ABSTRACTS OF
The International Symposium on Musical Acoustics 1998

Saturday Morning, 27 June 1998
1A. Opening Session

Thomas Rossing (Chair), Chapel Theater

8:35 AM Alpenhorn Fanfare

8:45 AM Announcements and Introductions

8:55 AM [Invited]

Introductory Remarks, Carleen M. Hutchins (Catgut Acoustical Society, 112 Essex Avenue, Montclair, NJ 07042, e-mail: catgutas@msn.com)

9:15 AM [Invited]

1A1. New perspectives on the brass instruments, R. Dean Ayers (Department of Physics and Astronomy, California State University, Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840, e-mail: rdayers@csulb.edu)

I. The air column as a doubly closed pipe: A new approach for studying the linear behavior of an air column divides it into three major segments and moves back and forth freely between the time and frequency domains. Brass instruments are seen to mimic doubly closed pipes in both domains. Two useful results are a convenient effective length for gauging the harmonicity of the impedance peaks and a faster algorithm for modeling the interaction with the lip reed.

II. Rayleigh waves on the performer's upper lip: Careful observations of magnified, stroboscopic images through a mouthpiece with a flat window have revealed that different portions of the upper lip are significantly out of phase with each other. A heavily damped, strongly driven, surface wave propagates in the direction of the net air flow and provides valving action on that flow. A model for the interaction of this wave with the flow will be complicated and may not show much improvement over the two-dimensional model of Adachi and Sato (JASA **99**, 1200-1209, 1996). Of potentially greater value is a more accurate mental image for performers, especially those involved in the early trial-and-error stages of learning.

9:45 AM [Invited]

1A2. Innovation in violin making, Joseph Curtin (Joseph Curtin Studios, 205 N. Main St., Ann Arbor, MI, 48104, e-mail: joseph@jcstudios.com)

The violin is a cultural icon as well as a working tool, and departures from its traditional form have been variously regarded as impossible (it would no longer be a violin), unnecessary (the violin is already perfect), and unacceptable (players would not play it). Is it possible to "improve" on the classical violin, viola, or cello? Where would one begin?

A number of highly qualified violin makers and researchers are investigating innovative approaches to violin making. While the craft has withstood many similar efforts in the past, makers today are able to learn from acousticians, engineers, and material scientists, as well as from the four centuries of violin making which precede them.

In order to be successful, an innovation - whether in the acoustical, aesthetic, or ergonomic domain - must offer the violinist some tangible advantage over a more traditional instrument. Equally important, it must satisfy the violin maker's sense of craftsmanship and professionalism. Innovation in violin making is fueled (and moderated) by the demands of the player and by the maker's evolving sense of aural and visual beauty.

10:15-10:45 AM, Break

Saturday Morning, 27 June 1998
1B. Violin Family, I

Roger Hanson (Chair), Chapel Theater

10:45 AM

1B1. The principal vibrating modes of a violin which produce sound, Oliver E. Rodgers (University of Delaware, Mechanical Engineering, Newark, DE, 19716)

Very few of the modes of vibration of a violin produce sound. An experimental study has been made of a number of violins using the CONQT analysis of glissando tones played on all strings to identify the modes which do produce sound. A nodal line seeker technique is then used consisting of a squealer to excite the sound producing modes and a tiny microphone to seek out the nodal lines on the plate surfaces. This can define roughly the vibrating configurations at these frequencies. It has been possible to identify ten or more modes which are the principal sound emitting sources on all the violins tested to date. Some of the modes are entirely vibrations of the air system, some of the mechanical system, and many are combinations. Each of these modes is described geometrically and physically. Some indication is given of the exciting force system of each and the extent to which the frequencies can be altered by adjustments to the violin structure. This paper is coupled to a companion paper on tuning.

11:05 AM

1B2. On the acoustical making of the violin, Martin Schleske (Workshop for Violin-Making, Seitzstr.4, D-80638 München, Germany)

In the tradition of violin making, making copies of fine old master instruments is a conventional experience. A violin whose outward form (arching, shape, varnish etc.) has a resemblance to the original one, is regarded as a "copy," even if the acoustical function usually is not taken into consideration. As it is the acoustical function and not the outward form that determines the sound of the instrument, the sound of those copies clearly differs from the original one.

The aim of a "tonal copy" is to adjust and reach certain acoustical parameters during the making of the instrument. These acoustical parameters must be taken into consideration when constructing the outline, the arching, the thickness graduation and the varnish treatment. This paper tries to indicate some clues for making "tonal copies" of violins and to demonstrate some methods concerning an analysis of construction in terms of modal and acoustic parameters of the violin.

11:25 AM

1B3. What violin makers can learn from modal analysis, George Bissinger (Physics Department, East Carolina University, Greenville, NC 27858, e-mail: bissingerg@mail.ecu.edu)

The concept of violin normal modes as the building blocks for the overall vibration of the violin for any excitation whatsoever provides a valuable conceptual basis for makers to help understand violin mechanics. Because these normal modes are an intrinsic property of the violin and are dependent only on the mass (density), stiffness, damping and shape of the materials used in its construction, they are of great relevance to makers. Modal analysis makes matters such as mode coupling explicit, allows categorizing of individual mode shapes and intercomparison of modes among individual violins, produces explicit mode damping values, generates a detailed modal database, etc. Modal analysis works equally well for substructures such as bridges or top plates, or even for independent (but integral to performance) devices such as the bow. Moreover, the allied radiation properties of each normal mode - the radiation directivity and efficiency - can be calculated directly for each mechanical mode. A simple model combining the dual aspects of vibration and radiation can give the maker insights into what is happening when the sound post is adjusted, or bridge trimmed, as well as some sense for how the harmonic structure of the violin tone is affected by such modifications.

11:45 AM

1B4. Bowing positions to play cello tones on the violin, Shigeru Yoshikawa (3-12-2-6304 Nagase, Yokosuka, 239 Japan)

A physical basis of producing "anomalous low frequencies" (ALF) or subharmonics on an open G string of the violin has already been explained [R.J. Hanson *et al.* J. Catgut Acoust. Soc. 2 (Ser. 2) 1-7 (1994)] from the measurements of the transverse wave which misses an ordinary slip opportunity a few times in the stick-slip motion [K. Guettler *ibid.*, 8-14 (1994)] from simulations incorporating the torsional wave which possibly triggers the stick-slip motion for ALF. In this report four types of fundamental trigger paths determining ALF periods are proposed based on the reflection/transmission of the transverse wave and the generation of the torsional wave at the bowing position. Also, other secondary trigger paths are derived from the fundamental ones. Moreover, the torsional trigger path starting with the torsional wave instead of the transverse wave may be one of candidates for ALF. These candidates for trigger paths are applied to estimate the bowing positions demonstrated by a violinist, Mari Kimura, who developed her revolutionary technique for playing cello (even contrabass) tones on the violin. Although a reliable experimental value of the velocity ratio of the transverse to the torsional wave was not available, an assumption of its value as about 0.21 gave a reasonable agreement between the calculated and the played bowing positions for the ALF tones from G3 (196.0 Hz) down to F2$\sharp$ (92.5 Hz).

Saturday Morning, 27 June 1998
1C. Pianos and Kettledrums

Uwe Hansen (Chair), Woodpecker Room

10:45 AM

1C1. Inharmonicity and quality of piano tones, Alexander Galembo (Dept. of Psychology, Queen's University, Kingston, ON, K7L 3N6, Canada, e-mail: galembo@pavlov.psyc.queensu.ca), Anders Askenfelt (Dept. of Speech, Music and Hearing, KTH, Box 70014, s-10044, Stockholm), and Lola L. Cuddy (Dept. of Psychology, Queen's University, Kingston, ON, K7L 3N6, Canada)

The spectrum of piano tones is inharmonic and contains components of several origins. The well-known inharmonicity of the transverse string modes caused by the bending stiffness of the string, stretches the partial frequencies and influences both pitch and timbre of the tone (Fletcher, 1962; Galembo and Cuddy, 1997). The longitudinal modes of the strings, which are not at all harmonically related to the transverse modes, add strongly inharmonic spectral components which also influence the quality of piano tones (Conklin, 1990). A noise, or "thump," component, due to the response of the piano structure to the acceleration of the hammer and key during the touch process, and the following shock excitation at string impact are especially prominent in the treble range and yet another important quality criterion of piano tones (Galembo and Ivanovskaya, 1977). This report surveys well and less well known works considering inharmonicity and thump components in piano tones and their relations to timbre and instrument quality.

11:05 AM

1C2. Optimum piano tuning: A matrix generalized inverse approach, J. Agulló, and X. Pagès (Department of Mechanical Engineering, Av. Diagonal, 647, 08028 Barcelona, Spain, e-mail: agullo@em.upc.es)

The tuning of the modern piano is a matter of compromise, particularly difficult because of the inharmonicity of the partials of its stiff strings. As the dissonance of two sounds is associated with the beats between their partials, a compromise concerning the beat frequency, intensity and duration needs to be reached. This concept has not been fully used to improve the tuning process. Lattard (JASA **94**, 46-53, 1993) developed a numerical simulation - solved by trial and error - of the traditional tuning process of the tempered octave.

This paper develops further the simulation of the tuning process in order to obtain algorithmically an optimum personalized tuning extended to the full piano. A set of overdetermined algebraic linear equations is formulated by equating the beat frequency of each relevant pair of partials to a target value. The unknowns are the frequencies - one per key - to be tuned. The optimum solution is obtained by means of the Moore-Penrose generalized inverse matrix, which allows the use of a metrical matrix in order to properly weight the relevancy of each equation. The choice of the target beat frequencies and the metrical matrix provides the method with enough freedom to accommodate personalized tuning. An example application is presented.

11:25 AM

1C3. Comparison of the effect of hammer striking irregularities and mistuning on the double decay of piano tones, René Caussé, Olivier Thomas, David Rousseau, and Eric Marandas, (I.R.C.A.M., 1 place Igor Stravinsky, F-75004, Paris, France, e-mail: causse@ircam.fr)

A characteristic of piano tones is their double decay (the initial sound followed by the "aftersound"), related to the existence of two polarizations. The goal of this study is to understand and to compare more quantitatively than previous work the influence of parameters which are under the control of the piano tuner: the mistuning and irregularities in striking action of the hammer. We simulated on a computer the vibration of a unison group of strings, which includes the dominant damping at the bridge as well as the vertical coupling between strings. Excitation irregularities were simulated by varying the initial displacements and velocities of the strings.

