Real-time Animation of Human Characters' Anatomy

Supplementary Material

1 Introduction

In a similar manner to real bones, the virtual skeleton allows the body movements. The virtual skeleton is represented by a hierarchical set of connected virtual bones. The movement of each virtual bone is defined by a rotation in the bone's local coordinate system. This local coordinate system is computed according to the method proposed below.

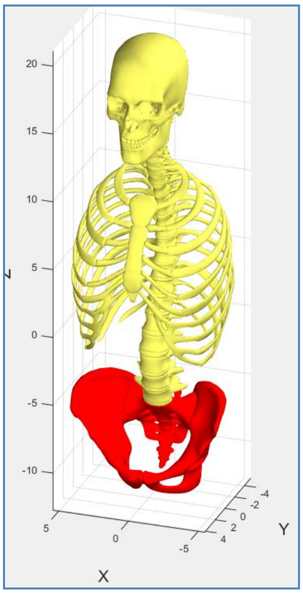
We plan to integrate our algorithm into a system to build virtual patient models for virtual reality medical simulators. Each virtual patient is built registering a generic virtual model into real patient data.

In the generic model bone tissue (before the registering process), some anatomically meaningful regions of the bone tissue are manually identified, labelling some of their vertices.
We are assuming that when the generic model is registered to patient-specific data, these identified regions will also represent the same anatomical region of the patient. In order to make the virtual skeleton calculations more robust the algorithm considers, when it is possible, large regions for which most of the vertices will be registered properly, outnumbering the failure cases. After the registering process, these labelled regions are used to compute the local reference system of each bone. This process was specifically designed for each bone of our virtual skeleton and it is detailed in the following sections:

2 Hips

Rotation Centre

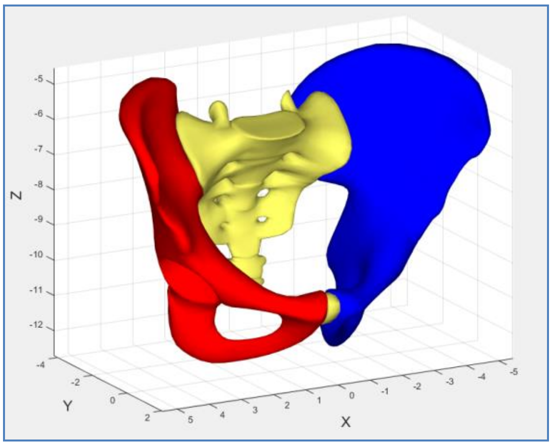
Calculated as the barycentre of the pelvis region, highlighted in red on the following figure:



Basis vectors

- The Y vector is calculated as the vector from the Hips coordinate system centre to the Spine coordinate centre (see below) and normalized

- The X vector is calculated as the vector from barycentre of the Ilium region Left (in blue on the following figure) to the barycentre of the Ilium region Right (in red on the following figure), and then projected into the plane whose Y-vector is a normal to ensure that X and Y are exactly orthogonal, and finally normalized

