**2.2 User requirements – parametric surfaces and muscle wrapping**

**Generation of parametric surfaces**

**1) All results must be described and how these results should be presented. = OUTPUT data from new operations.**

The coordinator ULB previously developed three-dimensional (3D) quadric surface fitting in particular bones (humerus, femur, pelvis, tibia)(Sholukha et al., 2011; Chapman et al., 2015). Three-dimensional quadric surface fitting is the fitting of 3D shapes (i.e. ellipsoids, spheres, one sheet hyperboloid and two sheets hyperboloid) onto bones to accurately mathematically model the bone and to enable direct comparisons with other similar bones. This is a useful tool for anthropologists as you could analyse positions of quadric surfaces and also compare measurements of the surfaces with other bones. Quadric surfaces could also be useful as parametric objects to enable muscle wrapping to analyse fossil hominid locomotion.

Parametric objects need to be more stable so that muscle wrapping is possible. However, many of the parametric surfaces are not suitable for field work. The parametric surface ‘Sphere’ seems the most stable. However, after creating a plane, it cannot be found in the 3D space. Therefore the first task could be to ensure that parametric surfaces correctly work in the system. The stabilisation of parametric surfaces will also assist with the fitting of 3D shapes onto bones for analysis (which could be useful measurement tools) similar to the paper done by (Sholukha et al., 2011; Chapman et al., 2015).

A. The mechanism building parametric surfaces within FusionBox should be improved.

B. Automated measurements should be performed from the available parametric surfaces (which were present in MATLAB), which take the length and width of the object automatically.

C. It should be possible to export these measurements easily and from a group (similar to distance measurements)

**2) Methods and algorithms (with bibliographic references) to produce these results must be detailed.**

An elegant solution would be to estimate the best parametric surfaces from a set of landmarks located in space. Victor is working on a Matlab code to do this.

***An algorithm for tting an ellipsoid to data***

Quadric surface (QS) fitting approximate cloud of points using linear (least square) or/and optimisation (searching for best transform and three size parameters) solutions (Turner et al., 1999). Initially, we consider an algebraic representation of a QS and develop a linear least squares approach to the fitting problem (this does not in general yield the best geometric fit). This representation is then used as the basis for a parametric form for expressing QS, and we are able to derive an iterative algorithm for obtaining the best geometric fit, using the algebraic fit as a first estimate. By means of numerical examples, this new method is shown to be particularly suited to fitting near-spherical data with an ellipsoid, as well as being effective for data sets representing more eccentric ellipsoids or QS. For more references please see “Task 2.1 Literature review OCT.docx”.

***Numerical Computation of Geodesics on Combined Piecewise-Smooth Surfaces***

Numerical computation of geodesics (Caplan et al., 2009) on parameterized surfaces has a number of useful applications. The method describes an approach of using a geodesic evolution algorithm to evolve an initial curve to a geodesic by computing numerical properties of the curve and moving the discrete points that approximate the curve in the direction of the geodesic curvature vector. Over time, the curve converges, to within a tolerance, to the geodesic whose geodesic curvature is numerically equivalent to zero. While focused on a single surface, the algorithm could be integrated within a larger software package to calculate the geodesic across multiple surfaces and boundaries.

***A General Approach To Muscle Wrapping Over Multiple Surfaces***

A common approach to represent muscle wrapping uses approximate discretized wrapping curves (Delp and Loan, 1995). In dynamics simulations, discontinuous changes in wrapping paths due to discretization can degrade simulation performance. Another approach to model muscle wrapping uses analytical equations for simple shapes such as spheres and cylinders (Garner and Pandy, 2000; Marsden et al., 2008). This approach does not generalize to muscle paths that wrap around more than two surfaces or complex wrapping surfaces.

Here we introduce (Stavness et al., 2012) a novel formulation to compute smooth wrapping curves for arbitrary numbers of wrap surfaces. The formulation permits the use of general smooth geometric surfaces with implicit or parametric representations and incorporates fast analytical equations for the special cases of simple shapes. This method generates smooth wrapping paths suitable for high-order time integration, and allows biomechanical models of the spine, finger, shoulder, and other systems to incorporate wrapping paths over multiple anatomical structures with complex shapes. For more references please see “Task 2.1 Literature review OCT.docx”.

**References**

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**3) User interface and user actions required to inject INPUT data into the algorithms**

A. Generation of parametric surfaces

**Muscle wrapping**

**1) All results must be described and how these results should be presented. = OUTPUT data from new operations.**

An important feature in musculoskeletal analysis if muscle behavior during motions. The FusionBox already include such a feature that runs according to several strategies: 1) muscle line-of-action (LOA) as a straight line (this feature works correctly, no muscle wrapping); 2) muscle LOA including wrapping defined with so-called wrapping point (this feature works correctly; but in practise wrapping points are difficult to define); 3) muscle LOA including wrapping around parametric surfaces (here the behaviour of the muscle LOA is somehow unpredictable because, we believe, not enough constraints has been implemented in the code).

A. The wrapping method around parametric surfaces should therefore be improved.

B. An Excursion tendon method could also be incorporated into lhpFusionBox – this will help with the analysis of muscle wrapping

**2) Methods and algorithms (with bibliographic references) to produce these results must be detailed.**

**3) User interface and user actions required to inject INPUT data into the algorithms**