This study analyzes the ratio of the aftersound to the immediate sound, the slopes of the compound decay, and the amount of destructive interference. This interference can be seen where the slope of the decay curve changes. It is most pronounced at the bridge, where the strings are dynamically coupled.

This comparison leads to the conclusion that, if necessary, the piano tuner can, to a certain extent, correct for a poorly adjusted hammer by modifying the mistuning. But a properly adjusted hammer is essential for a constant, uniform aftersound level for all notes, which is necessary for a very good piano.

11:45 AM

1C4. Effects of wall reflections on the sound radiation from a kettledrum: A numerical study, U. Peter Svensson, Mayumi Nakano, Kimihiro Sakagami, Masayuki Morimoto (Environmental Acoustics Laboratory, Faculty of Engineering, Kobe University, Rokko, Nada, Kobe 657, Japan, e-mail: peter@ta.chalmers.se)

This paper studies the radiation efficiency of theoretical mode shapes of a kettledrum membrane taking reflecting surfaces into account. A numerical calculation method, the equivalent source method is used, in a form which is equivalent with a time-iterative boundary element method. The kettledrum is modelled as a rigid cylindrical body and a Green function technique is used to calculate the sound radiation from a single source point on the rigid kettledrum. With access to Green functions from all points on the membrane, all vibration patterns can be synthesized by superposition. This way the radiation efficiency of any mode shape can be calculated. Results indicate that the membrane radiates in free-field at low frequencies, and a baffle model applies only at high frequencies, well above the mode resonance frequencies. Furthermore, reflecting walls, within a half to one wavelength, can affect the radiation efficiency significantly. The floor plus a sidewall modified the radiation efficiency of the free kettledrum by approx. ± 2 dB for the first modes. Since radiation loading might be the dominating loss mechanism for the kettledrum membrane, the change in radiation efficiency affects both the level of the harmonics and their decay times.

Sunday Morning, 28 June 1998
2A. Violin Family, II

Jürgen Meyer (Chair), Chapel Theater

8:45 AM

2A1. On the tonal adjustment of the violin, Martin Schleske (Workshop for Violin-Making, Seitzstr.4, D-80638 München, Germany)

In the daily work of any workshop for violin making it is a well known experience that the adjustments of a violin have a huge influence on its tone. These adjustments, which do not change the construction of the instrument itself but affect its acoustical function, concern the bridge, sound post, fingerboard and tailpiece, as well as the strings and bass bar.

This paper tries to demonstrate some examples how certain weaknesses in the tonal or playing characteristics of the violin can be eliminated by a well-aimed adjustment. This is particularly relevant for the tonal color and the articulation of the instrument. Some results of parametric studies of those adjustments will be shown. Furthermore, it will be indicated how acoustical measurements can be a helpful complement to subjective hearing ability.

9:05 AM

2A2. A computer-based method for quality control of violins using impulse excitation, Lars Henrik Morset, and Ole Johan Løkberg (Applied Optics Group, Institute of Physics, Norwegian University of Science and Technology, 7035 Trondheim, Norway, e-mail: Lars.Morset@phys.ntnu.no and lokbero@phys.ntnu.no) and Asbjørn Krokstad (Group of Acoustics, Electrical Department, Norwegian University of Science and Technology, 7035 Trondheim, Norway, e-mail: krokstad@tele.ntnu.no)

We describe a computer based technique for quality control of assembled violins. The technique is fairly inexpensive in terms of instrumentation since it is based on a PC with a standard sound card. It is simple to use and yields fast and accurate results over the audible frequency range. The bridge of the violin is excited with an impulse hammer including a force transducer. The resulting vibration is detected at the violin body by an accelerometer placed close to the bridge. The data are processed using standard software. By using deconvolution, a complex transfer admittance is obtained of which the frequency response is displayed. The accuracy and reproducibility of the measurements are studied. We will also discuss different methods for post-processing of these data. A similar method, based on MLS (maximum length sequence) pseudo-random noise excitation, will be used for comparison with the impulse excitation method. Since this method is very immune to noise, it is also convenient for measuring sound pressure levels in addition to the vibration at the violin body. An important goal of this research is to develop a tool which violin makers can use in their work in comparing and constructing violins.

9:25 AM

2A3. A technical approach in 1998 to violin plate and corpus tuning and adjusting, Oliver E. Rodgers, (University of Delaware, Mechanical Engineering, Newark, DE, 19716)

This overview paper is based primarily on the author's work to date on computer analyses of violin components, experimental analyses of the vibrating modes of complete instruments as they are being played, experimental analyses of the effect of various adjustments and modifications on the vibrating modes, and controlled experiments working with violin makers. It should be read in conjunction with the paper by the present author which described some of the principal modes of vibration.

Topics covered are: free plate tuning - advantages and limitations, plate edge thickness patterns, corpus plate tuning, ribs, bass bar contours, sound post adjusting, fingerboard and neck modification, bridge tuning, asymmetry, and strings.

The meager available information on the desirable and undesirable frequency ranges for harmonics is summarized and some important vibrating modes that need special attention by the maker are identified. Areas for future technical work that seem to promise immediate help for violin makers are identified.

9:45 AM

2A4. The influence of the bandora on the acoustics and origin of the baroque baryton and its characteristic tonal feature of sympathetic resonance (later to become the defining feature of the classical baryton), Terence M. Pamplin, (London Guildhall University, Sir John Cass Department of Design and Technology, 41, Commercial Road, London, E1 1LA, United Kingdom, e-mail: pamplin@lgu.ac.uk)

Published studies of the baryton have typically given as the origin of the instruments sympathetic strings the influence of contact with Indian culture through the formation of the East India Company, ca 1600. A closer study of the original 17th century baroque baryton reveals it as a two-manual stringed instrument with the lower instrument tuned an octave lower than that used by Haydn and the Esterhazy composers. The main function of the lower manual wire strings was to provide a bass accompaniment to the upper bowed instrument and not to provide sympathetic resonance (which is a natural consequence of the coupled vibration of the undamped lower manual wire strings).

The baroque baryton in concept is a lyra viol played from French lute tablature for the upper instrument, combined with a bass wire strung instrument for the lower manual. John Playford [Musics Recreation to the Viol Lyra Way, London 1661] states that the origin of the lyra-viol was derived from the old English lute or bandora. This wire strung bass instrument of the cittern family also can be seen to be the precursor of the lower manual of the baryton.

The purpose of this paper is to demonstrate that the defining acoustic feature of the classical baryton -(sympathetic vibration) - is derived from the undamped coupled vibration of a hybrid lyra viol/ bandora based baroque baryton and not from external cultural influences.

10:05-10:35, Break

Sunday Morning, 28 June 1998
2B. Organ

Neville Fletcher (Chair), Chapel Theater

10:35 AM [Invited]

2B1. Organ-pipe jet behaviors in pre-saturated, post-saturated, and mode-transitional conditions, Shigeru Yoshikawa (3-12-2-6304 Nagase, Yokosuka, 239 Japan)

A smoked organ-pipe jet is visualized with a digital high-speed video camera. The results demonstrated the behaviors of the steady-state oscillations, which are categorized by the degree of the saturation. The so-called amplitude saturation may be governed by a full switching deflection of the jet across the edge, which yields a rectangular-like waveform of the acoustic pressure. However, such a rectangular-like waveform is not a final “frozen” waveform. The pressure waveform in an organ pipe keeps changing even after the amplitude saturation. The second harmonic appreciably affects the jet deflection in the post-saturated condition. As the result, the jet deflection is a superposition of a primary wave generated by the fundamental and a secondary wave generated by the second harmonic. The secondary wave keeps growing as the blowing pressure increases more. When such a secondary jet wave becomes dominant, a transition from the first to the second mode occurs. The process of this mode transition will be traced with flow visualization and the associated change of pressure waveform. Also, the spatial growth rate of an organ pipe jet in the pre- and post-saturated conditions is estimated from the envelope of instantaneous wave shapes concerning the primary wave. A brief discussion is devoted to an unsolved problem of whether an organ pipe jet shares wave characteristics with an acoustically-perturbed free jet or not.

11:05 AM

2B2. Acoustics of the khaen, James P. Cottingham and Casey A. Fetzer (Physics Department, Coe College, Cedar Rapids, IA 52402, e-mail: jcotting@coe.edu)

The khaen is a free-reed mouth organ constructed with metal reeds mounted in bamboo pipe walls inside a carved wooden windchest. For a tube of effective length L, the reed is typically mounted at a position $L/4$ from the end and sounds for both directions of air flow (blowing and drawing). The reed vibration is strongly coupled to the pipe resonance, and the reed normally sounds near the resonant frequency of the pipe and sounds only if a small finger hole is closed. For some examples of khaen made in northeastern Thailand, variations in frequency and sound spectrum with blowing pressure have been studied, and some aspects of reed design and construction have been investigated. The relationship between frequency of reed vibration and pipe length has been studied to determine the range of pipe length over which the reed can be made to sound, as well as the amount of frequency shift associated with changes in resonance frequency of the pipe. In the case of the khaen, unlike most other free-reed instruments, the sounding frequency is determined primarily by adjustments in the effective length of the resonating tube, with only a rough dependence on reed dimensions.

11:25 AM

2B3. Sound radiation of open labial organ pipes; the effect of the size of the openings on the formant structure, A. Miklós and J. Angster (Fraunhofer-Institut für Bauphysik, Nobelstr.12, D-70569 Stuttgart, Germany, e-mail: angster@ibp.fhg.de)

Stationary sound spectra have been measured near to the mouth and to the open end of labial organ pipes having different tuning devices. Three diapason pipes have been built from the same metal sheet with identical dimensions. The open end of the first pipe was cut clear, while the second and third pipes were equipped with a tuning roll and a tuning slot, respectively. The values of the mouth height and width were the same at all pipes. The stationary spectra measured at the two openings of each pipe show different formant structures. The spectrum at the mouth has a formant minimum around the fifth or sixth partial for the pipes with the clear cut and the tuning roll, while the spectra at the open ends of these pipes have gradually decreasing partials. The third pipe with a tuning slot shows a different behavior; the spectrum measured near the tuning slot has a formant minimum at the eighth partial, while the spectrum at the mouth has a gradually falling envelope. Theoretical explanation is given to the behavior of the pipes.

