PhD Position

« Biomechanics and self-sustained vibrations of the human vocal folds: computer modelling and experimental validation »

Project summary

Human phonation is produced through periodic self-sustained oscillations of the vocal folds excited by air flowing from the lungs. Vocal-fold tissues possess remarkable abilities to endure large reversible deformations despite of the collisions they are subjected to at each periodic cycle, to vibrate from 50Hz up to 1500Hz and to adapt their vibratory behaviour to external loadings (fluid, acoustics). Such unique performances result from complex biomechanical features and fluid-structure-acoustic interactions which remain poorly understood so far. The global motivation of this project is to gain an in-depth understanding of the multi-physics processes driving human phonation, so as to improve the current clinical plans for patients with voice disorders and prepare the future development of suitable biomaterials for voice rehabilitation.

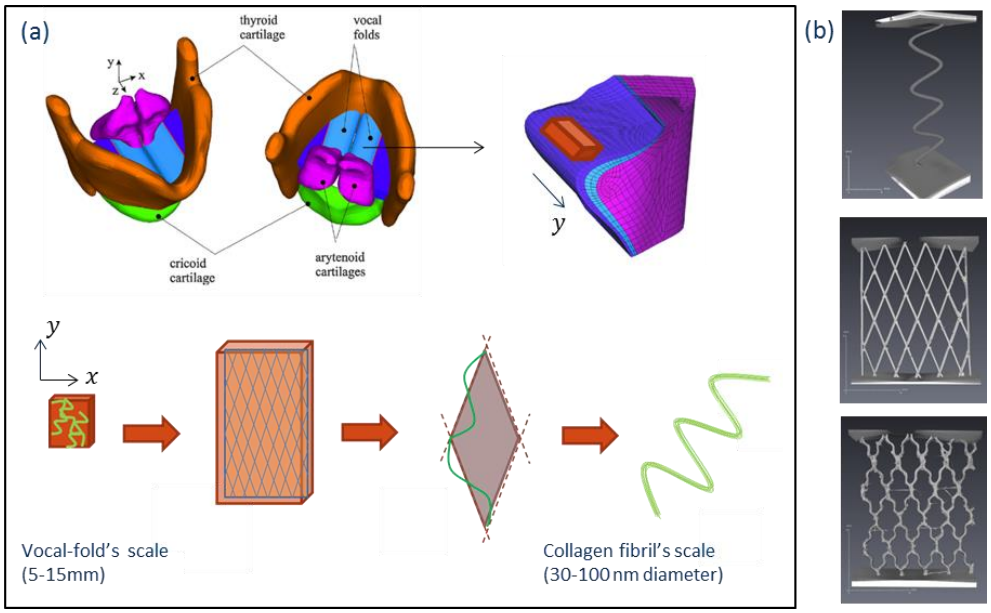

Figure 1: (a) Current 3D finite element model of the human larynx developed by the Czech Team (from Vampola et al., 2016) and scheme of the upscaling approach used by the French Team to model the micro-mechanical behaviour of vocal-fold tissue (Cochereau et al., 2016, Bailly et al., 2014) ; (b) Illustrations of artificial fibrous networks realised for model validation.

To this end, this PhD aims to **develop and validate a 3D realistic biomechanical model of human phonation**, **able to simulate the multi-scale physiological deformation of laryngeal tissues under fluid/structure interaction**. The planned strategy is divided into three progressive phases:

(i) from the mechanical modelling of one vocal-fold single layer without any fluid loading,
(ii) to that of the whole 3D multi-layered structure,
(iii) to finally consider the airflow loading and the ability of the coupled system to simulate flow-induced vibrations.

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During each modelling phase, a specific focus will be given to the specificities of vocal tissue's structural (microstructural arrangement of collagen and elastin fibrous networks, mass of the different constitutive layers) and mechanical properties (non-linear elasticity, viscosity), to their impact on vocal-fold vibromechanical properties and thereby, on voice quality. Though the PhD student will be mostly involved in theoretical and numerical tasks, experimental tests will be performed on several biomimetic composite materials for model validation.

The project is a collaborative work between scientists from Grenoble (France) and Prag (Czech Republic): Lucie Bailly and Laurent Orgéas (**3SR Lab**, https://www.3sr-grenoble.fr/), Tomáš Vampola (**CTU**, www.cvut.cz/en), Nathalie Henrich Bernardoni (**GIPSA-lab**, www.gipsa-lab.grenoble-inp.fr/), and Jaromír Horáček (**IT CAS**, http://www.it.cas.cz/en/). Thereby, this project gathers a Czech team known for having developed one of the last 3D fully parametric model of the human larynx specially adapted for numerical simulation of vocal-fold vibrations with collisions, and a French team actively working in mechanics and physics of soft fibrous (bio)materials, with recent theoretical and experimental developments applied on vocal-fold multiscale mechanics (see Figure 1).

Location and practical aspects

The successful applicant will be hosted:

- For half the duration, by the laboratory **Soils, Solids, Structures, Risks** (**3SR Lab**, UMR5521 - Grenoble, France) in the research group "mechanics and multiphysics couplings in heterogeneous media".
- For the other duration by the Czech Technical University (**CTU**- Faculty of Mechanical Engineering – Prag, Czech Republic) in the Department of Mechanics, Biomechanics and Mechatronics.

The PhD fellowship offer is available from **October 2017** for a period of **3 years**.

Qualifications of the applicant

Applicants must have a Master 2 or an equivalent degree, when starting the PhD.

Candidates with academic backgrounds in solid mechanics, material and structural engineering are expected. Specific skills in dynamics of composites, vibromechanics, and numerical mechanics will be strongly appreciated. Additional knowledge in acoustics and/or biomechanics of soft tissues will be interestingly examined.

Applications

Interested candidates should send: their **CV**, a **cover letter** and **official transcripts and ranks of the last two years** (Master M1 + Master M2 or engineering school) before **2017, July the 07th** to both:

- Lucie BAILLY, lucie.bailly@3sr-grenoble.fr, (+33) (0)4 76 82 70 85
- Tomáš VAMPOLA, Tomas.Vampola@fs.cvut.cz, +420 22435-7244.

References

BAILLY L., TOUNGARA M., ORGÉAS L., BERTRAND E., DEPLANO V. AND GEINDREAU C. (2014). *In-plane mechanics of soft architectured fibre-reinforced silicone rubber membranes.* J Mech Behav Biomed Mater 40:339-353.

COCHEREAU, T., BAILLY, L., ORGÉAS L., HENRICH BERNARDONI, N. AND CHAFFANJON P. (2016). *A micro-mechanical model of the vocal-fold upper layers*. 22nd Congress Europ Soc Biomech, July 10 - 13, 2016, Lyon, France.

VAMPOLA, T.; HORÁČEK, J.; KLEPÁČEK, I (2016). *Computer simulation of mucosal waves on vibrating human vocal folds*. Biocybernetics and Biomedical Engineering, roč. 36, č. 3, s. 451-465.