper discusses the design, realization and acoustical performance of a newly opened large TV production studios in Polish National Television complex, in Warsaw, Poland. Several design aspects are discussed including location of smaller studios one over another, design of inner walls with both wide-band frequency absorption and impact resistance requirements as well as sound insulation of roof penetrations. Designs with computer models as well as the acoustical performance of the finished rooms are discussed. Construction details of the interior surfaces and of the technical installations and their influence on the acoustics are also discussed.

13:50	A.Kanapesky and T. Foulkes	Renovation of a Historic 1920's Theater to Create a First-Rate Cinema in the Balcony of a Live Music Performance Hall.

The United Theater in Westerly, RI opened as a vaudeville theater in 1926, evolved into a cinema which closed 60 years later. In the 2010's, the deteriorated space became an informal black box space for performance of music and drama. This met with some success, sparking efforts to revitalize and reprogram the building along with a neighboring historic building. The plans grew to include a new music school, a 76 seat cinema, a 24 seat micro cinema, plus the original 700 seat theater. The historic 700 seat theater would eventually be designed so that the balcony would function as first-rate, 100-seat cinema, on a day-to-day basis. This was accomplished without sacrificing the ability to use the entire theater, including balcony, for live performances by touring and local musicians alike. In this case study, we present some of the surprises we found exploring the existing conditions, challenges with historic restoration interests, and the process we used to understand the acoustic requirements of the dual-purpose programming. We will discuss our experience with this unique design of a convertible cinema on the balcony of a traditional theater.

the reed "model" (e.g., classical, jazz, etc.). Each cane reed was "played" semi-continuously for 4 hours, while synthetic reeds were played for 16 hours (with one extended test to 48 hours). Measurements of reed stiffness, blowing pressure, lip force, reed vibration velocity, acoustic pressure in the mouthpiece and sound measured near the saxophone bell were taken at times of 0.25 (cane reeds only), 0.5, 1, 2, 4, 8, 16, 24 and 48 hours. The measurements involved stopping the system, making measurements with the reed remaining in place, and then restarting the system. Results showed clear trends in decreasing reed stiffness with playing duration. The stiffness of natural cane reeds decreased faster than for synthetic reeds, by a factor of 2–3 over a 4-hour playing epoch. Trends in sound quality were more difficult to quantify, as changes in mechanical player parameters necessary to keep the reeds oscillating as they fatigued over longer durations led to variations in reed vibrational regimes and control conditions. Challenges and solutions in developing a mechanical blowing system that could operate for extended durations are discussed.

Time	Author	Title
11:50	R. Mores, R. Bader and S. Linke	The Khaen of the Hmong in Northern Laos

The khaen free-reed wind instrument of the Hmong ethnic group in Northern Laos differs from khaens of other ethnic groups in Laos but also from other Asian mouth organs, like the Chinese hulusi or hulusheng, or the Japanese sheng, and so do the played styles and sound textures. The tone holes utilize two different principles of operation in the pipe. When opening the tone hole, the bordun pipe alternates its pitch, while all others become silent. The two bordun tones differ by a whole tone, and these represent the highest tones in the instrument. The temperament is mainly pure tone, and the third, the fourth, the two fifths and the two octaves below the bordun tones are tuned such that they almost synchronize with the respective bordun tone.

Lunch Break 12:10 - 13:10

13:10	S. Thompson	Results from a time-domain clarinet model: articulation and changing notes

A time-domain model of a clarinet-like system (previously reported) has been enhanced to allow the intentional manipulation of lip force and blowing pressure, and tounging articulation to start the note. Changes to the (simulated) played note are made by altering the configuration of open and closed finger holes. Investigations are underway to verify ability of this model to simulate realistic clarinet behavior to match published measurements. The model is implemented using the Simscape physical modeling software. The model uses several custom Simscape components to model acoustical systems. All of the custom components and model files are freely distributed by the author through the MathWorks File Exchange. Work is in process to create an executable version of this model that will be freely available for use without the need for a MathWorks software license.

