Université de technologie de Compiègne – Thesis proposal

Part 1: Scientific sheet	
Title	Toward a patient-specific digital twin of the face: finite element modeling and multiscale active behavior of facial muscles from multimodal data.
PhD grant	ANR PEPR Santé Numérique (Projet PREDIT4FACE)
Research laboratory	BMBI Biomechanics and Bioengineering UMR CNRS 7338 web site: https://bmbi.utc.fr/ research team: C2MUST
Thesis supervisor(s)	Professor Marie-Christine HO BA THO (BMBI) Associate Professor Mohamed RACHIK (Roberval) Co-supervisors : Professor Tien Tuan DAO (BioTiM@LamCUBE, Centrale Lille Institut) Associate Professor Olfa TRABELSI (BMBI)
Scientific domain(s)	Biomedical and health sciences Computer science and information technologies
Research work	**Context:** The PhD research topic is part of the multidisciplinary PREDIT4FACE project, which was selected within the PEPR Digital Health Call for Projects of France 2030. PREDIT4FACE (**PRE**dictive **DI**gital **T**wins for **FAC**ial **E**xpression) aims to develop a multiscale predictive digital twin of the face to better understand, model, and rehabilitate facial expressions. The project is led by the BMBI laboratory (UTC-CNRS) and brings together a multidisciplinary consortium with the following partners: CHIMERE (UPJV-CHU Amiens, INSERM), LaMcube (Centrale Lille Institut, CNRS), LATIM (IMT Atlantique, INSERM), and Roberval (UTC). **Description:** Understanding the mechanical function of facial muscles during expressions and mimetic movements is crucial for establishing quantitative diagnoses and designing personalized functional rehabilitation strategies in patients with facial paralysis or after face transplantation. Finite element models have been developed to investigate muscle activation, contraction, and coordination during facial expressions [1,2]. However, this mechanical function remains poorly understood due to oversimplified muscle constitutive laws and muscle network representations. The objective of this PhD project is to develop a patient-specific digital twin of the face using the finite element method and multimodal MRI data. A multiscale active constitutive law for facial muscles will be developed to describe different contraction patterns (longitudinal and circumferential). The multiscale mathematical formulation and the identification of the associated parameters of the proposed constitutive law will be carried out using data from multiple sources (in vivo imaging, in vitro experiments, correlation, and regression) [3, 4, 5]. In particular, magnetic resonance imaging (MRI) will be used both to construct the finite element model and to characterize muscle contraction patterns during facial expressions and mimetic movements, which will subsequently be used for simulation and evaluation of the results. The PhD project is divided into five following tasks: 1) state of the art of the face finite element modeling, 2) patient-specific Face Modeling derived from MRI, 3) implementation of multiscale behavior of soft tissue and muscle 4) simulation of facial expression and 5) evaluation and comparison with MRI data. **References** [1] Fan A-F., Dakpé S., Dao T.T, Pouletaut P., Rachik M., Ho Ba Tho M-C (2017) MRI-based finite element modeling of facial mimics: a case study on the paired zygomaticus major muscles. Comput Methods Biomech Biomed Engin 20(9):919-928. https://doi.org/10.1080/10255842.2017.1305363

	[2] Dao TT, Fan AX, Dakpe S, Pouletaut P, Rachik M, Ho Ba Tho MC (2018). Image-based skeletal muscle coordination: case study on a subject specific facial mimic simulation. Journal of Mechanics in Medicine and Biology https://doi.org/10.1142/S0219519418500203 [3] Ho Ba Tho M-C., Dao TT (2019) Knowledge Extraction From Medical Imaging for Advanced Patient-Specific Musculoskeletal Models. Encyclopedia of Biomedical Engineering, 135-142 https://doi.org/10.1016/B978-0-12-801238-3.99935-5 [4] Tran H. V., Charleux F., Rachik M., Ehrlacher A., Ho Ba Tho M. C (2007). In vivo characterization of the mechanical properties of human skin derived from MRI and indentation techniques. Computer Methods in Biomechanics and Biomedical Engineering Volume 10-Issue 6, Pages 401-407. https://doi.org/10.1080/10255840701550287 [5] Maillet, M, Kammoun M, Avril S, Ho Ba Tho M-C, Trabelsi O (2023). Non-destructive Characterization of Skeletal Muscle Extracellular Matrix Morphology by Combining Optical Coherence Tomography (OCT) Imaging with Tissue Clearing, Ann Biomed Eng, 51, 2323–2336. https://doi.org/10.1007/s10439-023-03274-2.
Key words	Digital twin of the face, Finite Element Modelling, multiscale mechanical behavior, muscle, multimodalities MRI data
Requirements	Master in Biomechanics, biomedical engineering, computer science, computer engineering
Starting time	October 2026
Location	Biomécanique et Bioingénierie BMBI, Université de technologie de Compiègne

Part 2: Job description	
Duration	36 months
Material resources	Hardware and software facilities of the C2MUST team, BMBI lab and UTC computational facilities https://pilcam2.utc.fr
Human resources	~ 40 permanent staffs, ~ 50 PhD students, postdocs, interns, master's students
Financial resources	Financial support for missions, international conferences
Working conditions	Weekly meetings with supervisors, monthly report, specific meeting with the consortium of the project PREDIT4FACE
Profile	Strong theoretical and practical knowledge of Finite Element Method Modeling and simulation of complex biomechanical systems Medical imaging knowledge Programming in Python and/or Fortran
Research project	Projet PREDIT4FACE (PEPR Santé Numérique)
National collaborations	PREDIT4FACE Consortium BMBI (UTC CNRS) CHIMERE (UPJV-CHU Amiens, INSERM), LaMcube (Centrale Lille Institut, CNRS), ROBERVAL (UTC) LATIM (IMT Atlantique, INSERM)
Application materials	CV, cover letter, academic transcripts, letter(s) of recommendation, publications
Contacts	Marie-Christine Ho Ba Tho (hobatho@utc.fr) Mohamed Rachik (mohamed.rachik@utc.fr) Tien Tuan Dao (tien-tuan.dao@centralelille.fr) Olfa Trabelsi (olfa.trabelsi@utc.fr)

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