INFORMATION, COMMUNICATION & COMPUTING

Fields of Expertise TU Graz

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Kay Uwe Römer,
Information, Communication & Computing
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After a COVID-induced break of three years, we have restarted the Field of Expertise Information, Communication & Computing colloquium. The colloquium – offered twice per year in spring and fall – plays an important role in realizing the mission of the Field of Expertise to bring together researchers from different disciplines to facilitate interdisciplinary research. The colloquium features an invited talk by a distinguished expert who is experienced with such interdisciplinary research and who can address the broad audience of the FoE with researchers from the mathematics, electrical engineering, and computer science faculties. In the most recent edition of the colloquium, Utz Roedig, head of school at University College Cork in Ireland, showed how research on wireless communications, physics, and speech processing can be combined to secure access to smart devices in the digital world. Another element of the colloquium are short pitch presentations by recent winners of competitive initial funding grants, highlighting their new research directions. This is a good opportunity to get an overview about the breadth of recent research activities in the Field of Expertise and to connect to the researchers for possible collaborations. In the most recent edition we learned about AI-based methods for analysis of Spanish literature, about collaborative diagnosis of problems in industrial robots, and about how distributed computing theory can benefit from more realistic models of the internet. To discuss these topics with the presenters and to get in touch with other members, the colloquium also features a buffet with snacks and drinks. All members – from PhD students to professors – are cordially invited to join our colloquia, the next one is planned for fall 2023.

In this edition of TU Graz research, Stefan Schoder gives us some insights on his research. Enjoy reading!

Stefan Schoder

Flow acoustics

Flow acoustics studies the flow-induced generation of sound, its propagation, and mitigation inside flowing and heterogeneous media. Flow instabilities, wave propagation phenomena, and structural interaction are current topics in the field. The prediction methods are frequently applied to technical and biological flows. Applications range from sound generated from heat pumps in front of your house to the voice generation process.

Flow acoustics impacts our daily life with every meter we walk. Firstly, we look at beautiful aspects of flow acoustics, such as music, and the phonation of humans and animals. In classical musical instruments, energy is usually transferred in concentrated form to the acoustic wave via mechanical or fluid dynamic excitation. The produced sound waves are then modulated by a resonating body or volume and perceived by the ear as distinctive and clear sounds. Every type of sound, such as music, voice, or noise is perceived by humans through our ears. The ear, as our acoustic perception instrument, converts the acoustic wave with the help of vibroacoustic coupling at the eardrum and successive translation in the cochlea, located in the inner ear, into a nerve signal that can be processed by the human brain. Recently investigated by our research group at the Institute of Fundamentals and Theory in Electrical Engineering (IGTE), the lungs cause the vocal folds to vibrate due to excess pressure. The periodically constricted fluid flow forms the source signal for the human voice. A cut at the sagittal plane and a 3D-visualization of this acoustic source signal inside a human larynx model are shown in Figure 1. The larynx model consists of oscillating vocal folds and stationary false vocal folds. Via the resonating upper airways, i.e., mouth and nasal cavities, the sound waves are modulated to become a pleasant-sounding voice. Besides, vowels, consonants, >

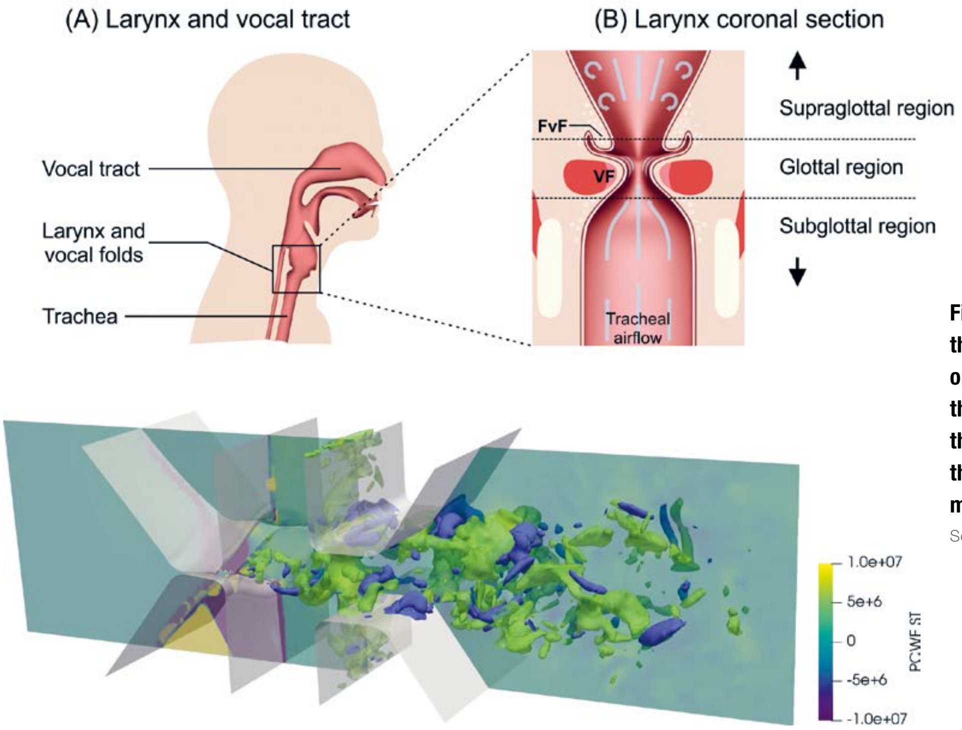


Figure 1: Sagittal cut showing the human larynx and upper airways on the right, a detail of the larynx in the middle, and a 3d visualization of the acoustic source signal inside the larynx section of the simVoice model on the left.