11:45 AM

2B4. Preliminary study of an organ builder's perception of a flue pipe sound, Vincent Rioux, e-mail: vr@ta.chalmers.se) Munetaka Yokota (Gothenburg Organ Art Center (GOArt) Organ Research Workshop, varbergsgatan 2, se-41265, Gothenburg, Sweden) Daniel Västfjäll, Matthias Scholz, and Mendel Kleiner (Department of Applied Acoustics, 8a Sven Hultinsgatan, Chalmers Institute of Technology, se-41296, Gothenburg, Sweden)

The work done by organ builder Munetaka Yokota, within the latest project of the Gothenburg Organ Art Center, to build a replica of a north German baroque organ, leads to a fundamental question : "Why do historical pipes sound different compared to pipes made according to modern techniques of organ building?" This paper presents a preliminary attempt to define a set of attributes (in English) suited for the description of flue organ pipe sound. Two historical pipes were chosen, and a set of geometrically reconstructed pipes were built. Recordings of the pipe sounds through the voicing process provide a set of sounds. Following the work of Mercer (JASA, 1951), Nolle (JASA, 1979) and Angster (ISMA, 1997), the voicing process is regarded as a crucial operation for the sound quality of flue pipes. Signal analysis of the recorded sounds was done, including short time Fourier transforms and perceptual filter representations. In order to check the validity of descriptors, a number of specialists in organ performance, music theory, history and building were asked to take part in a psychoacoustic test. A dedicated computer program was used for the test administration. Results were obtained from a grouping test, a difference test and a scaling test.

Sunday Afternoon, 28 June 1998
2P. Poster Session

Woodpecker Room

Authors of 'A' abstracts are at their poster from 1:45-3:00 PM, and authors of 'B' abstracts are at their posters from 3:00-4:15 PM. Authors assemble posters from 1:15-1:45.

2P1 [A]. Simple demonstration of Helmholtz motion of a bowed violin string, Paula M. Marston (730 S.W. Cityview, Pullman, WA, 99163) and Philip L. Marston (Physics Department, Washington State University, Pullman, WA, 99164-2814; e-mail: marston@wsu.edu)

Commonly available components were used to give a simple demonstration of Helmholtz motion. The local transverse string velocity of a violin was sensed with electromagnetic induction. Two small jewelry magnets were taped in series to the end of the finger board just below the "g" string. The ends of the metallic string were wired to the primary of a step-up transformer with the secondary connected to the microphone input of a Macintosh computer. The voltage was recorded and plotted as a function of time. Bowing the string above the magnet produced time records of the string velocity that were periodic and approximately rectangular, the form expected for Helmholtz motion. The evolution of the spectrum of the velocity after lifting the bow was also displayed.

2P2 [B]. Violin wood treatment, Kazuyuki Tomarikawa (Tama-shi ochiai 5-1-5-101, Tokyo, Japan, e-mail: gs8k-tmrk@ashahi-net.or.jp)

The acoustic properties of violin plates are analyzed before and after wood treatment. Spruce and maple test pieces with longitudinal and radial cuts are used. The test results are summarized by the change of weight, stiffness, and damping factor (or Q). The summary also provides the mode 2 - mode 5 frequency change of the violin top/back plate in white which will give violin makers some ideas during the graduating process. The treatments used in this report are the acrylic and urethane filler, low molecular weight phenolic resin (LPR) and tetraethylorthosilicate (TEOS).

2P3 [A]. Towards a general theory of violin eigenmode tuning, Duane Voskuil (Voskuil Violins, 1002N.8th St., Bismarck, ND 58501, e-mail: dvoskuil@tic.bisman.com)

Altering violin eigenmode intervals (like A1 to B1) affects an instrument's quality. A conceptual scheme is developed to explain why this may be so and to help predict successful placements of additional radiating and bending modes below 1000 Hz. To this end, a theory of the intrinsic relationships of pure notes (as forming a spiral on a sphere) is proposed analogous to the three-dimensional potential color sphere.

Good violins radiate and bend with strong and diverse, but harmonized, eigenmodes, one or more of which will reinforce every octave note. To do so, the violin's eigenmodes (and their complements, and their reinforcing interactions) must be placed somewhat evenly (within two or three semitones of each note played) around the octave; yet, placed so the modes don't interact dissidently, compromising strength, responsiveness and tone.

Greatest harmony is found where an eigenmode reinforces another in octave unison, or as its twelfth or fifth. Greatest diversity is found where a mode (or its complement, including some of its own upper partials or subharmonics) are at right angles to another, that is, a quarter octave apart (regardless of the interval's absolute frequency). Instruments successfully illustrating these principles and suggestions for further experimentation are discussed.

2P4 [B]. On the tuning of the cello: The effect of damping in the sound-board, Lamberto Tronchin and Alessandro Cocchi (DIENCA - CIARM University of Bologna, Viale Risorgimento, 2, I-40136 Bologna, Italy, e-mail: tronchin@ciarm.ing.unibo.it)

For the performer, as well as the violin maker, it is usual to tune the cello by moving some parts of the instrument, e.g. the bridge, to get the best sound from the sound chest of the cello. From a musical point of view, one tries to achieve a well-balanced sound from the instrument, in order to get the harmonic distribution of partials among all the notes as good as possible. From an mechano-acoustical point of view, one modifies the position of the bridge on the sound board, and changes the force from the string applied throughout the bridge. Owing to the non-homogeneity of the wood in the chest, such a modification produces a different mobility of the sound-board, and therefore, a modification of damping in the whole sound-chest. In this research the damping characteristics of the sound-chest of a cello have been measured, using a impedance head transducer, positioned on the bridge, while the damping factor has been calculated from the measurements of the structural reverberation time in almost 30 points, for two different tuning configurations. The results point out interesting differences on damping before and after tuning.

2P5 [A]. The influence of different machining processes on the acoustic properties of wooden resonant board, Samo Sali (Faculty of Mechanical Engineering, Askerceva 6, 1000 Ljubljana, Slovenia), e-mail: Samo.Sali@guest.arnes.si) and Janez Kopac (Faculty of Mechanical Engineering, Askerceva 6, 1000 Ljubljana, Slovenia, e-mail: janez.kopac@fs.uni-lj.si)

The influence of the machining of wooden resonant boards for guitars on the projected acoustic properties of this instrument has been studied. Square-shaped spruce boards (*Picea abies* Karst.) were selected to represent a typical portion of the guitar resonant board. Three different machining processes were used to prepare the test specimens: planing, sanding and milling. Vibration of the specimens was initiated by impacting them with a small wooden ball, and the oscillations, measured by an accelerometer mounted on the board, were processed by a frequency analyzer. The measured response, in terms of amplitude, damping and power spectrum, of the differently machined boards was analyzed statistically in order to distinguish between the different acoustic properties of the boards. For the given material, board shape, and board fixation it was found that the selected type of machining had a strong effect on the vibrational, and thus on the acoustical, properties of the tested boards.

2P6 [B]. Arthur H. Benade on sound radiation in the classical guitar, Ricardo R. Boullosa and Felipe Orduña-Bustamante (Centro de Instrumentos UNAM, Circuito Exterior CU, CP 04510, México DF, Mexico, e-mail: felipe@aleph.cinstrum.unam.mx)

Some 14 years ago the first author did some experimental work on issues related to sound radiation in the classical guitar. He submitted his work to the Journal of the Acoustical Society of America when Professor Arthur H. Benade was still editor of musical acoustics. Professor Benade was very much interested in the experiments and wrote (with contributions from an anonymous referee) a very extensive and detailed letter (6 pages, dated March 2, 1984) in which he pointed out some very deep implications of the experimental data. Unfortunately, the work required to fulfil Benade's suggestions could not be completed at that time. It was only recently that we have rediscovered this letter and decided to finish the work and bring to light these valuable, and apparently unpublished, comments of Arthur H. Benade.

2P7 [A]. The acoustics of the ancient Greek guitar, Maria Pavlidou (collaboration with the University of Athens, 4 Diomidous Komninou St., Ano Pefki, Attica 151-21, Greece, e-mail: mpavlid@atlas.uoa.gr) and Bernard E. Richardson (University of Wales, Cardiff, Dept. of Physics and Astronomy, University of Wales, Cardiff, PO Box 913, Cardiff CF2 3YB, U.K., e-mail: RichardsonBE@cardiff.ac.uk)

The ancient Greek guitar is an extinct stringed instrument. It originally came from Mesopotamia and appeared in Greece around the 8th century BC (Homer's time). Its basic construction consisted of a single box-resonator, two parallel arms fixed to the box, and a rod which joined the arms. The strings were tied around the rod and fixed to the box end. From written descriptions it is clear that although the Greeks kept its basic construction, they allowed for the arms to move in relation to the box. The Greek version of the Eastern instrument was a system under dynamic equilibrium (i.e. like the hunting bow); if the strings were cut the instrument would fall apart.

The present research aims to understand the acoustical principles of the Greek construction and mechanism. All our knowledge is extracted from written sources and drawings of the times. Although the project is in its initial stage, we plan to perform experiments in order to see what sort of waveform is produced when the string is suspended with the hunting-bow mechanism. Moreover, the study of the mechanism using a physical model would be very interesting, particularly if this proves to have non-linear aspects.

2P8 [B]. Energy transfer into a drumhead from steel and nylon ball impacts, James H. Irwin Jr. (ECET Department, Bradley University, Peoria, IL, 61625, e-mail: jhirwin@bradley.edu)

The relationships of the mass/diameter/velocity of steel and nylon balls to the relative energy transferred to a drumhead through free-fall impact was investigated. The velocity and energy values were determined from ball height measurements (relative to the drumhead surface and corrected for ball diameter), and the energy transferred to the drumhead was normalized to the input energy giving a relative energy transfer. In all cases the drum tension and position of impact were fixed. The initial experiments suggest the following conclusions: Identical masses transfer identical relative energy independent of diameter. Identical diameters, but different masses, do not transfer identical relative energy. Identical input energy, but different masses and diameters, do not transfer identical relative energy. Smaller masses, for identical diameter, velocity, or energy, transfer more relative energy than larger masses. These effects are linked to the local vs. global characteristics of the drumhead. Since most drumstick tips have diameters, and "masses," within the range tested, this information can guide a drummer in the choice of drumsticks.

2P9 [A]. Measurement of performance response differences using aluminum and brass marimba resonators, Barry J. Larkin (Department of Music, Iowa State University, Ames, IA, 50011) and Ronald A. Roberts (Aerospace Engineering and Engineering Mechanics, Iowa State University, Center for Non-Destructive Evaluation, Ames, IA. 50011)

Historically, percussionists have maintained that a perceptible difference exists in the responses of aluminum and brass marimba resonators. Brass resonators are thought to produce a fuller and richer sound, whereas aluminum resonators are considered to yield an inferior, thinner sound. Marimba performers will seek out and pay a premium price for instruments equipped with brass resonators, while lower cost aluminum resonators are found primarily on student model instruments.