13:30	G. Talaski, T. Smyth and G.Scavone	A Clarinetist's Exploration of Clarinet Tone through Advanced Technique, Instrument Configuration and Acoustic Impedance

In this work, sound pitch and spectral production/control is explored on the clarinet with reference to the measured impedance of different advanced (non standard) fingering and instrument configurations used in the author's own performance practice. Instrument configurations incude the mouthpiece alone, with barrel, with barrel and upper joint (upper demi-clarinet), with lower joint and bell (lower demi-clarinet) and the complete clarinet. Sound spectra of select pitches, produced by

Room Acoustics (ISRA) Sessions - Miller 114

Time	Author	Title
14:10	L. Shtrepi D. Cetani, S. Rovera, L. Teppati Lose', F. Chiabrando, M. Masoero and A.Astolfi	Audiovisual integration effect on the perception of the overall acoustic and architectural quality: the case of a conference room in a historical building

Given the complexity of historical spaces, a detailed geometric 3D survey is essential to build an accurate visual model that realistically integrates the proposed design solutions for their acoustic enhancement. This work aims to investigate the audiovisual integration on the perception of the overall acoustic and architectural quality. It investigates two different design alternatives proposed for speech intelligibility improvements in a conference room inside the historical building at the Egyptian Museum of Turin. The first part of the research focused on acquiring and processing data for a detailed 3D geometric and acoustic model. Spatial room impulse responses have been measured in the existing conditions and have been used for the model calibration in the geometrical acoustic-based software Ramsete. Simulations have been performed for two solutions installations that share similar objective acoustic parameters: S1) plaster-based seamless acoustic system, and S2) parametrically shaped felt baffles. An immersive 3D render has been developed using a LiDAR and a photogrammetric-based model, that incorporate the designed acoustic elements. Listening tests have been presented through 3rd order ambisonics scenes at the Audio Space Lab (ASL) at Politecnico di Torino. The results show a significant preference for the baffle-based solution, despite no substantial differences in auditory perception.

14:30	Tim Gulsrud	Acoustics Design for Contemporary Americana Folk/Bluegrass Music: a case study

Contemporary Americana music in the folk/bluegrass styles is performed in both indoor and outdoor settings with varying degrees of amplification. Many artists who do use amplification prefer to use minimalist microphone techniques that take advantage of the natural acoustics of the performance space. When reverberation times in the venue are excessive, however, providing sound reinforcement with adequate loudness, clarity, and gain before feedback can be a serious challenge for audio engineers. This paper discusses some recent experience with optimizing acoustics for Americana folk/bluegrass music in the Wildflower Pavilion at Planet Bluegrass in Lyons, Colorado. The venue is a wood barn-like structure partially open to the outside to take advantage of its setting along the banks of the St. Vrain River. Musicians and audio engineers reported difficulties with hearing conditions on stage and sound quality in the house. An initial acoustics evaluation revealed that reverberation times were excessive, and new sound-absorbing and sound-diffusing finishes were recommended for the venue. Room acoustics measurements made through the house PA system before and after installation of the new finishes will be discussed, including a unique spatial acoustics measurement approach utilizing wave field analysis.

15:00	Closing Remarks - Miller 114

the author using advanced techniques and the above configurations (each of which having a host of non-standard fingerings), are analyzed next to the magnitude of the corresponding measured impedance. The alignment of peaks in spectral and impedance magnitudes are studied and used to explain the tone's timbral (spectral) varieties and possible difficulties in its steady sound production and/or tuning. This study is a means of informing a musical performance practice, informing the performer of sound production possibilities and limitations. As this study involved producing a significant increase in available impedance measurements for the clarinet, it is hoped that it will also serve to inform future research and development in clarinet synthesis (while further enhancing the performer's tools for live performance). This unique study allows acoustic effects/principles to be understood and heard from the perspective of an accomplished performer---considering the player, the instrument and their coupling.