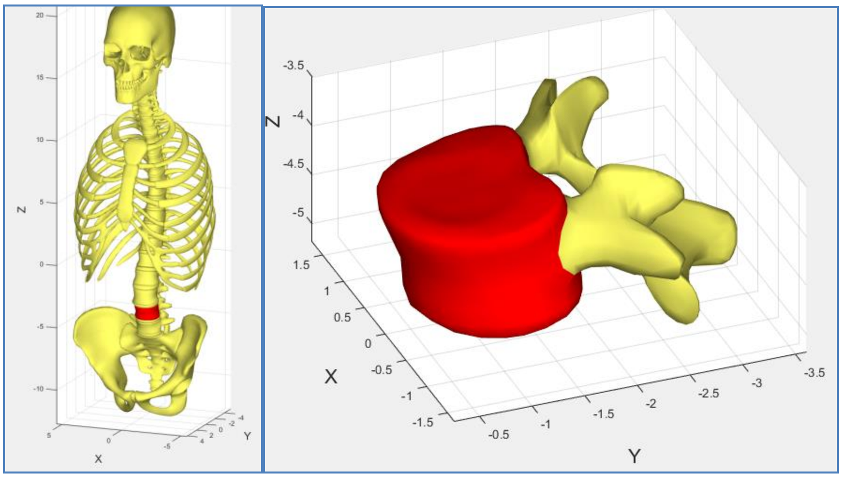


- The Z vector is the cross product of X and Y vectors

3 Lower Spine

Rotation Centre

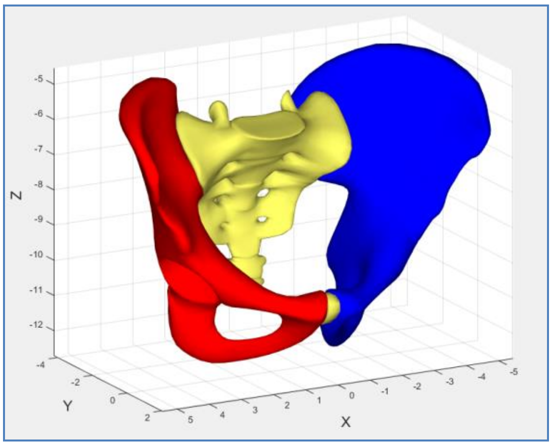
Calculated as the barycentre of the body region of the L4 vertebra, highlighted in red on the following figures:



Basis vectors

- The Y vector is calculated as the vector from the Lower Spine coordinate system centre to the Chest coordinate centre (see below) and normalized

- The X vector is also calculated as the vector from barycentre of the Ilium region Left (in blue on the following figure) to the barycentre of the Ilium region Right (in red on the following figure), and then projected into the plane whose Y-vector is a normal to ensure that X and Y are exactly orthogonal, and finally normalized

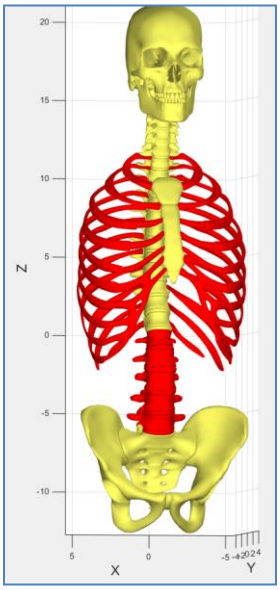


- The Z vector is the cross product of X and Y vectors

4 Chest

Rotation Centre

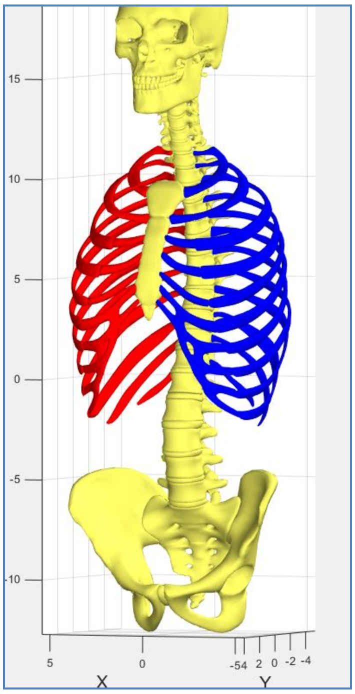
Calculated as the barycentre of the lumbar spine and ribs regions, highlighted in red on the following figure:



Basis vectors

- The Y vector is calculated as the vector from the Chest coordinate system centre to the barycentre of the two shoulder coordinate centres (see below) and normalized

- The X vector is also calculated as the vector from barycentre of the Ribs region Left (in blue on the following figure) to the barycentre of the Ribs region Right (in red on the following figure), and then projected into the plane whose Y-vector is a normal to ensure that X and Y are exactly orthogonal, and finally normalized