Preliminary work was performed during 1997 using brass and aluminum resonators fabricated from thick-wall commercially-available tubing. Although subtle differences were observed in the data analysis, it was felt that the thick-wall tubing did satisfactorily represent actual resonators. Recently, resonators of both types have been supplied by a marimba manufacturer. This paper will present the analysis of resonator response characteristics collected on these resonators. Comparisons are made between ensembles of marimba bar strokes recorded using both the brass and aluminum resonators, under anechoic and concert hall conditions. Data analysis will be summarized, and results will be presented showing the nature of measured differences in both overtone structure and response evolution. Quantitative observations will be correlated with one musicians perception (BL).

2P10 [B]. Active control applied on musical instruments: First results, Charles Besnainou (Laboratoire d'Acoustique Musicale, CNRS-Ministère de la Culture-Université, Paris 6, 4, place Jussieu, 75252 Paris cedex 5, France, e-mail: chbesnai@ccr.jussieu.fr)

Recent research on composite materials applied to musical instruments has been extended to the active materials concept. Indeed, with composite materials the mastership of mechanical properties naturally opens the way to the dynamic control of some mechanical parameters of the material, such as damping or stiffness. By manipulating, in real time, mechanical properties of the materials constituting the instruments, a new concept of the sound material produced by the musical instrument itself is drawn. In addition, this concept allows the extension of the expressive field of traditional instruments by taking into account the apprenticeship and the musician's gesture. One can assert that the paradigm of musical instruments is then widened, by unifying traditional instruments and computer sound synthesis.

This concept relies on a feedback loop. A set of sensors captures the structure's movements, and an electronic active control system computes a signal for a set of actuators locally injecting forces on the structure so that the behavior and the radiation is then modified.

We shall present different strategies to manipulate mechanical parameters, the Helmholtz resonance, and the coupling admittance between strings and bridge.

Sunday Evening, 28 June 1998
2E. Guitars

Antoine Chaigne (Chair), Chapel Theater

6:30 PM [Invited]

2E1. The classical guitar: Tone by design, Bernard E. Richardson (Department of Physics and Astronomy, University of Wales Cardiff, PO Box 913, Cardiff, CF2 3YB, UK, e-mail: RichardsonBE@Cardiff.ac.uk)

One of the most fascinating aspects of the acoustics of stringed musical instruments is understanding how, and to what extent, the maker can control the playing and tone qualities of the completed instrument by active choice of design and selection of materials during construction. This review paper draws together the theories and experiences of acousticians and makers and presents simple physical models to demonstrate the important acoustical parameters of the classical guitar and the traditional and more experimental means by which makers control these parameters.

7:00 PM

2E2. The relation of musical acoustics research to guitar design and building, Gila Eban (22 Licata Terrace, Cos Cob, Connecticut, 06807, e-mail: geguitars@aol.com)

Guitar acoustics research by Caldersmith, Dickens, Richardson, Rossing, and others has been producing results and findings which are increasingly meaningful and relevant to guitar makers. How do guitar makers apply, and benefit from, this new knowledge? How can luthiers do so without frequent access to acoustics laboratories and without the ability to test every stage and aspect of new designs, new materials, and new construction-methods? How can a guitar maker bridge between the observations of musical acousticians and the evaluations, comments, critiques, and demands from players?

An approach I've used successfully in my guitar building, employing a mix of "assimilated" acoustics research-findings, educated guesswork, and "artistic" decisions wherever more than one structure is possible, will be presented.

7:20 PM

2E3. Another window on tone? Re-scaling frequency response functions, Evan B. Davis (8556 Burke Ave. N. Seattle WA. 98103, e-mail: evan.b.davis@boeing.com)

The best-sounding musical instrument is the one designed, built, or otherwise selected by a person who believes they have designed, built, or selected the best-sounding musical instrument. An ability to correlate the perceived tone quality of the finished instrument with a predicted frequency response characteristic would have important artistic and economic benefits. The problem of correlating the frequency response characteristics of a musical instrument with the tone quality of an instrument is greatly complicated by the involvement of the human judges. A first step in correlating sound quality with the frequency response characteristics is to study the frequency responses and then identify parameters which may correlate with perceived sound quality. This parameter identification task is examined by re-scaling the predicted frequency response characteristics using human response "filter".

Guitar frequency responses are reduced to a simple mathematical representation and then these representations are plotted against various frequency and amplitude scales to gain a better understanding of which physical characteristics of an instrument are potential keys to the perceived sound quality of that instrument. The re-scaling process in part confirms previous efforts to correlate frequency response functions and instrument sound quality and raises new questions.

7:40 PM

2E4. Using TV holography with phase modulation to determine the deflection phase in a baritone guitar, Fredrik Engström[1] and Thomas D. Rossing (Physics Department, Northern Illinois University, DeKalb, IL 60115, e-mail: rossing@physics.niu.edu)

Time-average holographic interferometry and TV holography are both capable of mapping eigenmodes in vibrating structures with fine spatial resolution when the damping is small or when the modes are well separated in frequency. However, at a frequency where two or more eigenmodes contribute to the operating deflecting shape, a complicated phase pattern is likely to appear that cannot be resolved. By adding sinusoidal phase modulation to the reference beam with a vibrating mirror, however, it is possible to calculate the relative phase of each point with respect to some reference point on the structure.

We have used this method to map the phase of a baritone guitar top plate at several frequencies where two or more eigenmodes contribute to the response. These maps confirm that phases other than 0 and 180 degrees occur under these conditions. The effectiveness of various techniques for noise reduction, such as frame averaging, speckle averaging, low modulation pixel reduction, convolution, and median filtering, are discussed.

[1] Permanent address: LuleaUniversity of Technology, Division of Experimental Mechanics, S-971, 87 Lulea, Sweden.

Monday Morning, 29 June 1998
3A. Computers and Music

Xavier Rodet (Chair), Chapel Theater

8:45 AM [Invited]

3A1. Vicarious synthesizers: Listening for timbre, Chris Chafe (CCRMA, Stanford University, Stanford, CA, 94305, e-mail: cc@ccrma.stanford,edu)

The timbre of a synthesized musical sound is usually determined by a group of control parameters, as for example in bowed string models (bow force-velocity-position), sung vowels (complex vocal tract shape and glottal source) and frequency modulation (modulation index and oscillator tuning ratios). In this work, which concentrates on the bowed string physical model, possible qualities are depicted on a two-dimensional map whose axes represent the principle timbral determinants of the synthesis method. Expressive control of timbre in real-time is achieved by navigating the space with a pointing device which includes force-feedback, allowing the musician to feel as well as hear timbral change. Timbral features are displayed to the kinesthetic sense along with the sound's direct (real-time) vibration. At standard MIDI resolution, *circa* 16,000 tones (the number of grid points in a 127×127 plane) are synthesized and features of their timbral differences displayed haptically. Locations of particular bowed timbres and nearby qualities in their environs are easily learned as well as musically important trajectories.

Timbral nuances in performance have, in the past, been difficult to represent in a meaningful way for synthesis. Using the control matrix described, an analyzer matches timbral expression from digitized performances with trajectories in the plane. After "listening," trajectories can be physically played back on the haptic pointing device while time-varying envelopes control their synthesis in a simulated performance. The synthesist literally has a hand on the recorded performance, vicariously learning how to master timbral nuance on the bowed string synthesizer.

9:15 AM

3A2. Use of truncated infinite impulse response (TIIR) filters in implementing efficient digital waveguide models of flared horns and piecewise-conical bores with unstable one-pole filter elements, Maarten van Walstijn (Faculty of Music, University of Edinburgh, 12 Nicholson Square, EH8 9DF, Edinburgh, Scotland) and Julius Smith (Center for Computer Research in Music and Acoustics, MS 8180, Music Department, Stanford University, Stanford, CA 94305-8180, e-mail:jos@ccrma.Stanford.edu).

In time-domain modeling of brass instruments, the bell is generally modeled as a lumped reflectance. A straightforward but computationally expensive discrete-time model of the bell is to use its impulse response as a convolution filter. In general, a comparable approximation can be obtained using an IIR filter of a much lower order, but prevalent phase-sensitive IIR filter-design methods perform poorly when applied to an empirically derived bell reflectance. This is due in part to a long, slowly rising, quasi-exponential portion of the time-domain response, arising from the Bessel-like profile of the bell. A truncated growing exponential response can be efficiently and practically devised using previously published but not well known "Truncated infinite impulse response" (TIIR) digital filtering techniques. The main topic of this paper is to propose a new class of computational models for bell reflection transfer functions based in part on TIIR digital filter sections. However, as an additional application of TIIR methods, we discuss also the modeling of piecewise conical bores. In summary, the TIIR modeling approach gives improved efficiency, accuracy and stability over conventional computational models of flared and piecewise conical bores. It is therefore highly suitable for real-time simulations of woodwind and brass instruments.

9:35 AM

3A3. Analysis of cymbal vibrations and sound using nonlinear signal processing methods, C. Touzé and A. Chaigne (ENST, Signal Department, 46 rue Barrault, 75634, Paris cedex 13, France, e-mail: touze@sig.enst.fr, chaigne@sig.enst.fr), T. Rossing (Department of Physics, Northern Illinois University, DeKalb, IL 60115, USA.), and S. Schedin (Division of Experimental Mechanics, Lulea University of Technology, SE-97187, Lulea, Sweden.)

The vibratory motion and the acoustic field of cymbals are presented using general methods and tools of nonlinear dynamical systems. The analyzed signals were obtained from experiments conducted by T. Rossing, A. Chaigne and S. Schedin on a thin crash cymbal, excited by a shaker at its center. By controlling both the excitation frequency and the magnitude of the shaker, transitions from linear to chaotic motion can be observed.

In the initial quasi-linear part of the signals, an analysis based on short time Fourier transform clearly shows successive bifurcations and period doubling. Through comparisons with eigenmodes of the same cymbal measured by C. Wilbur and T. Rossing, it was concluded that the bifurcations occur more easily when the driving frequency is twice an eigenfrequency. In addition, no exact period doubling takes place if the driving frequency has no exact harmonic relationship with the eigenfrequency.

Nonlinear signal processing methods were used for analyzing the chaotic part of the signal. The first step was to reconstruct the dynamics of the system in the state space. Then, using methods of false nearest neighbors and correlation integral, the number of active degrees of freedom has been estimated. This approach should be of help for designing a time-domain model of cymbal sounds.

