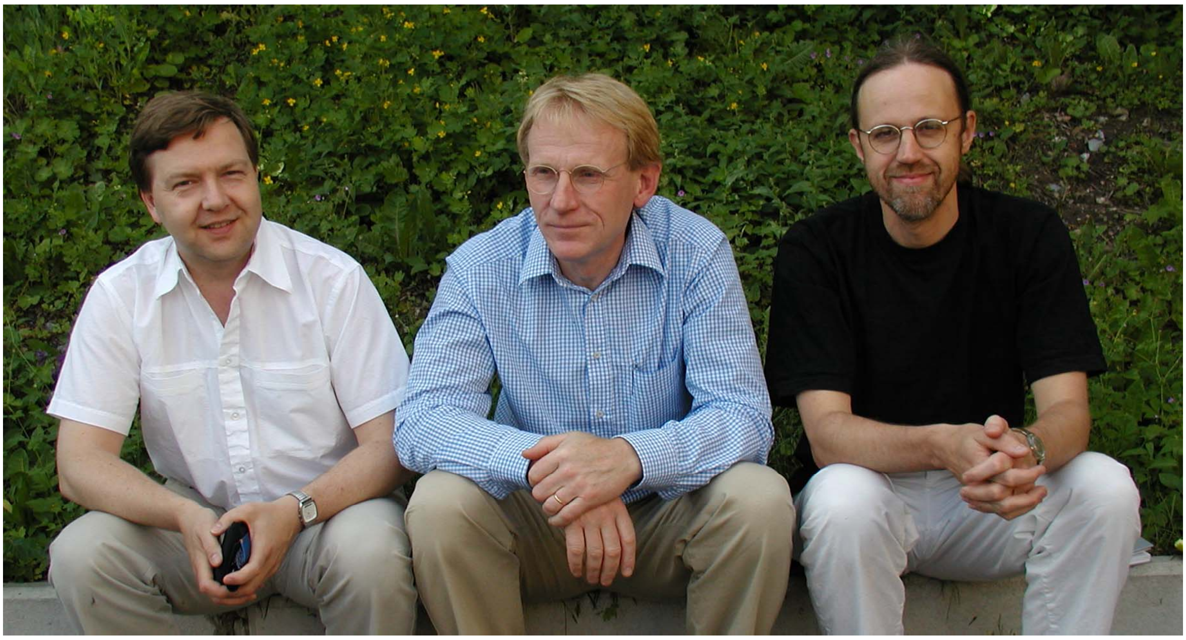
Music Acoustics



The Music Acoustics group is directed by three senior members: Sten Ternström, Anders Askenfelt and Anders Friberg (left to right).

The Music Acoustics group is the second largest at the department. During 2002, seven senior scientists, five research students, eight international guests and three project workers, in all 25 persons, were working in the group. During the period 2001 – 2004 the group has been appointed to be a Marie Curie Training Site in Music Acoustics, which makes it possible to receive doctoral students for a training period of up to one year. This program is an important contact link, which helps us to continue and extend the co-operation with our colleagues at music acoustic laboratories in the European countries. During 2002 we received two research students within this program.

The Music Acoustics group is currently directed by an executive committee consisting of three of the senior members. The activity in the group can be structured into three main research topics: voice, musical instruments, and music performance.

VOICE

Our voice is an essential component of our personality. We normally speak for a large part of the day, filling the hours we are awake with chats, telephone calls, quarrels, and meetings. A well-functioning voice is a must in many professions. For the professional singer and actor, the voice is the tool by which the artistic message is conveyed. Trained voices can be used in a much more complex manner than untrained, but both types share the basic principles and means of control that need to be mastered. A thorough understanding of the voice production, including all its physiological and acoustical aspects, is a long-term research interest in the Music Acoustics group. Our well-established co-operation with the Department of Phoniatrics and Logopedics at Huddinge University Hospital, Sweden, as well as other voice clinics in Europe, is of pivotal importance to this work.