Time	Author	Title
13:50	M. Kob, J. Thilakan and T. Grothe	Simulation and interpretation of wind instrument directivity using a point source approach

"The radiation of sound from musical instruments can vary from simple, omnidirectional to highly complex characteristics. Since the directivity studies on orchestral instruments by Jürgen Meyer, recent measurement methods with high spectral, temporal and spatial resolution produced a more comprehensive understanding of instruments' directivities but also deeper insight into the dependence of the accuracy of measurement and evaluation methods on the directivity estimation. However, increasing accuracy contrasts with the ease of the description and interpretation of the directivity using a low number of parameters. We present a modelling approach using point sources for each area of the instrument that contributes to its radiation. The sources radiate with volume velocities either chosen from theory or from a waveguide model based on the instruments' geometries. A cardioid correction is implemented for areas with larger Helmholtz numbers. The method is applied to three configurations of a flue organ pipe and a bassoon, and compared to high-resolution directivity measurements for selected frequencies. A Matlab tool is presented that can be used in education or research. The simulation approach could be useful for a better understanding of the functions of the instruments and their application in simulation environments."

14:10	C. Darabundit, V. Chatziioannou and G. Scavone	Mapping woodwind playability using measurement based physical models

Playability diagrams can provide insight into the behavior of a musical instrument under different playing conditions by visualizing the interaction between various musician-controlled playing parameters and their effects on the instrument's sound. These diagrams are created using measurements of real instruments or physics-based simulations. Recently, there has been an interest in producing playability diagrams of single-reed woodwind instruments using physical models. Our study furthers this exploration by using measured woodwind impedances and mouthpiece geometries to synthesize realistic instrument tones. By analyzing these tones, we aim to characterize the effects of different mouthpieces and instrument responses on playability and tone quality.

14:30	Whitney Coyle, Max Griffin and Makayle Kellison	Computational Detection of Articulation Transients in Clarinet Performance

Accurate measurement of note-to-note transitions is essential for analyzing articulation in clarinet performance. Traditional methods rely on either subjective

Notes

amplitude thresholds—such as the time between 5% and 95% RMS levels—or direct measurement of tongue-reed contact time using reed-mounted sensors. These approaches are limited by their dependence on user-defined parameters or invasive hardware. This study proposes a computational alternative: Delta T, a curvature-based metric defined as the time interval between surrounding minima in the second derivative of the mouthpiece pressure envelope. Using data from a sensor-equipped mouthpiece (SEM), we compare Delta T to both threshold-based timing (Tt) and tongue contact duration (Tc) across portato and staccato articulations. Our findings show that Delta T closely tracks both Tt and Tc in structured articulations, with minimal absolute difference and robust repeatability. These results support the use of Delta T as a non-invasive, objective, and reliable estimate of transition duration, enabling broader application in performance analysis, pedagogy, and real-time feedback systems.

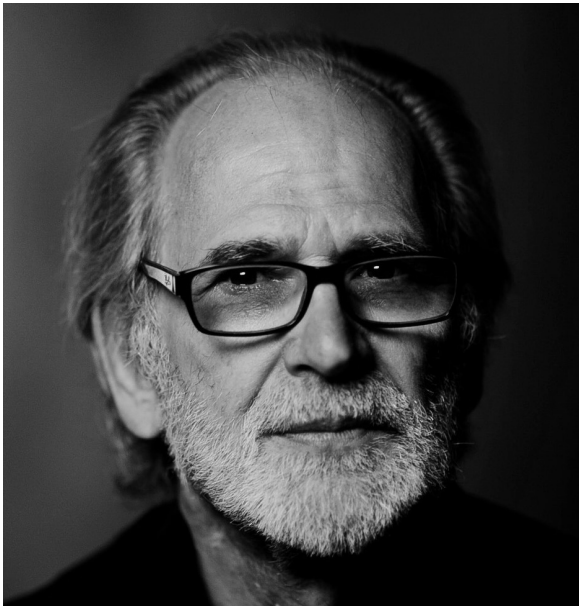
15:00	Closing Remarks - Miller 114

Pavel Zahorik

Using psychoacoustic approaches to understand and predict perception of sound in rooms