9:55 AM

3A4. A database of measured musical instrument body radiation impulse responses, and computer applications for exploring and utilizing the measured filter functions, Perry Cook (Computer Science Department, Princeton University, 35 Olden St., Princeton, NJ, 08544-2087, e-mail: prc@cs.princeton.edu) and Dan Trueman (Music Department, Princeton University, Woolworth Music Center, Princeton, NJ, 08544-1007)

Directional impulse responses were collected for a number of stringed instruments, including acoustic guitar, mandolin, violin, and Hardanger (Norwegian folk) fiddle. Impulse responses were recorded simultaneously from 12 microphones spaced uniformly at the vertices of an icosahedron, both with a human player holding the instrument, and with the instrument suspended without being held by the player. The instrument position was adjusted by small angles, and more impulse responses were recorded, resulting in a total of 72 impulse responses for each instrument. The impulse responses were factored into the main Helmholtz cavity resonance, the top plate wood resonances, and the remaining impulse response samples (residual).

A software workbench was created which allows virtual microphones to be placed around an instrument, and then allows signals to be processed through the resulting derived transfer functions. Signal sources for the application include MIDI controlled plucked and bowed string physical synthesis models, or any external sound source. Instrument body transfer characteristics can be parametrically edited, adjusting body size, main resonances, etc. Applications of the database and application software have included adding directional radiation models to physical models for virtual reality and composition, and adding more realistic body resonances to electronic stringed instruments for real-time performance.

10:15-10:45 AM, Break

Monday Morning, 29 June 1998
3B. Woodwinds

Douglas Keefe (Chair), Chapel Theater

10:45 AM [Invited]

3B1. Reed triggering in cylinders and cones, William J. Strong (Department of Physics and Astronomy, Brigham Young University, Provo, UT, 84602, e-mail: strongw@acoust.byu.edu)

Members of the clarinet family have approximately cylindrical bores. Members of the saxophone and double-reed families have approximately conical bores. A positive pressure pulse introduced at the reed (closed) end of a cylinder makes two round trips from the reed to the open end of the bore and back before triggering the reed to open. A positive pressure pulse introduced at the reed end of a cone makes only one round trip before triggering the reed to open. (Because of this behavior conical bore instruments are sometimes described in terms of a doubly closed cylinder.) Computer simulations are being run for models in which a mouthpiece with a single reed is attached to either a cylinder or a cone. The impulse response at the reed is obtained from an inverse Fourier transform of the input impedance of the mouthpiece plus bore. The impulse response is convolved with the reed aperture airflow to obtain the mouthpiece pressure driving the reed. Waveforms resulting from the simulations include blowing pressure, mouthpiece pressure, radiated pressure, reed displacement, and reed aperture airflow. Audio recordings of the radiated pressure will enable listeners to hear the outputs of the quasi-instruments.

11:15 AM

3B2. Recorder windway profile: Influences on sound production, C. Segoufin, B. Fabre, and M.P. Verge (LAM Case Courrier 161, Université Paris 6, 4 place Jussieu, F-75252 Paris Cedex 05, France, e-mail : segoufin@ccr.jussieu.fr) and A. Hirschberg and A.P.J. Wijnands (Eindhoven University of Technology, W&S 054, Postbus 513, NL-5600 MB Eindhoven, The Netherlands)

According to recorder makers, the longitudinal profile of the windway of the instrument is crucial to the playability as well as the sound quality of the instrument. During attack transients, the mass of air in the windway is responsible for inertia limiting the rise time of the jet velocity: a shorter windway yields a faster jet formation affecting the transient behavior of the pipe. During steady-state, the shear layers bounding the jet are affected by the windway profile. As shown at first by Rayleigh, reducing shear layer thickness increases the frequency for maximum jet instability. In a uniform section windway, calculations assuming a linear velocity profile show that the longer the windway is, the wider the shear layers are, up to the critical length for which a Poiseuille flow is reached. Recorder windways show a converging profile that tends to reduce the shear layer thickness.

We present experimental data related to theory for different windway profiles. When the windway is shortened, steady-state measurements show an increase in higher harmonic content, while transient behavior shows a steeper rise resulting in a dominance of higher oscillating modes of the resonator during transients.

11:35 AM

3B3. Experimental determination of the influences of bore perturbations on resonance frequencies of woodwind instruments, Cornelis J. Nederveen (Acacialaan 20, 2641 AC Pijnacker, The Netherlands, e-mail: cinederv@xs4all.nl) and Jean-Pierre Dalmont (Laboratoire d'Acoustique, Université du Maine, 72017 Le Mans Cedex, France)

Local perturbations (bends, side holes) in the bore of wind instruments induce local changes in compliance and inertance, causing changes in the resonance frequencies. The extra compliance is proportional to the extra volume and is found from accurately determining the dimensions. The extra inertance is related to a certain fraction of the extra volume, the magnitude of which is the subject of the present investigations. In the measurement assembly, the perturbation is situated in between two equally long straight cylinders closed at their ends. The resonance frequencies of the first six modes are measured. The dimensions of the perturbation are chosen small with respect to the wavelength, so the effect of the perturbation can be considered to be an extra compliance in even modes and an extra inertance in odd modes. Depending on the particular inertance term to be studied, the cylinder axes are coinciding (series-hole inertance), at right-angles (shunt-hole inertance) or parallel (180 degree bend). Precautions were taken to minimize disturbing influences of temperature unevenness, wall damping, and dimensional inaccuracies. Results appear consistent with theoretical expectations within measurement inaccuracies.

11:55 AM

3B4. Model of the vibroacoustic behavior of a clarinet, F. Gautier and N. Tahani (Institut d'Acoustique et de Mecanique, Laboratoire d'Acoustique de l'Université du Maine, UMR, CNRS 6613, Av. O. Messiaen, 72085 Le Mans Cedex 9, France, e-mail: gautier@laum.univ-lemans.fr)

The influence of the wall vibrations of a musical wind instrument on tone quality remains an open question. In order to quantify the effects of these vibrations, a model of the vibroacoustic behavior of a simplified instrument (clarinet-like instrument) is proposed. The reed, which is represented by mechanical and acoustical harmonic sources, excites a thin cylindrical shell, filled and surrounded with air. The sound radiation due to wall vibrations has two origins, which are decoupled in the model making use of artificial baffles. The first one corresponds to the direct radiation of the shell in the external fluid. The second one is created by the internal radiation of the shell, which is then radiated outside the tube through its open end. Three kinds of vibroacoustic couplings are involved in this situation: structure/internal fluid, structure/external fluid, and inter-modal acoustic coupling due to sound radiation at the open end of the duct. A modal formulation of the problem is proposed which takes into account these three couplings. The discrepancies between the sound power radiated from the open end when the tube vibrates and when it is rigid are exhibited and interpreted in term of acoustic resonance frequency shifts due to wall vibrations.

Monday Afternoon, 29 June 1998
3P. Poster Session

Woodpecker Room

Authors of 'A' abstracts are at their poster from 1:45-3:00 PM, and authors of 'B' abstracts are at their posters from 3:00-4:15 PM. Authors assemble posters from 1:15-1:45.

3P1 [A]. The influence of the mouthpiece on the timbre of cup-mouthpiece wind instruments, H. A. K. Wright and D. M. Campbell (University of Edinburgh, Dept. of Physics and Astronomy, King's Buildings, University of Edinburgh, Mayfield Road, Edinburgh, EH9 3JZ, UK, e-mail: Howard.Wright@ed.ac.uk)

The perceived timbre of cup-mouthpiece wind instruments may be altered significantly when different mouthpieces are used. Greater understanding of the way in which timbre is influenced by mouthpiece shape requires knowledge of (i) the features of the sound to which the ear-brain system is particularly

sensitive, and (ii) the way in which the mouthpiece design affects those features. This paper concentrates primarily on the first aspect.

Recordings of trumpet and cornetto notes were made using several different mouthpieces. The notes were processed to produce steady-state sounds of equal loudness which were used in psychoacoustical listening tests to evaluate the perceived differences in timbre associated with a change in mouthpiece.

As expected, changes in the amplitudes of the partials account for much of the perceptually significant information. However, the effect on perceived timbre of a change in partial amplitude depends, to some extent, on the change in the overall profile (shape) of the harmonic spectrum. In addition, non-harmonic, noise-like components of the sound play a perceptually significant role.

Further psychoacoustical tests were carried out using resynthesized and filtered versions of the recorded sounds to quantify the effects on perceived timbre of controlled changes to the harmonic and non-harmonic components of the sound.

3P2 [B]. Wind instrument body vibrations and their contribution to the sound field, P. L. Hoekje and Andrew Morrison (Physics Dept., Univ. of Northern Iowa, Cedar Falls, IA, 50614-0150, e-mail: hoekje@uni.edu).

The vibrations of the body of a wind instrument contribute a small but potentially perceptible component to the instrument's sound field. These vibrations have implications both for the tone color in the radiated field and for feedback to the sound production mechanism. Holographic interferometry shows that an isolated trombone bell has several resonances below 1000 Hz, but the density of states is much greater at frequencies above 2000 Hz. Many of these modes exhibit symmetric vibration patterns that result in little or no radiation at low frequencies due to acoustic short-circuiting. However, radiation efficiency is improved at higher frequencies or when the vibration pattern is asymmetric. Mapping of the acoustic intensity in the near field reveals power flow in a closed vortex when two modes of the same symmetry are slightly detuned, and confirms outward power flow for asymmetric modes. Finite element analysis modeling is used to predict the effects of adding structural elements, such as the bell rim or braces, which can shift individual modes either up or down in frequency and can introduce asymmetries. [Supported by the Carver Foundation]

3P3 [A]. Sounding mechanism of a cylindrical air column blown with the clarinet mouthpiece, Taka'aki Tachibana and Ken'ichiro Man'syo (The Physics Laboratories, Kyushu Institute of Technology, Kawazu 680-4, Iizuka Fukuoka-ken 820, Japan), Ken'ichi Onodera (Institute of Applied Physics, University of Tsukuba, Tsukuba, Ibaraki-ken 305, Japan), Kin'ya Takahashi (The Physics Laboratories, Kyushu Institute of Technology, Kawazu 680-4, Iizuka Fukuoka-ken 820, Japan, e-mail: takahasi@poincare.mse.kyutech.ac.jp), and Tohru Idogawa (Saitama Institute of Technology, 1690 Husaiji Okabe-machi, Ohsato-gun Saitama-ken, 369-02, Japan)

We have investigated experimentally and numerically the sounding mechanism of a simplified clarinet which is a cylindrical pipe fitted with the clarinet mouthpiece. First, by using the artificial blowing technique, it has been found experimentally that the simple system has basically the same sounding mechanism as that of the clarinet; various periodic and quasi-periodic sounds are emitted, among which the lowest pitch is $\mathrm{C}_3^{\#}$, and the associated hysteretic transitions are observed between them, when the blowing pressure is increased and decreased under the same lip adjustment. Next, our system has been simulated by the model of Schumacher (Acustica **48**, 71-85, 1981), in which we have assumed a reflection function consisting of two inverted peaks; the dominant one is the reflection from the open pipe-end and the other originates from the bore shape of the mouthpiece. This numerical model well reproduces periodic and quasi-periodic air-column vibrations as well as the hysteretic transitions similar to those observed by experiments. Our results strongly suggest that the sound wave reflection inside the mouthpiece is one of the essentials of the woodwind sounding.