Pressed voice

In voice production, the ‘pinching’ of the glottis by the muscles in the larynx, known as the adduction, is an important control parameter. Too much adduction gives a ”pressed” voice quality, which normally is perceived as unappealing, and may lead to voice dysfunction. Several attempts to measure the degree of adduction by processing the speech sounds have been made. The ratio between the peak flow amplitude through glottis and the maximum in the flow derivative during closure (originally proposed by colleagues at Helsinki University of Technology) has been evaluated in order to see if it could be used as an indicator of the degree of pressed phonation. In a study including a set of perceptually rated voices with varying degree of pressed quality, it was shown that this quotient actually is quite effective in predicting the degree of perceived ”pressedness.” It seems that yet another parameter can be added to the set of voice quality parameters which can be obtained automatically by acoustic analysis of the speech.

Subglottal pressure and larynx height

Actors use their voice differently when performing compared to everyday life. In a study of the subglottal pressure when reciting poems, it turned out that professional actors use carefully controlled pressure variations, never observed in spontaneous speech. Contrary to the assumption that these pressure boosts were used to increase the loudness of stressed syllables, it turned out that they served the purpose of increasing the loudness of unstressed consonants, which normally would have been faint. Actors share the need for a precise control of the subglottal pressure with singers and wind players. All three groups of artists stress the importance of highly developed control of the breathing processes, often summarized in the far-reaching term ”support.”

It is clear that the breathing process can have a pronounced effect on the conditioning of the larynx, and in turn, on voice quality. There are biomechanical links between the breathing and voice producing apparatus. For example, in untrained subjects the larynx tends to rise as the air in the lungs is consumed, and the lung volume decreases. This automatically gives a decrease in the adduction of the glottis and a change in voice quality. For professional singers such changes are not acceptable and they must learn to compensate for them. In line with expectations it was found that larynx height in professional singers is much less dependent on momentary lung volume than in untrained subjects. This observation demonstrates one particular aspect of what seems to be a general quality mark of a performing artist. By mastering the control apparatus, be it breathing in singers, or arm, wrist, and finger motions in percussion, piano, and string players, the artist is at any moment free to chose the expression which is motivated by the music, not by the limitations of the voice or body control.