Room acoustics critically shape our perceptual listening experience. They can make or break musical performances or be the difference between successful and unsuccessful speech communication. Scientific study of room acoustics has identified a variety of metrics that describe various physical acoustic properties of rooms (e.g., ISO 3382), and many of these metrics have subsequently been shown to be associated with specific perceptual aspects of sound in rooms. Because the associations are complex and multidimensional, it is often difficult to conclusively link physical room-acoustic metrics to perception, however. Over the past half century, the field of psychoacoustics has developed and validated computational modeling techniques that describe and predict the function of the human auditory system at various mechanistic levels. The purpose of this talk is to suggest and to show that incorporating psychoacoustic modeling techniques into the associative process between physical room acoustics and perception can be hugely beneficial. A primary advantage of this approach is that it inserts a level of automaticity into the associative process that allows for many more associations to be explored and predicted. Additional advantages include the ability to flexibly examine effects of different source materials, dynamics, and listener characteristics, including the effects of hearing impairment and listening with hearing devices.

Pavel Zahorik is a Professor in the School of Communication Sciences and Disorders at the University of Central Florida, where he is proud to be part of a dynamic and growing research team at the Communication Technologies Research Center. From 2003 to 2023, Pavel was a faculty member at the University of Louisville, where he held the Heuser Hearing Research Professorship since 2013. He has studied human perception and performance in sound-reflective environments for over 25 years and has been funded by the NIH, the Air Force Office of Scientific Research, and Sonova. He is a Fellow of the Acoustical Society of America (ASA) and is currently the Associate Editor for the Journal of the Acoustical Society of America – Psychological Acoustics Technical Area.



Trimpin

Engaging the room: Contraptions for Art and Sound

Trimpin is an internationally renowned artist and composer whose work integrates sculpture and sound across a variety of media including fixed installation, live music, theater, and dance performance. His ingenious sound art installations, which typically feature the acoustics of everyday objects with computer controlled actuators, have been commissioned throughout Europe and North America. Based in the Pacific Northwest, Trimpin is a regular artist in residence at the California Institute of the Arts, Stanford's CCRMA, and the MIT Center for Arts, Science, and Technology. He has collaborated with the playwright Samuel Becket, composer Conlan Nancarrow, and the Kronos Quartet, among others. He is a MacArthur Fellow and the subject of the 2011 Peter Esmonde documentary "Trimpin: the Sound of Invention".

Margriet Lautenbach

Room acoustics for classical halls: Practice, theory and music

Room acoustics as a science is relatively young. When the Concertgebouw in Amsterdam was designed in the 1880's, it wasn't possible to hire an acoustician to join the design team. Knowledge about room acoustics started only a decade or so later, with the investigations of the well known W.C. Sabine.

More than a century later it still feels that there is a lot to gain in the knowledge of room acoustics, especially for non-amplified music. In a hall for classical music, room acoustics is the main tool to transfer the music form the musicians on stage to the listeners in the hall in the most beautiful way possible.

In this talk I want to reflect on different room acoustic aspects from the consultant (practical) point of view, being the bridge between musical goals and acoustical science. The design of a hall starts and ends with music. A client will emphasize his or her musical goals like sound quality, playing conditions on stage, surround sound and intimacy, presence and definition. In the design process the acoustic consultant has to mould these goals into numbers, parameters and models in order to transfer the musical goals into architectural requirements and solutions. With reference to the design process of recently finished concert halls like Kulturpalast Dresden and Casals Forum Kronberg we will compare these musical goals with the available acoustical knowledge from standards and literature, recent investigations and possible ways to think about acoustics and reflection patterns where proven knowledge still fails us.