3P4 [B]. Acoustical comparison of bassoon crooks, D. B. Sharp, T. J. MacGillivray, J. M. Buick and D. M. Campbell (Department of Physics and Astronomy, The University of Edinburgh, The Kings Buildings, Mayfield Road, Edinburgh, EH9 3JZ, UK, e-mail: d.b.sharp@ed.ac.uk)

The effect of the crook on a bassoon's playing characteristics has long been considered as particularly significant. In this paper, pulse reflectometry is used to obtain internal bore profiles of a selection of bassoon crooks. The accuracy of the technique enables differences of the order of 0.1mm in the radii of the different crooks to be measured. In an attempt to understand how a crook's profile affects its acoustical properties, two impedance measurements were carried out on each crook. The first measurement was taken on the unattached crook, and the second was taken on the crook coupled to a reference bassoon. The results are presented and discussed. The importance of a crook's capillary hole is also investigated by carrying out impedance measurements on the same crook, both with and without its capillary hole blocked.

3P5 [A]. Towards a local theory of reverberation: Monitoring the behavior of energetic quantities during the sound decay within a

pipe, Domenico Stanzial (CIARM-CEMOTER, National Research Council of Italy, v. Canal Bianco, 28, I-44044 Cassana - Ferrara, Italy, e-mail: stanzial@cemoter.bo.cnr.it) and Davide Bonsi (CIARM Physics Department, University of Ferrara)

The consideration that the perception of the reverberation of sound must depend only on the local properties of the acoustic field seems to be an absolutely obvious one. Usually, however, the only behavior which is monitored during the sound decay is that of the sound pressure, and only recently a "couple" of sound pressure decays (the so called binaural impulse responses) are widely used for the auralization process. Thus the perceptual evidence that acoustical information is better simulated by means of binaural technology is nowadays a matter of fact. In spite of this, no serious attempt has been made to reformulate the theory of sound reverberation on a local basis. Questions concerning the decay of sound energy density and its relationship to the transient behavior of the sound energy flux are not yet well understood, and certainly this acoustical topic is a very hot one. As an experimental basis for the formulation of a local theory of sound reverberation, this paper reports some measurements which have been accomplished within a 4-m long square pipe arranged with different absorbing conditions during an MLSSA-simulated sound decay. Besides the sound pressure, also the particle velocity and other classical and newly-defined intensimetric quantities have been monitored. In particular, the true decays of the sound energy density, as well as those of its kinetic and potential part, are graphically rendered.

3P6 [B]. The effect of design on the tone and response of clarinet mouthpieces: The use of PC based wave analysis as an aid to design, comparison with empirical results, Edward Pillinger (London Guildhall University, Musical Instrument Technology, 41-71 Commercial Road, London E1 1LA, England, e-mail: EdPillinger@compuserve.com)

Part of my research has been to find inexpensive PC-based sound analysis packages to help define what effect incremental changes to any of the parameters inherent in the design of clarinet mouthpieces have on the harmonic structure of the sound.

This research was undertaken from the standpoint of a performer/maker (I have been a professional clarinetist for 25 years and now also make mouthpieces), and whilst a basic understanding of the physics of acoustics has been essential, I have not set out to present any findings in the form of mathematical models. My aim has been to better understand how the various operating systems of the mouthpiece interact (reed, lay, tone chamber and bore) and how it might be possible to adjust the shapes to move the tone towards or away from tone associated with a specific school of playing.

The importance of the body of a clarinet cannot be underestimated but the mouthpiece is arguably even more crucial. The tone of a good clarinet will be ruined by a poor mouthpiece, whilst that of an indifferent instrument can be vastly improved with a fine mouthpiece. Technicians at the clarinet makers Wurlitzer in Germany maintain that it is impossible to produce German tone from a Boehm clarinet simply by substituting a German style mouthpiece. However, early recordings of Boehm clarinettists (1900-1930s) demonstrate how players such as Charles and Haydn Draper could produce a pure, dark, tone (not unlike some modern German players) on Boehm clarinets based on Martell designs. Examination of the mouthpieces used by these early players reveals bore, tone chamber and lay profile dimensions quite different from the more usual, present day, French style mouthpieces, but having some similarities with certain German styles.

I conducted an extensive survey of mouthpieces presently available and these were measured and tested. Analysis methods and techniques were refined as well as experimentation with different ways of presenting the data e.g. FFT spectra, formant waves, and tristimulus graphs.

An artificial embouchure was constructed in order to control and monitor all playing parameters. Much was learnt from this device which performed so well, as to bring into question the effect, if any, of the shape and resonances of the vocal tract on overall tone.

As the resources for most instrument makers and repair workshops are limited, I am interested in finding economical ways to analyze the tone produced by different set-ups. I have experimented with inexpensive PC based methods and my findings will be discussed in the paper.

3P7 [A]. More measurements of energetic parameters of the sound field inside and outside an open organ pipe, Domenico Stanzial (CIARM-CEMOTER, National Research Council of Italy, v. Canal Bianco, 28, I-44044 Cassana - Ferrara, Italy, e-mail: stanzial@cemoter.bo.cnr.it) and Davide Bonsi (CIARM Physics Department, University of Ferrara) and Nicola Prodi (CIARM Engineering Department, University of Ferrara)

The average energy transfer in a stationary sound field is properly described by two quantities: the radiant intensity and the oscillating intensity. In fact, along with the net propagation given by the usual time-average energy flux, it is necessary to consider a quantity which accounts for that part of energy which oscillates locally. The interplay of these two effects is also fundamental for understanding how an acoustic source, like a musical instrument, generates sound in the environment. From this point of view, the organ pipe gives us the opportunity to analyze the properties of the acoustic energy transfer with respect to the boundary conditions. For instance, it can be easily seen that the nature of the sound field changes from oscillating-like to radiating-like when passing from the inside to the outside of the pipe. Following a previous work (ISMA97), we present and discuss a set of new measurements performed on an open organ pipe by means of an intensity meter specially constructed for evaluating the oscillating part of the sound intensity.

3P8 [B]. Oscillations of reed-like cylindrical instruments: transition between "cooperating" modes and "non-cooperating" modes, Jean Kergomard and Joël Gilbert (Laboratoire d'Acoustique de l'Université du Maine UMR CNRS 6613, Avenue Olivier Messiaen, 72085 Le Mans Cedex 9, France, e-mail: kergo@laum.univ-lemans.fr)

"At these [high] frequencies the air column has changed from a resonator [at low frequencies] into a sort of megaphone ...": so Benade (1976) explained what happens at frequencies for which no air-column resonances occur. Recent results allow further understanding of the transition between low and high frequencies with respect to the dissipation mechanism. If no losses are taken into account in the resonator, a well known solution for the steady-state regime is a square signal, the spectrum being independent of the excitation level. If losses are taken into account, at the limit of the oscillations threshold, Grand *et al.* (Acta Acustica, 1995) have shown that the amplitude of the lower harmonics is determined with respect to the nonlinear characteristic of the excitation and the value of the input impedance.

Using the harmonic balance technique, the transition between these two extreme cases is analyzed: for a given thermoviscous loss factor, the relation between a transition frequency and the blowing pressure is discussed, and the influence of dispersion is examined. The analysis is made using a simple model including three dimensionless parameters (Kergomard, Mechanics of Musical Instruments, Springer, 1996). Musical consequences are discussed.

3P9 [A]. Standard and inverted Helmholtz motion in conical woodwinds, Jean-Pierre Dalmont and Joël Gilbert (Institut d'Acoustique et de Mecanique, Laboratoire d'Acoustique de l'Université du Maine, UMR CNRS 6613, 72085 Le Mans Cedex 9, France, e-mail: dalmont@laum.univ-lemans.fr)

The motion of the reed in woodwinds can be regarded as an analogue to the motion of the contact point between the bow and the string (J.P. Dalmont and J. Kergomard, Proceedings of the ISMA95, Dourdan, France, 114-120, 1995). In the so called Helmholtz motion, schematically two states alternate: a short slipping episode and a longer sticking episode. An inverted scheme in which a long slipping episode is followed by a short sticking episode is theoretically possible but never observed (G. Weinreich and R. Caussé, JASA **89** 887-895, 1991). In conical woodwinds, in a standard regime, a short closed episode is followed by a longer open episode. An inverted Helmholtz motion has been observed, and the aim of this paper is to study this particular regime. This regime is stable, and the input pressure signal is very similar to the standard one, but it is naturally inverted, and the mouth pressure is more than twice as important for the same input pressure level. The two regimes have been theoretically predicted using the harmonic balance technique based on measured input impedances of a saxophone (J. Gilbert *et al.*, JASA **86**, 35-41, 1989). Comparison between experimental and theoretical results will be presented.

3P10 [B]. Beats in piano sounds and short time Fourier transform, L. Rossi and G. Girolami (URA 2053 CNRS, SDEM, Equipe Ondes et Acoustique, Université de Corse, Faculté des Sciences, BP 52, 20250 CORTE, France, e-mail: lrossi@univ-corse.fr)

The aim of this paper is to show that variations of instantaneous frequency (IF) lead to changes in FFT bin numbers when using a Short-Term Fourier Transform (STFT) to find the partials of piano notes. Most musical signal identification algorithms use spectral information, and the positions of a note's partials in the frequency domain are important in determining the fundamental frequency. The identification of the fundamental frequency of musical signals is a difficult task especially because of the non-stationary comportment of these signals. In the particular case of piano sounds, and due to beats, the partials of notes can exhibit important amplitude and instantaneous frequency variations with time. The STFT is often used to process musical signals. The temporal resolution is obtained by the use of a window which is translated on the temporal signal, and a FFT is carried out on the weighted signal. When the window includes a minimum of the amplitude of a partial, the FFT bin number associated with the frequency of this partial is different from the number obtained with a window containing a maximum of the amplitude. This phenomenon must be taken into account when devising an identification procedure.

