International Joint PhD: South Africa and France

PhD Title: Bone quality estimation by 3D ultrasound: A learning approach for bone surgery planning applications

Locations: IMT Atlantique, LaTIM, INSERM UMR 1101, Brest, France ***AND***
Division of Biomedical Engineering, University Cape Town (UCT BME), South Africa

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Context and Objectives

Ultrasound imaging (US) is a non-invasive and portable modality for imaging fragile people or people with restricted mobility (children, older adults with osteoporosis etc.). However, it is limited to qualitative assessment of musculoskeletal disorders (MSD) primarily spanning soft tissues. While quantifying bone quality is an important step in the treatment of MSD for e.g surgery planning, diagnosis of osteoporosis, this metric is typically derived with the help of other imaging modalities such as Computed Tomography (CT) or DEXA scans. Moreover, in the context of resource-limited settings such as in South Africa, use of the US can be cost effective as well as patient friendly. Another interest of US imaging is its portability and ability for free-motion acquisition. For shoulder joints in particular, it is not possible to obtain CT or magnetic resonance imaging (MRI) for any flexion angle, which is a limitation for obtaining an accurate diagnosis in terms of joint functionality. For this PhD, the aim is twofold. First, we want to study the correlation between CT and US to obtain bone quality parameters (cortical surface roughness, thickness, fractal index of the trabecular bone, etc.) from the surface information obtained by 3D compounding of US imaging. Second, the 3D compounding needs to be obtained from deep-learning based markerless-probe avoiding occlusion problems and high costs from typical probe tracker systems. This project capitalizes on the previous expertise of two labs, UCT BME and IMT Atlantique/LaTIM and extends the collaboration to SCMIA, Pune, India. Indeed, thanks to 3D reconstruction in different flexions, our previously developed statistical Shape-Motion-Intensity framework [Fouefack] can be leveraged to provide a model of shoulder including shape, bone quality, and range of motion from the US.

Methodology

We plan to introduce learning methods, for obtaining the correlation between the bone surface appearance and the trabecular bone quality, and for estimating the 3D point cloud representing the US acquired objects. Reconstruction of 3D anatomy from ultrasound has been an active research area for over 20 years [Huang17]. [Barry97] proposed a reconstruction algorithm based on an electromagnetic probe position sensor. Since then, the methods have become more accurate and faster, introducing robustness via real-time signal processing and regularization by statistical models [Mahfouz21]. However, the basic principle remains the same: control the geometry, reposition the 3D images and obtain a point cloud of the surface to be studied. We propose to develop a deep learning algorithm capable of estimating the succession of rigid transformations underlying the probe trajectory.

Finally, the relative 3D positions of the reconstructed surfaces can then be validated on cadaveric data with bone trackers, or by a method already developed at the LaTIM for the pelvis [Guezou20]. We aim to use image data from several patients as input to build the statistical model of the shoulder, with real and free movement using a previously developed framework [Fouefack21], which integrates the correlations between the key characteristics of the bone components of the joint (shape, pose and volumetric intensities).

- Qinghua Huang, 2017, doi:10.1155/2017/6027029
- C. D. Barry, 1997, doi: 10.1016/S0301-5629(97)00123-3
- M.R. Mahfouz, 2021, doi: 10.1302/0301-620X.103B6.BJJ-2020-2455.R1
- Guezou-Philippe, 2020, doi: 10.29007/p362
- J.R. Fouefack, theses.fr/2021IMTA0240

International scientific environment

The candidate will work within the IMAGINE team of the LaTIM and the orthopedic surgery department of the CHRU of Brest (France). The subject is at the heart of the themes of the LaTIM's Imagine team, namely the diagnosis and management of musculoskeletal diseases through the development of personalized dynamic models based on learning methods and 3D statistical modeling. This PhD continues the dynamic research in the lab credited with a dozen publications and the acceptance of 2 regional, 1 national and 2 international projects.

It should be noted that it also has a strong international dimension since it confirms and strengthens a collaboration that has existed since 2012 between the Division of Biomedical Engineering (BME) of the University of Cape Town (UCT) in South Africa and the LaTIM in Brest. The first joint PhD degree was defended in March 2021. It also extends the collaboration to the SCMIA research center in Pune, India.

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Candidate profile

- Master degree with solid knowledge in image processing and applied mathematics
- Strong background in object-oriented programming language (C++, Java), Python
- Knowledge of VTK, ITK and Scalismo libraries
- English speaking, reading and writing is mandatory - French speaking is an advantage
- Good communication skills and ability to work in a team

Interested candidates (Please use subject line **DIPEKO22** in your message)

Send a link of downloading the following documents before **15 June 2022** to valerie.burdin@imt-atlantique.fr and please cc: tinashe.mutsvangwa@uct.ac.za

- Curriculum Vitae
- Motivation letter (one page maximum)
- All transcripts of the last 3 years of most recent qualifications
- Recommendation letter from two previous supervisors