PeRSAFE: Personalizing Reverse Shoulder Arthroplasty planning with Finite Elements

The SEED[1] program (academic track)

www.imt-atlantique.fr/seed

PhD topic open for applications until March 20, 2025

1 Definition

1.1 Domain and scientific/technical context

Osteoarthritis is a degenerative joint condition affecting about 528 million people worldwide. It affects the entire joint, causing pain, swelling and stiffness. When the joint is too severely affected, replacement surgery is needed to replace the damaged parts of bones by implants. While reverse total shoulder arthroplasty (RTSA) have become the treatment of choice for glenohumeral arthrosis and numerous other indications, its complication rate remains high (up to 58%) compared to other arthroplasties (around 5% for hip and knee). RTSA failures are mainly due to the implant malpositioning, since the surgery is usually not adapted to the patient's specific shoulder mechanical and functional properties. Bone anatomy, density and posture but also joint motion, muscle lengths and insertions are key elements for the shoulder proper functioning, however, their role and optimal contribution to RTSA outcomes remain unclear. Because of RTSA's growing incidence and high complication rate, it is critical to personalize RTSA to significantly improve the clinical outcomes and consequently improve patient quality of life and reduce the healthcare expenses.

[1] Co-funded by the European Union under Grant Agreement no. 101126644

1.2 Scientific/technical challenges

To improve implant positioning and overcome RTSA complications, one major challenge is to enable the fast and reliable computation of bone mechanical characteristics. Finite element (FE) modelling is an engineering tool for structural analysis that has been used for many years to assess the relationship between load transfer and bone morphology. Patient-specific FE models have shown to be valuable tools to optimise the design and fixation of orthopaedic implants, to assess the risks of fractures or to optimise pre-operative planning of implant placement. However, FE models are limited by their stability, generalisation ability, and computational speed thus restricting their wide adoption in clinical routine. The PhD objectives are therefore: (1) to quantify the variability of subject-specific material properties of the scapula in RTSA patients, to further define boundary and loading conditions based on individualised data; (2) to speed up FE model computation through machine learning prediction, in order to make it usable in clinical routine; (3) to conduct experimental validation of FE prediction results, in order to establish their significance for clinical improvements.

1.3 Considered methods, targeted results and impacts

A Statistical Shape and Density Model (SSDM) of the scapula will be developed to describe both the variation in bone shape and material properties, i.e. the bone density. The SSDM will be used to generate any number of example bones, controlling the bone characteristics a-priori and thus design a study 'population' to broadly span patient variability. Machine learning (ML) will be used to predict the highly informative results of an FE simulation for a specific patient without actually having to conduct the analysis. FE analysis, SSDM and ML prediction will be implemented and merged into one computational tool to allow the rapid determination of the scapula mechanical characteristics. Particular attention will be given to ensure that FE analysis conditions are adapted to the patient physiological data and that experimental validation is thoroughly conducted.

1.4 Environment (partners, places, specific tools and hardware)

The PhD project will take place at IMT Atlantique and LaTIM (Laboratory of Medical information Processing) in Brest. It will benefit from the cluster centre of IMT Atlantique and LaTIM, which are regularly used to develop SSDM and ML models. LaTIM will provide a privileged access to the PACS (picture archiving and communication system) of the University Hospital of Brest, ensuring the data anonymisation and patients consent to their data being used for research purposes.

1.5 Interdisciplinarity aspects

The proposed PhD will mix knowledge from multiple domains: (1) orthopaedics with the focus on shoulder surgery, (2) computer vision with the SSDM to model the scapula, (3) biomechanics with FE models and their experimental validation, and (4) artificial intelligence with the implementation of a machine learned model for predicting FE models.

2 Partners and study periods

2.1 Supervisors and study periods

- **IMT Atlantique**: Prof. Tinashe Mutsvangwa and _Assoc.-Prof.Aziliz Guezou Philippe _, IMT Atlantique, Brest, France
- **International partner**: Assist.-Prof. Josh W. Giles, Victoria, Canada

  The PhD student will stay 1 year at University of Victoria.
- **Non-academic partner(s)**: for short-term visits have not yet been determined. However, cooperations with non-academic partners on similar topics will be harnessed, notably avec University Hospital of Brest.

2.2 Hosting organizations

2.2.1 IMT Atlantique

IMT Atlantique, internationally recognized for the quality of its research, is a leading French technological university under the supervision of the Ministry of Industry and Digital Technology. IMT Atlantique maintains privileged relationships with major national and international industrial partners, as well as with a dense network of SMEs, start-ups, and innovation networks. With 290 permanent staff, 2,200 students, including 300 doctoral students, IMT Atlantique produces 1,000 publications each year and raises 18€ million in research funds.

2.2.2 University of Victoria

At University of Victoria we combine three elements: dynamic learning, vital impact and our extraordinary academic environment. Together, these three elements nurture an environment of discovery, innovation and creativity. This fortifies our work in sustainability and healthy societies. It shapes our world view with diverse perspectives, including those from Indigenous and international communities. It fuels our commitment to economic well-being, technological advances and social justice.