3P11 [A]. Real-time computer modeling of woodwind instruments, Gary P. Scavone (Center for Computer Research in Music and Acoustics, Department of Music, Stanford University, Stanford, CA, 94305, e-mail: gary@ccrma.stanford.edu)

This paper presents a digital waveguide woodwind instrument model which incorporates improved articulation and dynamic tone hole state controls. This model is implemented in a cross-platform, real-time computer programming environment. A new wind controller created to control the woodwind model is also presented. Digital waveguide tone hole modeling techniques [Scavone, 1997] are implemented for real-time dynamic tone hole state modification. This computer model seeks a balance between accuracy of acoustic principles and simplifications for the sake of real-time processing efficiency. Issues regarding control of computer-based real-time physical models are discussed and a scheme is presented to allow non-traditional fingerings and "continuous" tone hole control between open and closed states.

3P12 [B]. The sound quality of Dutch wind instruments from the baroque period: The results, Rob van Acht (Haags Gemeentemuseum, The Hague, Music Department, and the Royal Conservatory, Institute of Sonology, The Hague, The Netherlands)

The sound analysis of Dutch baroque wind instruments was the subject of this study. Wind instruments from the collection of the Haags Gemeentemuseum were played, and the resulting sounds were analyzed. The points of departure were presented at the ISMA in Edinburgh in 1997. The instruments were played by baroque specialists Wilbert Hazelzet, Piet Dhont, and Eric Hoeprich. Sound analyses yielded the following results: The pitch of Dutch oboes of the period, for instance, lies between 409 and 413 Hz for A1. On average, the tuning conforms with meantone temperament for the tones C through A. In the spectrum of the six types of wind instruments: recorder, traverso, baroque oboe, clarinet, bassoon, and baroque rackett, the odd harmonics 3, 5 and 7 were stronger than in modern wind instruments. The exception was Philip Borkens' clarinet of about 1720, which had a slightly sharper timbre. For all these instruments, the deviation of harmonicity in the attack was very different. The differences are shown in a few examples. Generally speaking, Dutch baroque wind instruments have a distinctive tone character.

3P13 [A]. Long-term stability of listening strategies determined by MDS, Kristin Precoda and Teresa H. Meng (Stanford University, Dept. of Electrical Engineering, e-mail: precoda@leland.stanford.edu)

Multidimensional scaling analyses have been used in a variety of studies of listener strategies in the perception of sound quality of instrumental music (e.g. Serafini 1995 on timbre perception, Gromko 1993 on differences between expert and novice listeners, Nakajima *et al.* 1988 on perception of dynamic pitch). But how stable over time are the perceptual strategies found in this way? To answer this question, three listeners with different levels of musical expertise judged the similarity of all pairs of fifteen signals, an original and fourteen generated by different audio compression algorithms, for each of two samples of music (solo violin and solo flute). The same listeners repeated the experiment approximately one year later.

An individual-differences multidimensional scaling analysis for each instrument included the two time-separated sessions for the three listeners. The strategies used in each session were compared by the conventional method of calculating angles between weight vectors in subject space. Individual listeners' ratings within each session were reliable at well above chance levels, but within-listener variation in strategy over time was not significantly smaller than between-listener variation. Implications and possible effects of analysis method, listener expertise, and task will be discussed. [Work supported by JSEP.]

3P14 [B]. Temporal and spectral features for musical instrument identification, Judith C. Brown (Physics Department, Wellesley College, Wellesley, MA 02181 and MIT Media Lab, Cambridge, MA 02139, e-mail: brown@media.mit.edu)

Recent results on computer recognition of musical instruments (J.C. Brown, "Cluster-based probability model for musical instrument identification," JASA May 1997; J.C. Brown, "Musical instrument identification using cepstral coefficients as features," submitted to JASA) using cepstral coefficients as features have been very successful in distinguishing the oboe and saxophone. Similar calculations in the time domain using autocorrelation coefficients as features have been carried out for comparison. Approximately 30 samples of duration 2-10 s of each of the instruments comprise the test set. The training set consists of longer segments of approximately 1 min duration. Fifty autocorrelation coefficients covering the range of frequencies 200 Hz to 11025 were calculated for each of the sounds. The training data were summarized by a cluster analysis with Gaussian probability density functions formed from the mean and variance for each of the clusters. The probability of belonging to each of the two classes was then calculated for the test sounds, and a Bayes decision rule was invoked to assign them to one of the classes. Results indicate that the spectral domain is better suited for automatic recognition of musical instruments.

3P15 [A]. Taking the fifth (and the fourth): An affirmation of the age-old belief in a mathematical link between music and nature, Helen Pearson Fowler (1 Battle Square, Apt. 1201, Asheville, NC 28801, e-mail: bradypf@cphl.mindspring.com)

It is the cumbersomely large ratios of the perfect 5th series, geometrically multiplying as powers of three: 3-9-27-81- 243-729, which can be reduced to an open-ended series of ordinal numbers that perfectly correlate with the most familiar intervals. These "sign," "serial," or "S ratios" for the 2/1 Octave, 3/2 Perfect 5th and 4/3 Perfect 4th, for example, are zero, +1 and -1. These are followed by +2 through +5 for the majors and minors; and then by +6 through +11 for augmented and diminished intervals.

There is another less perfect correlation between the scales of the world and the fifth series. The recurrently discovered fifty-three note scale provides materials for any number of smaller ones; but relatively few of them have the particularly practical feature of being “two-unit scales,” i.e., of having only two (rather than three) kinds of step intervals. Of the forty-nine possible scales of from five to fifty-three notes, only seven have this feature, and the first four of them are: the five note Pentatonic, the seven note Diatonic, the twelve note Chromatic, and the seventeen note, much admired, Arab scale.

3P16 [B]. Conscious randomness at tempo, Minoru Matsuda and Kouichi Akiyama (Osaka Electro-Communication University, 18-8 Hatcho Neyagawa, Osaka 572, Japan, e-mail:matsuda@isc.osakac.ac.jp)

The subject of how the human makes rhythm or how the human recognizes rhythm has been discussed in several scientific fields. Typical examples of themes are “Spontaneous generation of rhythm” and “Time structure of rhythm in music”, etc. Authors also have already reported on “Existence of rest in Japanese song,” as rest has a big influence on the rhythm of music. On the other hand, the subject of the generation of non-rhythm, which is the antonym of rhythm, has not been reported. The word “non-rhythm” is not common. Therefore, it was decided to consider replacing “Generation of non-rhythm” with “Conscious random generation of time intervals”. An experiment made the subject do spontaneous random generation of time intervals by using tappings. We can consider that the characteristics that time interval between taps (TIBT) is near random numbers was assumed to be excellent randomness, that is, excellent non-rhythm. As a result of this experiment, several natures become clear, for example, the frequency of TIBT of the half note (M.M.120) is high by the subject, etc.

Tuesday Morning, 30 June 1998
4A. Musical Psychoacoustics

William M. Hartmann (Chair), Chapel Theater

8:45 AM [Invited]

4A1. Psychoacoustic aspects of music perception in normal and impaired hearing, Brian C. J. Moore (Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge, CB2 3EB, England, e-mail: bcjm@cus.cam.ac.uk)

This paper will review several aspects of auditory perception that are related to music perception and that are affected by cochlear hearing loss. Topics covered will include: (1) The perception of the pitch of pure tones, and pitch anomalies such as diplacusis and changes in pitch with level; (2) The perception of the pitch of complex tones, and the influence of component phase in normal and impaired hearing; (3) Perceptual grouping processes. People with cochlear hearing loss sometimes, but not always, perceive rapid tone sequences differently from normally hearing subjects, particularly with respect to the formation of perceptual streams. The mechanisms underlying this will be discussed and evaluated. Evidence will be presented showing that the perceptual grouping of rapid sequences of complex tones depends both upon spectral content and upon periodicity.

9:15 AM

4A2. The influence of subharmonic components of stationary violin tones on perception, Jan Stepanek and Zdenek Otcenasek (Music Faculty, Academy of Performing Arts, Prague, Czech Republic, e-mail: stepanek@h.amu.cz)

In an anechoic room, five different tones were played using a group of violins with a large range of timbre and quality. Recordings of the tones were subsequently adapted to disable the influence of transient parts on perception. Separate listening tests of all five tones resulted among others in words describing the timbre of the violin sound. For the highest tested tone, D6, a very high incidence of the word “rustle” (“sustivy” in Czech) was found. Subharmonic component levels and their temporal changes were determined in spectra calculated from the sustained part of the tones. A significant positive correlation between the levels of subharmonic components originated in the neighborhood of the frequencies of the resonance modes A0, T1, and C3, and the frequent occurrences of the word “rustle” was proved. The influence of these levels on sound perception was verified by subsequent listening to the tones modified by means of a spectrum shaper (third-octave filter).

9:35 AM

4A3. Analysis of difference between up-bowed and down-bowed violin tone, Myung Hyung Gook (Department of Electronics, Republic of Korea Air Force Academy, PO Box 335-1, Sangsoo-ri, Namil-myun, Chungwon-gun, Choongchungbuk-do, 363-849, South Korea, e-mail: gmahler@bigfoot.com) and Sung Goeng-Mo (Department of Electronics, Seoul National University, Shinlim-dong, Gwanak-gu, Seoul, South Korea)

Although it is quite difficult to perceive the difference between up-bowed and down-bowed violin tone, it can be anticipated that the tones may have some differences in their physical aspects due to

the slightly different arm position and bowing process. In order to investigate this possibility, sustained tones of four open notes (G3, D4, A4 and E5) were digitally recorded in an anechoic chamber for three different players and two different violins, using a DAT recorder. From the recordings, steady state and transient analyses up to 12kHz (sampling rate of 24kHz) were performed to analyze the difference between the up-bowed and down-bowed tone. In the steady-state analysis, a long-time FFT with a size of 65536 points (approximately 2.73 seconds under 24kHz sampling rate) was performed. A short-time FFT using a 1024 point Hanning window was used in the transient analysis. It was found that, although not perceptually significant, there are distinct differences between up-bowed and down-bowed tones according to the recording and analysis. For each of the three players and two violins, amplitudes of some harmonics differ significantly, and the frequencies also differ, even though the fundamental frequency was measured the same. Transient aspects also show some differences.