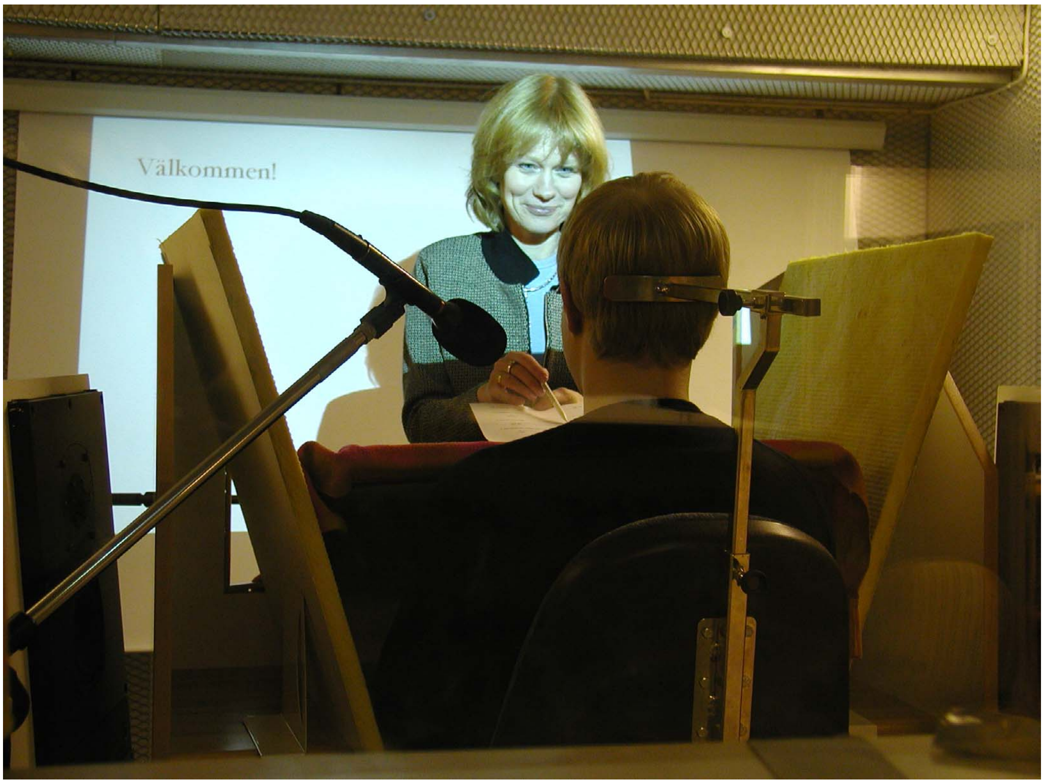
Voice load and voice quality

Voice quality is heavily influenced by the loudness level. In our ongoing studies of phonation habits under different voice load, a loud voice is induced by letting the subject speak in noisy environments reproduced over loudspeakers. After removing the noise by channel estimation techniques, the original voice signal is available for analyses. Among other things, the results show that male speakers typically speak 4-5 dB louder than females, while reporting less vocal effort. In all voices, the spectral slope changes with increasing loudness with a faster rise in the high-frequency range, but only up to a certain loudness level. At that point the vocal folds have reached maximum closing velocity. The marginal cost for increasing the loudness further is probably very high in terms of vocal effort, which may be connected with an increased risk of voice problems.

Other voice projects have dealt with acoustical correlates of a ”throaty” voice quality, new sensors for measuring the subglottal pressure through the glottis opening, and high-speed filming of the vocal folds in combination with flow measurements.

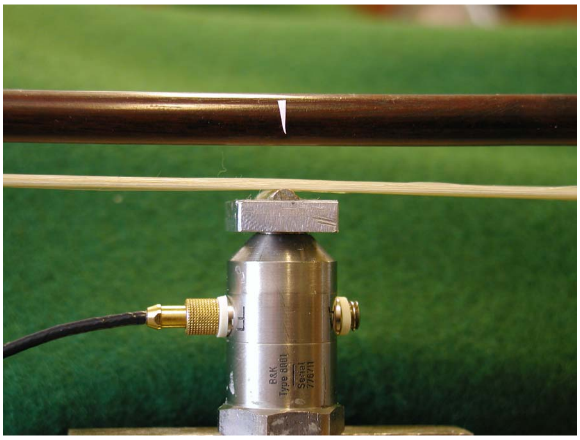
MUSICAL INSTRUMENTS

Tone generation in traditional stringed instruments, in particular the violin and piano, is a central research topic in the music acoustics group. Understanding the details of the design and their influence on the generated sound is an extensive task, which needs to be to carried forward in co-operation with musicians and instrument makers. Numerical simulations allow estimations of the influence of material and design parameters which may be verified in controlled experiment series and listening tests. The differences in tonal quality that are important for the professional musician are, however, in many cases of no great magnitude. Their acoustical correlates may barely be detectable and are seldom clearly separable from ‘natural’ variations in the acoustical output due to playing technique and habits, or even environmental factors (e.g. humidity and temperature).



Experimental view from the voice load project, studying how normal speakers and voice patients use their voices in noisy workplace environments. A subject is being interviewed by voice therapist Maria Södersten about experienced voice strain, after having spoken loudly over recorded environmental noise. Note loudspeakers to the sides and the projection screen with instructions at the rear of the sound-proofed booth.

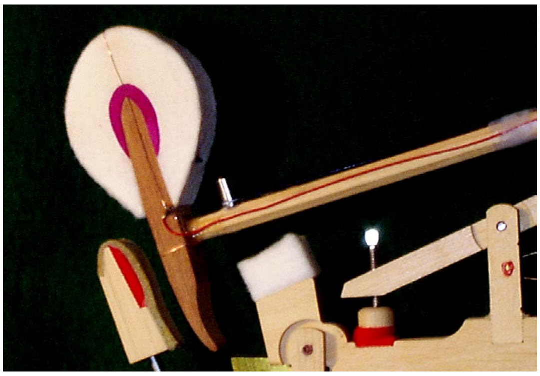
A particular quality of an instrument is seldom linked to only one design parameter. For example, the quality 'brilliance' in the sound of a violin is known to be influenced by the properties of the bridge. A broad peak observed in measurements of the input mobility at the bridge of many fine old Italian instruments is an indication of a prominent resonance. The resonance can be altered by tuning (cutting) the bridge. Recent experiments have shown, however, that the "bridge resonance" is much dependent on the stiffness of the top plate, and the mutual coupling bridge-top plate. This coupling is in turn to a large extent dependent on the distance between the bridge feet and the exact position of the bridge on the top plate. Further, the timbral differences due to a modest change of the bridge may well be of the same order of magnitude as the differences evoked by different styles of playing.