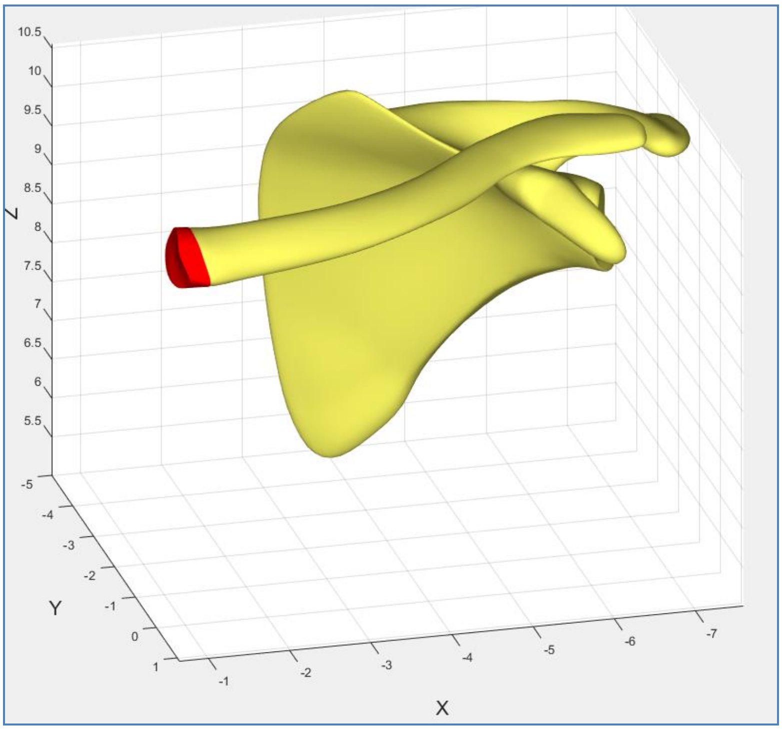


- The Z vector is the cross product of X and Y vectors

5 Shoulders

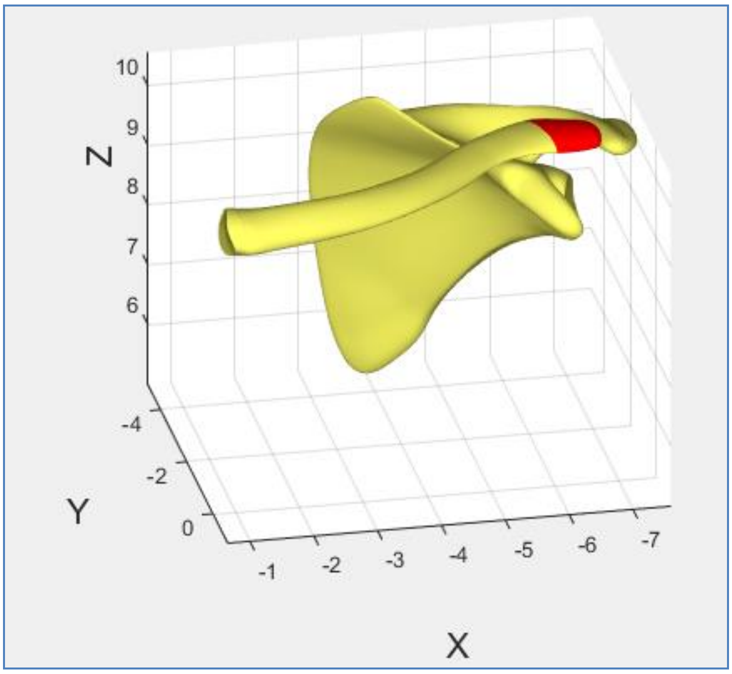
Rotation Centre

Calculated as the barycentre of the sternal region of the clavicle regions, highlighted in red on the following figure:

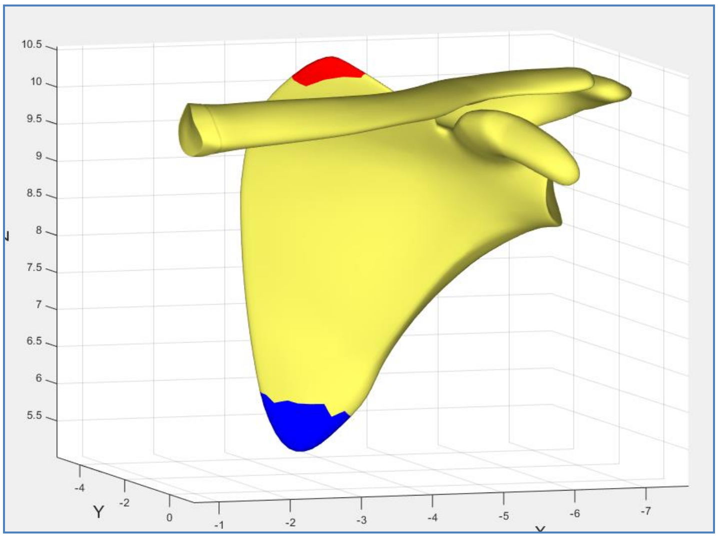


Basis vectors

- The Y vector is calculated as the vector from the Shoulder coordinate system centre to the barycenter of the acromial region of the clavicle (in red on the figure below) and normalized



- The Z vector is also calculated as the vector from barycentre of the Scapula Inferior region (in blue on the following figure) to the barycentre of the Scapula Superior region (in red on the following figure), and then projected into the plane whose Y-vector is a normal to ensure that Y and Z are exactly orthogonal, and finally normalized