Source: Stefan Schoder

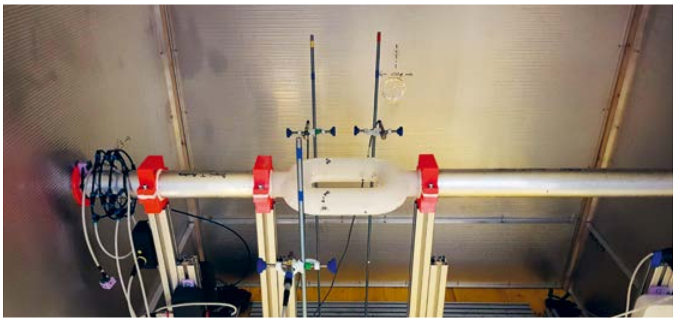
and fricatives are formed by the shaping of the mouth and throat area. Spoken language is an important form of human communication. Therefore, people suffering from voice disorders are severely restricted in their everyday lives and quality of life. Within the projects Numerical Computation of the Human Voice Source and Understanding Voice Disorders, a validated numerical model called simVoice for supporting the treatment of voice disorders was developed. Such numerical models can help deepen the understanding of complex sound generation mechanisms often including the interaction of acoustics with both flow and structural fields.

Fluid-structure-acoustic interaction is the basis for a multitude of parasitic acoustic effects of technical and medical applications, which influence our daily life through unwanted acoustic emissions commonly called noise. Among the disturbing emitters are transportation (e.g., automobiles, airplanes, helicopters, railways), moving machines of all kinds, production, and manufacturing (e.g., furnaces, separation plants, valves). Each of these applications emits noise which is essentially based on the same physical situation as previously presented for the musical instrument and human phonation. The energy in fluid motion and mechanical vibration is transferred to the acoustic wave. The sound waves are then modulated by a resonating body and perceived as characteristic sound. With the use of established and standardized experiments, we successfully studied an electric ducted fan unit (see Figure 2) which propels vertical take-off and landing air taxi. The outcome was a significant reduction of noise emission over the whole operating range.

Figure 2: Acoustic measurement setup to analyze the electric ducted fan unit.

Source: Jakob Schmidt

a)



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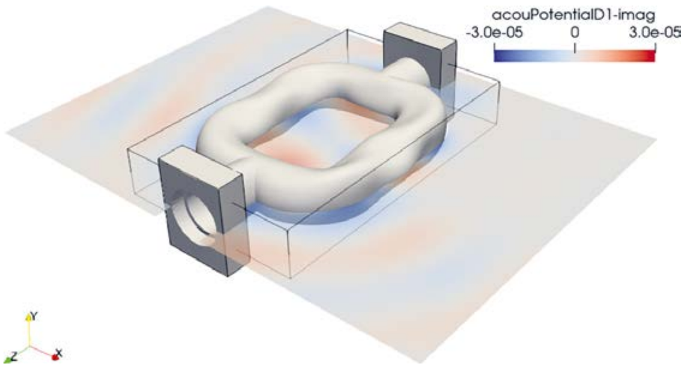

Figure 3: Experimental setup and the acoustic field results of the vibrating junction under investigation.
Source: Stefan Schoder

Another growing area of application is the ground transportation sector. Due to the absence of combustion noise in electric vehicles, other sources of sound become more dominant and thus have to be reduced for comparable or enhanced driving comfort. Besides the tire-rolling noise and flow-induced noise of the chassis, sound is generated in confined flows (internal fluid flow through a pipe-like structure or duct). Such internal flows can be found in the air conditioning and ventilation system, cooling systems, or also in fuel cell drives. The flow-guiding structures are often unfavorable in terms of flow conditions due to the strict packaging requirements which induce sources of sound. The resulting acoustic wave does not only propagate through the duct but also excites the flow-guiding structure, which consequently radiates sound to the environment. With the help of numerical simulation, this challenging task was investigated. The developed in-house aeroacoustics model is applied to a straight pipe, a pipe with a half-moon-shaped aperture, a 90° bend, and a junction, which are typical geometries of flow-guiding structures found in automotive engineering. These kinds of geometries result in detached flows and can create various kinds of flow vortices responsible for sound generation inside the pipe. Consequently, combined aerodynamic and aeroacoustic pressure fluctuations act as an excitation mechanism on the structure which transmits and radiates sound waves into the environment. To validate the numerical model, measurements are performed on a modular test rig with comprehensive state-of-the-art measurement equipment, as depicted in Figure 3a. High-performance pressure transducers, differential pressure sensors, acceleration sensors, microphones, and a flow meter provide the necessary validation data. A modular arrangement allows an adaptation to different flow-guiding structures, for instance, the junction. Flow velocities of 40 m/s for a pipe inner diameter of 50 mm can be achieved. To capture the vibroacoustic sound radiation of the flow-guiding structure, the measurement object and the surrounding microphones are encapsulated in an acoustically treated cabinet lined with micro-perforated plates. The combination of the numerical model and the modular measurement setup enables us to gain deep insight into the mechanisms of sound generation and radiation of confined flows. Exemplarily, a visualization of the numerically obtained structural deformation and the sound radiation for the junction are given in Figure 3b.

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