Size and Shape Optimization of a 3D printed Composite Foot Prosthesis

Prosthetic feet are usually made of carbon fibre laminates, the manufacturing of which usually requires expensive large moulds. Combined with the already high price of the material, these prostheses are usually very expensive and allow for very limited customisation. Additive Manufacturing (AM) of prostheses is one of the best ways to overcome these issues, since this technique allows an unprecedent design freedom with no mould or assembly costs [1].

The objective of this thesis is thus the numerical design and optimisation of an additively manufactured prosthetic foot, considering several biomechanical factors. In an earlier work, a finite element optimisation tool was already developed for this purpose using Matlab. While leading to the evaluation of several prosthetic foot shapes, the design tool was limited to the evaluation of the prostheses' stiffness in the mid-stance phase (foot parallel to the ground). The new work aims to a more holistic design, that takes into account bio-mechanical parameters characteristic of the whole gait cycle (e.g. roll-over shape) [2] and new geometrical descriptors (namely Bezier curves) [3].

The following activities are thus expected to be performed:

- Develop a code that generates several foot geometries using Bezier curves
- Implement the use of bio-mechanical parameters as possible design features
- Use the developed tool for the identification of an optimised prosthetic foot, and validate its performance with Abaqus

Required skills:

- Finite element theory and modelling with Abaqus
- Matlab or Python coding skills (or willingness to learn)
- Basic knowledge of the mechanical behaviour of composite materials

Expected duration: 6 months
Type: full thesis, with examiner (controrelatore)
Experimental activity: no

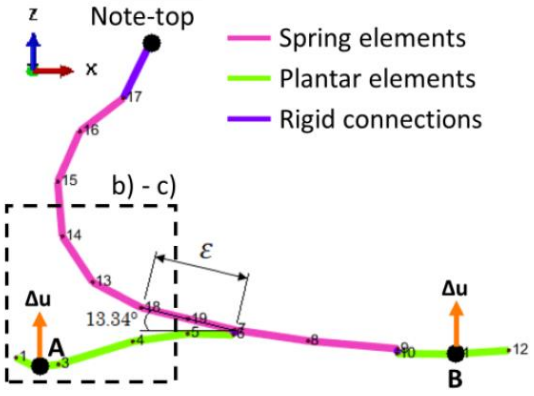

Figure 1: a) Example of a beam model of an additively manufactured prosthesis. Several designs can be obtained by varying the optimisation variables ε.

[1] Parandoush P, Lin D. A review on additive manufacturing of polymer-fiber composites. Compos Struct 2017; 182: 36–53.

[2] Hansen AH et al. The effects of prosthetic foot roll-over shape arc length on the gait of trans-tibial prosthesis users. Prosthet Orthot Int. 2006 Dec;30(3):286-99.

[3] Olesnavage KM, Prost V, Johnson WB, Amos Winter VG. Passive prosthetic foot shape and size optimization using lower leg trajectory error. J Mech Des Trans ASME 2018;140.