Professional players agree unanimously that stringed instruments *do* have inherent qualities, each instrument being an individual, but the long-term experience from the laboratory shows the many difficulties in isolating and pin-pointing simple explanations in the design. This complexity is hardly surprising as the traditional instruments have developed slowly over many centuries, giving time to adapt the design to the musicians' needs for a wide range in expression and control of even small nuances in tone color.

Our work on the stringed instruments has continued with studies of the violin, in particular the bridge-body matching, design parameters of the guitar, the string player's possibilities of varying the spectral properties by the control of the bow (bow velocity, bow force, bow-bridge distance, tilting), and the timbre of piano bass tones.

The study of piano tones have illustrated the interaction between the design parameters of an instrument mentioned above, and that 'established facts' need not be perfectly true. For many decades, the inharmonicity of the bass strings of the piano has been considered as a main quality parameter. Long bass strings, as in a concert grand piano, would ensure sufficiently low inharmonicity to give a good tone quality. In listening tests with synthesized 'hybrid' piano tones, which combined spectral characteristics of large and small pianos, it was shown that low inharmonicity in the bass is certainly one desirable characteristic of a high-quality piano. However, perceptually more important is a wide spectral range at the attack and the dynamic evolution of the spectrum; features which are closely related to the properties of the hammers and the soundboard. It is clear that the preferred bass tone quality of a large grand piano is a result of many design parameters, low inharmonicity being only one.



PERFORMANCE

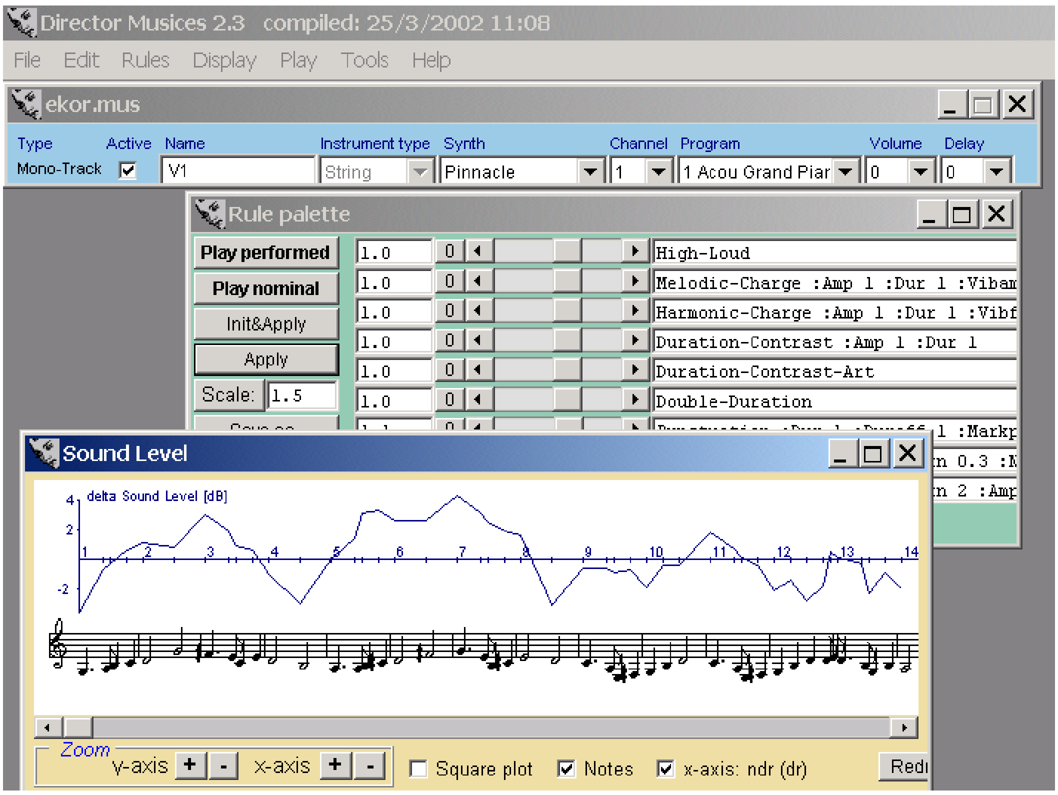
Every day we are exposed to artificially produced music which is delivered with no musical intention at all. The common use of melodies as ring tones in mobile phones has made many people aware of the piercing discrepancy between the nominal score of *"Für Elise,"* as mechanically reproduced by the phone, and a musician's interpretation. Music performance is a research field which has gained tremendously by the development of computer-controlled synthesis of music. Research questions which many scholars thought were out of reach for analyses as late as a couple of decades ago, being too ‘artistic’ or the like, are now getting more and more reliable answers. Striking examples are how the interpretation of rhythm depends on the musical context, and how emotions are efficiently conveyed in music communication

