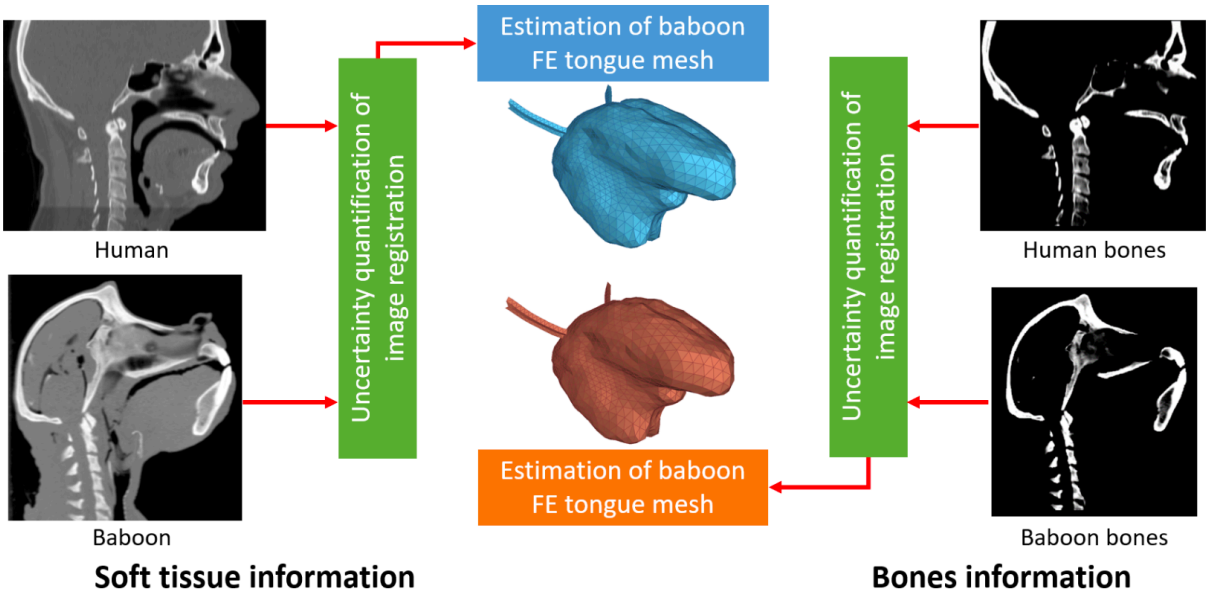
PhD Position at Sorbonne University in Paris, France
ISCD (Institut du Calcul et de la Simulation) : full time position , 36 months

Aeroacoustic modelling to investigate the phonic ability of Neanderthals

Context: The issue of the phylogenetic emergence of speech in humans is the focus of lively and strong debates. It questions both cognitive and physical capacities of fossil hominins to articulate speech. For the past 4 years, our multi-disciplinary research group "Origins of Speech" supported by ISCD in Sorbonne University has focused on the quantitative investigation of the physical aspects of the debate. More precisely, we rely on the design biomechanical models of fossil hominins' vocal tracts and on the assessment of their capacity to articulate distinctive sounds as is required for the emergence of spoken language. A first and important step has been reached with the validation of a predictive 3D finite-element model for tongue morphology which has been built using a mesh registration approach with 3D CT images of the head and neck. In [1] we have showed that this method has been able to accurately predict a female baboon tongue using combined data from a reference biomechanical tongue model of a living human from bony structures alone (see figure bellow extracted from [1]).



Currently, preliminary results has allowed us to generate the first prediction of tongue for a fossil hominin. Nevertheless, the qualitative assessment of the predicted tongue (for baboon or fossil hominin) alone does not provide information on the production of voiced speech.

The process of voice production is a complex process. Indeed, the primary source of sound in the vocal tract is the modulation of the glottal airflow by the vocal folds opening and closing periodically. The motion of the vocal folds depends on the pressure loading on their surfaces due to the airflow. In turn, the airflow through the vocal tract is altered by the presence and motion of static and dynamic laryngeal structures (see [2]). This airflow then enter the oral cavity where it is deviated by the tongue mouvement.

Objective: The aim of this PhD project is to study the phonic ability using the interaction of the activated tongue with the airflow generated in the vocal tract. An aeroacoustic model [3] which allows modeling the generation and propagation of waves in the supra-glottic system (the vocal tract) by using the principles of fluid mechanics and their interaction with structures will be exploited. We particularly aim in investigating accurate aeroacoustic models capable to predict consonants in such complex geometry since in this case the fluid-structure interaction are central to the sound prediction. We will first focus on studying and validating our aeroacoustic model on 2D cuts on the baboon tongue obtained in [1] using incompressible Navier-Stokes equations solved numerically in Basilisk solver [4]. The final aim of this study is to extend this analysis to the biomechanical tongue of the fossil hominin.

This research subject is defined on the tools and skills mobilized within the ISCD and meet the objectives of the scientific project "Origins of Speech". In this context, the PhD student will benefit from original study material such as experimental and simulated data for validation and verification purposes.

This is a multidisciplinary thesis supervised by a team of experts from National Museum of Natural History and from the mechanical institut Jean Le Rond d'Alembert at Sorbonne University.

Amélie Vialet - co-director (HdR).
Coordinator of the "Origins of speech" (2020-2022) team hosted by ISCD. She is a paleontropologist expert in the evolution of the cranial complex of the first Eurasian hominins

Anca Belme - co-director HdR (numerics in mechanical engineering)
Associate Professor at the mechanical institut Jean le Rond d'Alembert and member of « Origins of Speech » team, expert in applied mathematics to mechanical problems, more precisely in numerical methods for fluid flows simulations.

Antoine Hajczak (co-superviser) : Associate Professor at the mechanical institut Jean le Rond d'Alembert and member of « Origins of Speech » team, expert in aeroacoustic propagation and source.

Bibliography:

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[3] Hajczak, A. (2020). **Méthodes numériques d'identification des sources de bruit aérodynamique pour les trains d'atterrissage**. Sorbonne université.

[4] van Hooft, J.A., Popinet, S. **A fourth-order accurate adaptive solver for incompressible flow problems.** ***Journal of Computational Physics*** , 2022, 462, 111251 http://basilisk.fr/