9:55 AM

4A4. Pitch and pitch strength of cello vibrato tones, Ilia Kiuila, Andrzej Rakowski, Piotr Rogowski and Andrzej Miskiewicz (Chopin Academy of Music, Music Acoustics Lab, Okolnik 2, 00-368 Warsaw, Poland e-mail: rakowski@ plearn.edu.pl)

Physical and perceptual characteristics of cello tones, played with various amount of vibrato and without vibrato, were investigated using a computer analysis program and a psychoacoustic pitch-matching experiment. The tones were played mezzoforte in all pitch registers of a high-quality instrument by a professional cellist and recorded on a digital tape recorder. Two-second segments of a stationary part of each sound with uniformly shaped rise and decay periods were next used for further processing. Physical analysis led to the magnitude and the detailed shape of frequency and amplitude modulation of vibrato tones as well as to their frequency distributions. The pitch-matching experiment consisted in tuning the frequency of a 60-phon pure tone to equal pitch with each of the investigated cello tones. Ten music students were used as subjects in this investigation after being given a two-session practice in pitch matching. In a computer arrangement each student tuned a pure tone to each of the cello tones in random order 12 times. The whole experiment was performed in individual sessions lasting no longer than 30 min each. For each sound the results of 120 pitch matchings were pooled together. Then, medians and interquartile ranges of matching-tone data were taken as measures of pitch and pitch strength of particular cello tones. The results show that the pitch of cello vibrato tones decreases at large vibrato rate, and pitch strength is not much affected by vibrato.

10:15-10:45 AM, Break

Tuesday Morning, 30 June 1998
4B. Brass Instruments

Murray Campbell (Chair), Woodpecker Room

10:45 AM

4B1. Measure of brass-instrument nonlinearity at the lips on an artificial mouth with latex lips, Christophe Vergez (e-mail: Christophe.Vergez@ircam.fr) and Xavier Rodet (IRCAM, 1 pl Igor Stravinsky, 75004 Paris, France)

Details of aeroacoustics phenomena at the lips of a trumpet player are not well understood. To better understand the physics of real lips, an artificial mouth with latex lips has been built. When air pressure is applied, the artificial mouth plays the trumpet in the same way as a real trumpet player, as shown by the remarkable sonic results obtained. The latex lips' behavior has been analyzed according to different measurements. Interesting theoretical results have been obtained. Results from our numerical simulations performed on our trumpet physical models are compared to measurements.

On the "artificial mouth" device, the mouth pressure, the mouthpiece pressure, and the pressure in the instrument have been measured as well as the lips' aperture. Lips' aperture is obtained by the amount of infrared light emitted in the mouth and passing through the aperture. It is also obtained by a computer analysis of the aperture area recorded on stroboscopic video images. The three pressure measures are compared with the same pressure values recorded in the case of a real trumpet player. From all measures, the nonlinear coupling between the lips, the air flow and the mouthpiece pressure is estimated and compared with theoretical models used for simulation.

11:05 AM

4B2. Acoustical measurements in resonators driven by an artificial mouth, John S. Cullen (Department of Physics and Astronomy, The University of Edinburgh, Room 4201, J.C.M.B., The Kings Buildings, Mayfield Road, Edinburgh, EH9 3JZ, Scotland, e-mail: J.S.Cullen@ed.ac.uk), Joël Gilbert (Institut d'Acoustique et de Mecanique Laboratoire d'Acoustique de l'Universite du Maine - UMR CNRS 6613, Avenue Olivier Messiaen, 72085 Le Mans Cedex 9, France), D. Murray Campbell (Department of Physics and Astronomy, The University of Edinburgh, Room 4021, J.C.M.B.), and Clive A. Greated

(Department of Physics and Astronomy, The University of Edinburgh, Room 4404, J.C.M.B.)

Although considerable progress has been recently achieved in developing physical models of lip-excited wind instruments, a complete understanding of the functioning of the lips of a trumpet or trombone player is still lacking. Specific topics requiring clarification include the limitations of a single-mass model of the lips, the relative importance of the Bernoulli force in different playing regimes, and the phase relationships between lip displacement, pressure, and air flow in the mouthpiece.

The use of an artificial mouth with latex rubber lips has proved to be of great value in experimental investigations of brass instruments, since it allows stable regimes of oscillation to be set up with a reproducibility and long-term stability impossible for a live player. This paper is a progress report on studies in which an artificial mouth is used to drive several resonating systems whose input impedance characteristics have been separately determined. Acoustic flow velocity in the mouthpiece is measured using a specially constructed transparent mouthpiece and a laser Doppler anemometry system.

11:25 AM

4B3. Intonation of trumpets, Matthias Bertsch (University of Music and Performing Arts in Vienna [IWK], Singerstr. 26a / A-1010 Vienna, Austria, e-mail: bertsch@magnet.at)

If a note is played out of tune, the reason could be either (1) the instrument, (2) the player, or (3) both. (1) The intonation of the instrument ("objective intonation") is determined by the mechanical dimensions of the instrument and the mouthpiece. It can be calculated using the input impedance method. Statistical data from 35 trumpets will be presented. (2) Deviations of the pitch of notes blown by the player ("subjective intonation") may be caused by the physiological condition of the lips of a player and the increasing participation of higher harmonics in a crescendo. Additionally, the desired timbre of the sound can, as well, cause variations over 50 cents with the same instrument. (3) Recordings of 35 players with their own instruments as well as with a reference instrument have been analyzed. The results are compared with the "objective" intonations of the trumpets. The correlation of pitch and timbre give new and unexpected results. Sound demonstrations will illustrate this effect. Finally, the question of an optimal "objective intonation" will be discussed.

11:45 AM

4B4. The reconstruction of the carnyx, D. M. Campbell and T. McGillivray (Department of Physics and Astronomy, University of Edinburgh, Mayfield Road, Edinburgh, EH9 3JZ, UK, e-mail: D.M.Campbell@ed.ac.uk)

The carnyx was a large bronze horn which appears to have been played among Celtic tribes across Europe around two thousand years ago. Its most prominent feature was the open end, fashioned in the form of a boar's head. Although numerous illustrations are known, no complete instrument has survived. The Scottish craftsman John Creed has recently completed a reconstruction of a carnyx, based on a fragment dug up in the north of Scotland in the nineteenth century. Since the mouthpiece and the major portion of the tubing had been lost, the reconstruction of these sections involved consideration of historical, acoustical and musical aspects. This paper discusses several acoustical issues which arose during the project, in particular the taper of the tubing, the presence or absence of a throat in the mouthpiece, and the possible acoustical significance of the sprung and pivoted tongue which was a striking feature of the original head. Measurements of the acoustical properties of the completed instrument are presented and discussed. The talk is illustrated by a video of a performance on the carnyx by the trombonist John Kenny.

Tuesday Morning, 30 June 1998
4C. Strings, Resources, Folk Song

George Bissinger (Chair), Chapel Theater

10:45 AM

4C1. The simple theory of a bowed string and its consequences for the choice of strings, G. Müller and H. A. Müller (Müller-BBM GmbH, Robert-Koch-Str. 11, D-82152 Planegg, Germany, e-mail: ham@mbbm.de)

The motion of a bowed string exciting a violin, viola or a cello to a good sounding tone has been well known for a long time. In the meantime, many detailed questions have been the subject of sophisticated theoretical and practical research studies. It will be demonstrated that some important questions concerning the choice of the strings for bowed instruments can be deduced from the basic simple theory: the required mass per unit length, the bending stiffness, the internal damping of the strings and even the necessary impedance of the bridge. Furthermore, it will be shown how violinmakers judge these qualities by simple experiments without sophisticated instrumentation.

11:05 AM

4C2. The Musical Acoustics Research Library, Gary P. Scavone and Max V. Mathews (Center for Computer Research in Music and Acoustics, Department of Music, Stanford University, Stanford, CA, 94305, e-mail: gary@ccrma.stanford.edu)

The Musical Acoustics Research Library (MARL) is a collection of independent archives or libraries assembled by distinguished groups or individuals in the field of musical acoustics research. MARL is directed by representatives of each member library, in conjunction with the Center for Computer Research in Music and Acoustics (CCRMA) at Stanford University, which maintains the contents of each library. Currently, MARL is comprised of the Catgut Acoustical Society Library, the Arthur H. Benade Archive, and the John Backus Archive.

The Musical Acoustics Research Library at CCRMA has been established for the purpose of preserving and maintaining a complete and up-to-date repository of knowledge on musical acoustics. It is intended that the collection be made as accessible as possible and its existence be made known throughout the world. To this end, World Wide Web pages (http://www-ccrma.stanford.edu/CCRMA/Collections/MARL/) have been created to outline the contents of the library. Further, documents from the library will be made available, via the Web pages, in Portable Document Format (PDF) on a “per request” basis.

This presentation will outline the current status of MARL and provide an opportunity for discussion regarding its future role in the musical acoustics community.

11:25 AM

4C3. Teaching electronic music engineering, Paul A. Wheeler (Utah State University, Logan, UT, 84322-4120, e-mail: paul.wheeler@ece.usu.edu)

The Departments of Electrical Engineering and Music at Utah State University have teamed to offer a minor in electronic music. This paper summarizes the content of a new upper-division course in Electrical Engineering developed as part of this minor.

Students enrolled in the course are upper-division engineering majors who have had basic math, physics, and electrical circuits. The course begins with simple vibration leading into the acoustics of musical instruments. Musical instruments are then modeled using Wave-SE and Spectra Plus software packages. Several methods for synthesizing musical instruments are presented, including analog synthesis on the Arp, FM synthesis on the DX-7, sampling on the EPS, and computer synthesis using Csound. The course ends with discussions on multimedia, including MIDI file formats, sound cards, and CD-ROM specifications. For the lab, students are divided into small teams. Each team selects a different musical instrument to analyze and synthesize using the various methods discussed. The project report is presented as a web page on the internet.

More detail on the contents of the course will be discussed at the presentation of the paper and the results of the projects will be shown on the internet.

11:45 AM

4C4. A computerized study of Chinese folk songs: An analysis of the characteristics of the melodic schemes of the folk songs in the Chu area, Zhang Xiao-nong (The Arts Department of Shaanxi Normal University, Xi’an, P. R. of China, 710062)

By computer scanning the melodies of Chinese folk songs, analyzing their tonic scales, tritonics, special melodic sequences and typical tonic types, the biases and prejudices on the part of the researcher have, by a large measure, been eliminated, and the principles governing the melodic structures and schemes of the multitude of folk songs in China’s various areas have been revealed and, with it, the inner causes for the different styles of the regional folk songs. Such findings have not only provided the basis for formulating theories concerning Chinese folk songs but also prepared for us the crucial data for music composition by the computer. By programming some five hundred Hubei field songs and mountain airs, (Hubei is a central Chinese province around which the Chu region centers) adopting the method of inference, sample comparison we have derived some necessary data and meaningful conclusions, which have unveiled the characteristics of the melodic schemes of the folk songs in that cultural area.