Margriet Lautenbach is a room acoustic consultant for over 20 years. She has been investigating the use of calculation and scale models research as design tools. She was lead acoustician, or collaborated, in the design for the renovation of several theatres, opera halls and concert halls, such as Royal Theatre Carré Amsterdam, De Doelen concert hall Rotterdam, the Concertgebouw Amsterdam, the state opera in Berlin and the opera in Cologne. The experience from renovation projects with their possibility to compare models with the existing halls through measurements was of great advantage for the design of new concert halls as The Kulturpalast in Dresden, Parkzaal Musis in Arnhem and Casals Forum in Kronberg (Frankfurt).

Margriet has worked at Peutz from 2003 until 2022. In 2024 Margriet founded her own company Acoustic Reflections, as part of a not for profit organization with the mission: "More trees, more silence and more music". Since 2019 Margriet is president of the Netherlands Acoustical Society and she teaches room acoustics at the Higher Course in Acoustics in Antwerp.

Anders Friberg

Swing timing in a jazz ensemble: measurements and models

The groove or the swing is an important and unique aspect of classic jazz, debated and discussed among musicians and listeners based on the aural perception of the music. In the last decades there has been several objective timing studies showing that timing in a jazz ensemble follows an intricate pattern. The most well-known timing characteristic is the long-short pattern of consecutive eighth notes. However, it is varying for the instruments and is dependent on tempo. The instruments are also interlocked in a specific way, implying lack of synchronization on the downbeat. The soloist is typically playing behind the other instruments on the downbeat leading to what has been referred to as a “laid-back” playing. Intriguingly, some details of this interaction are often not even known to the jazz musicians themselves.

In this presentation I will give an overview of jazz timing measurements as well as presenting our recent models for controlling the timing in a jazz ensemble. The latter will be centered around four ensemble recordings of swing selected for their specific style led by Buddy Rich, Wynton Marsalis, Keith Jarrett and Peter Erskine. The role of these timing patterns as a tool for expression and possible usage of the models will be discussed.

These intricate timing patterns has presumably been developed in small jazz clubs in which the musicians are placed near each other and near the audience. Notably, jazz is still primarily performed in this way, thus enabling the utilization of micro-timing variations that can be perceived both by the musicians and the audience. Certainly, jazz concerts can also be appreciated in larger rooms with more reverberation but how this is perceived by the audience appears to be an open question.

Anders Friberg is Professor in music communication at KTH Royal Institute of Technology, Stockholm. He has been working mainly with the synthesis and analysis of music performance, leading to the rule system Director Musices translating the score to a performance. He has also been focusing on automatic extraction of music parameters from audio and its relation to emotional/motional expression. Recent works includes models for jazz timing, a model for dynamics in piano playing, and a model of immanent accents in music. On his free time, he is playing piano in several jazz groups.

Stefan Weinzierl

Generative design as a solution for room acoustic problems

In generative acoustic design, numerical methods are not used to test the acoustic behavior of a given scene, but rather to identify an acoustic scene that optimally produces a sound field with certain predefined characteristics. While this is a well-established practice in other disciplines such as architecture or structural design, it is only recently that several approaches have been explored in the field of room acoustics. These include (a) combining a generator with forward simulation and iterative optimization, (b) implementing differentiable geometric acoustic simulation and backpropagation from a target design, and (c) optimizing a wave-theoretic numerical solution to infer the geometry and boundary conditions that optimally generate a desired sound field. The talk will give examples of each of these approaches, discuss the challenges, and highlight the future potential for room acoustic design.

Stefan Weinzierl is head of the Audio Communication Group at the Technische Universität Berlin. His research focuses on audio technology, virtual acoustic reality, room acoustics, and musical acoustics. He coordinates a master's program in Audio Communication and Technology at TU Berlin. With a diploma in physics and sound engineering, he received his Ph.D. in musical acoustics from TU Berlin. He has coordinated international research consortia in the fields of virtual acoustic reality (SEACEN) and music information retrieval (ABC_DJ), and is a valued consultant for room acoustics in the construction and renovation of theaters and concert halls.