Mandatory use of the following format for the title of the file for the web site management.

PhD_ECM_IF_ DASILVA
ECXX = ECLi, ECL, ECM, ECN, CS
LABYY = acronyme du laboratoire
NOMChercheur = nom du chercheur émetteur du sujet – futur directeur de thèse

PhD Proposal 2019

School - Location: Ecole Centrale Marseille	
Laboratory: INSTITUT FRESNEL	Web site: www.fresnel.fr
Name of the supervisor: Dr Anabela DA SILVA	Email: anabela.dasilva@fresnel.fr

Title: Modeling, imaging, and diagnostic with PhotoAcoustics of biological tissue viability
Scientific field: Biophotonics-Bioengineering - Biomechanics
Key words: multiphysics modelling - quantitative imaging – finite element – degeneration diseases – intervertebral disc

Details for the subject:

Background, Context:

Everyone has had, or will have, one day a backache. This pathology is very common and unfortunately very incapacitating: lowback pain is the most relevant cause of sick leave in France, which represents 25% of the total daily allowances paid. In that framework rachis degeneration diseases (DD) are, normally, related to age but in some case can occur early without too much warning except a vague back pain. Unfortunately the later stages of the DD are very painful and disabling, and induce necessarily a surgical treatment. So, the early detection of these kind of disorders is of a great importance as this allows to set up less invasive treatment. In that study we will focus on the diagnostic of the intervertebral disc degeneration by combining an original coupling between data acquired by non invasive quantitative photoacoustics imaging system developed at the Institut Fresnel and state of the art biomechanical finite element models implemented at IRPHE, both in Marseille.

Research subject, work plan:

Intervertebral discs (IVD) are fibrocartilaginous organs that provide the linkage and mobility of the vertebrae of the spine. Healthy, they have a high water content, nearly 80% by volume, which

diminishes with age thus decreasing intervertebral mobility and nutritional contributions to disc cells. Disc degeneration (DD) is thus a process in principle natural that continues throughout life but can, under the influence of various factors, accelerate suddenly and become pathological. Early detection of this pathology, at the first signs of back pain, is therefore of great interest to quickly establish effective treatments. However, there is currently no non-intrusive technique for doing a reliable diagnosis of DD, and intrusive techniques (biopsies) cannot be used due to the lack of regeneration of the disc tissue when it is damaged. We have recently shown the central role played in this pathology by the regulation of the water content of the IVD which proceeds from a delicate balance between mechanical stresses exerted by the adjacent vertebrae, electrochemical phenomena within the extracellular matrix (ECM) and the performance of the nutritional transport processes throughout the ECM. The multiphysical model developed makes it possible to estimate the viability of the organ but requires the knowledge of geometric, mechanical and physical properties of the IVDs to initialize the calculation.

The objective of this thesis is to determine some of these properties by using data from quantitative imaging photo-acoustics, a hybrid imaging technique, combining optical illumination and acoustic detection. It has been shown that the water content of tissues or properties related to their internal structure (collagen network structure). By performing spectroscopic measurements (800-1100 nm), the photoacoustic technique allows to obtain the internal biodistribution of the chromophores constituting the probed organ. The research work will thus be both experimental and numerical with the participation in the photoacoustic measurement campaigns and the coupling with the multi-physics biomechanical model. The first semester of the PhD work will be devoted to bibliography related to the subject and to familiarize with the different theories and the implementation of the numerical models. During the second semester we will focus on a better description of the evolution of internal permeability of the collagen network under finite deformations. During the same time the PhD student will participate to experimental *ex vivo* campaigns using excised IVD from pigs. The last two years will be devoted on the coupling between data coming from the imaging techniques and the numerical model in order to assess reliable indicators of the disc viability.

This PhD program covers a wide range of disciplines, persons with a combination of experimental and physics skills, and a good computational background are particularly encouraged to apply. The student candidate should have a good knowledge in physics, mechanics and finite element methods. The knowledge of image processing techniques will be appreciated. Experience of or interest in working in a multi-disciplinary environment is a plus.

References:

- Ghiss, M., Giannesini, B., Tropiano, P. , Tourki, Z., Boiron, O. (2016). Quantitative MRI water content mapping of porcine intervertebral disc during axial compression. Computer Methods in Biomechanics and Biomedical Engineering, 19-10, 1079-1088
- M. A. Chetoui, O. Boiron, A. Dogui, V. Deplano., Prediction of intervertebral disc mechanical response to axial load using isotropic and fiber reinforced FE models. (2017) Computer Methods in Biomechanics and Biomedical Engineering, 20(S1), 39-40. Proceedings of the Congrès de la société de biomécanique, Reims (France) .
- A. Da Silva, et al., “Taking advantage of acoustic inhomogeneities in photoacoustic measurements,” J. Biomed. Opt. 22(4), 041012 (2017).
- A. Da Silva, K. Metwally, O. Boiron, V. Deplano, S. Prost, " Probing intervertebral discs with photoacoustics," OSA/SPIE European Conference on Biomedical Optcs, Munich (Germany), june 2019.