Studies of music performance were initiated 30 years ago within the music acoustics group at KTH and have now expanded to be the largest research area. Our generative grammar for performance of music *KTH Director Musices* (DM) is today an internationally recognized tool for automatic transformation of MIDI files into musically expressive performances. Recently, means for emotional coloring of the performance (e.g. happiness, sadness, fear) have been added. DM is an important tool for studies in music performance, through helping to answer questions like how an artist transforms a score into a musical performance (the means); why this is done (the goals), and for explaining the sometimes surprisingly large differences between professionals’ interpretations of one and the same piece.

The interpretation of one particular piece, *Piano Sonata in F major* (K332) by Mozart, was the subject for Stockholm Music Performance Symposium (STOMPS) in May 2002. A general observation was that a performance grammar like DM will hardly come close to any pianist’s performance. On the other hand it always will give an able interpretation, far from the mechanical reproduction of the score. An important feature added to the performance by DM is an enhancement of the structure of the piece, including phrases and harmonic progression. Unexpected elements in the piece are also ‘high-lighted.’ All together these signs of a ‘human’ interpretation give an impression that DM understands the music and strives to convey this information to the listener. This is a basic element in all music communication.

Research on music performance is performed in a number of on-going EU projects with partners in different European countries, in particular Italy.

In *MEGA* (“Multisensory Expressive Gesture Control”) the aim is to extract, synthesize and map expressive features in dance, musicians’ gestures, and music performance. The importance of the musician’s gestures in music communication has been clearly illustrated in a



WWW interface of KTH Director Musices.

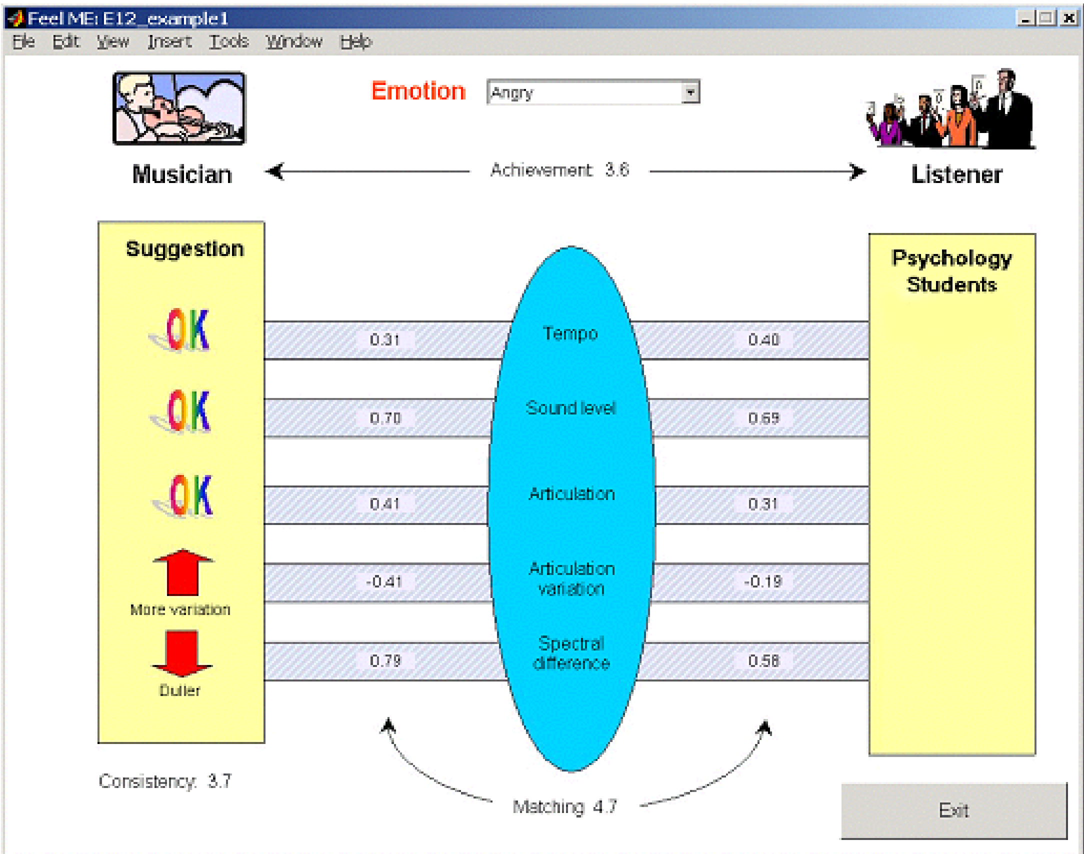
study of a marimba player. The player was asked to perform the same piece in different intended emotions (happiness, sadness, anger, fear). Subjects had in general no difficulties in identifying the intended emotions only by viewing video clips of selected parts of the body (without sound tracks). A little surprisingly, it turned out that the influence of viewing conditions was not so pronounced. Video clips showing the movements of the torso only (no head), and head only (no body or hands), were about equally informative in communicating the intended emotion.

The results illustrate the visual power of the body language in the performance. As instrumentalists produce the sounds and the music by movements of the fingers, hands, arms, and the whole body, the features of the body language will automatically be reflected in the sounding performance as well.

A novel application of results obtained within MEGA is the *Groove Machine*, by which a dancing disc jockey controls how the music is performed. A video camera records the dancer's motion. Body movement cues are extracted on the fly by real-time vision analysis and used to control the emotional character of a repeated rhythmic loop ('groove'). Alternatively, the dancer could control the pitches and durations of pre-recorded sounds by arm gestures in different directions. Also in this application, the performing artist is controlling the music by the body language, however, not as directly as the marimba player.

In *SOb* ("The Sounding Object"), the aim is to develop sound models which can be connected to various objects in a virtual reality world. Recently, an Irish friction drum, the 'bodhran,' has been implemented in a computer-based physical model and connected to various inter-faces, and also used in concert. An overall goal of this research is to develop control facilities for physical models which are intuitively easy to use by musicians.

Mosart ("Music Orchestration Systems in Algorithmic Research and Technology") is a EU training network focusing on music performance. Several guest researchers from European universities have visited our group, working on emotional and gestural content in music performance.



Screen view from FeelMe presenting cognitive feed back to the student.

In *FeelMe* ("Feedback Learning in Musical Performance"), a project in co-operation with the Department of Psychology, Uppsala University, the aim is to apply results from music performance research in a training program, teaching students to play expressively. At basic levels of music training, the playing technique with all its practical and motorical difficulties, is often put in focus at the expense of the emotional expression. The strategy in FeelMe is to extract some of the most important parameters in the sounding performance which carry emotional content ('cues'), and to use these cues for estimating how pronouncedly the student performed a particular emotion. The program gives cognitive feedback, with the aim to help the student to improve on the aspects in the performance which did not communicate the intended emotion convincingly. For example, a fast tempo in an intended sad performance gives a contradictory signal to the listener.

Other projects within music performance research deal with studies of the perception of drift in tempo, the influence of auditory delay on the performance of drummers, and physical modeling of 'scratching'. Scratching can be viewed as a novel musical instrument. The sound is produced by turning a vinyl disk back and forth with the pick-up resting on the disk. Like all successful musical instruments it can be precisely controlled by the skilled player, and not the least, many different versions of basically the same sound can be generated.