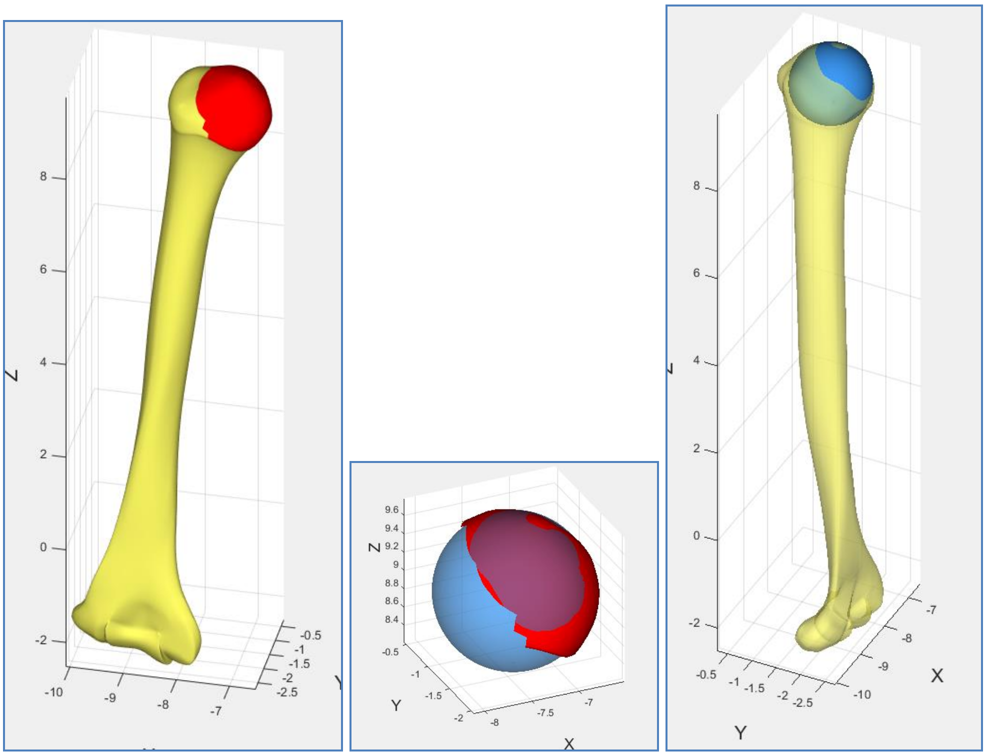


- The X vector is the cross product of Y and Z vectors

6 Upper arms

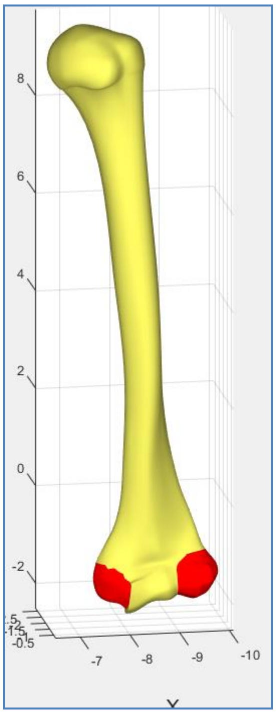
Rotation Centre

Calculated as the centre of the sphere fitting at best (in the least square sense) the Humerus Head region (in red below). The arm rotates around this head and the centre of the sphere should be therefore quite logically the centre of rotation:

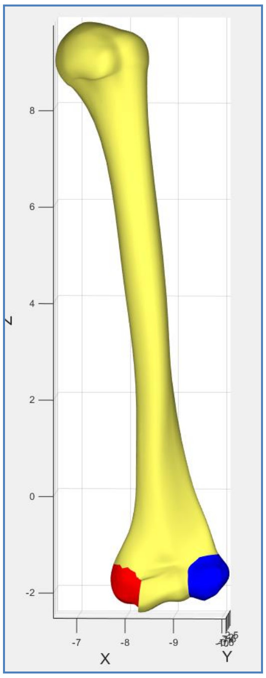


Basis vectors

- The Y vector is calculated as the vector from the Upper arm coordinate system centre to the barycentre of the medial and lateral Humerus condyles regions (in red on the figure below) and normalized



- For the left side, the X vector is also calculated as the vector from barycentre of the Humerus Condyle Lateral region (in blue on the following figure) to the barycentre of the Humerus Condyle Medial region (in red on the following figure), and then projected into the plane whose Y-vector is a normal to ensure that X and Y are exactly orthogonal, and finally normalized. The vector is in the opposite direction for the right side

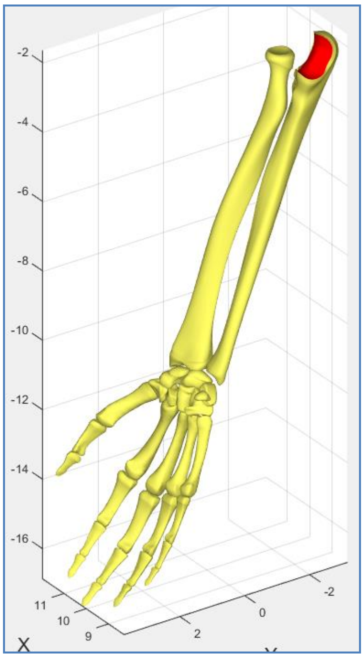


- The Z vector is the cross product of X and Y vectors

7 Fore arms

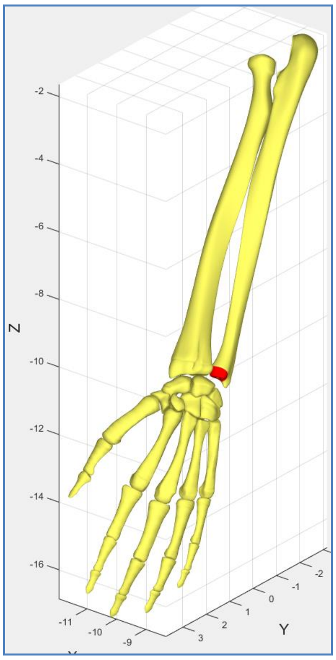
Rotation Centre

Calculated as the barycentre of the trochlea region of the ulna, highlighted in red on the following figure:



Basis vectors

- The Y vector is calculated as the vector from the Forearm coordinate system centre to the barycentre of the Ulna Head region (in red on the figure below) and normalized



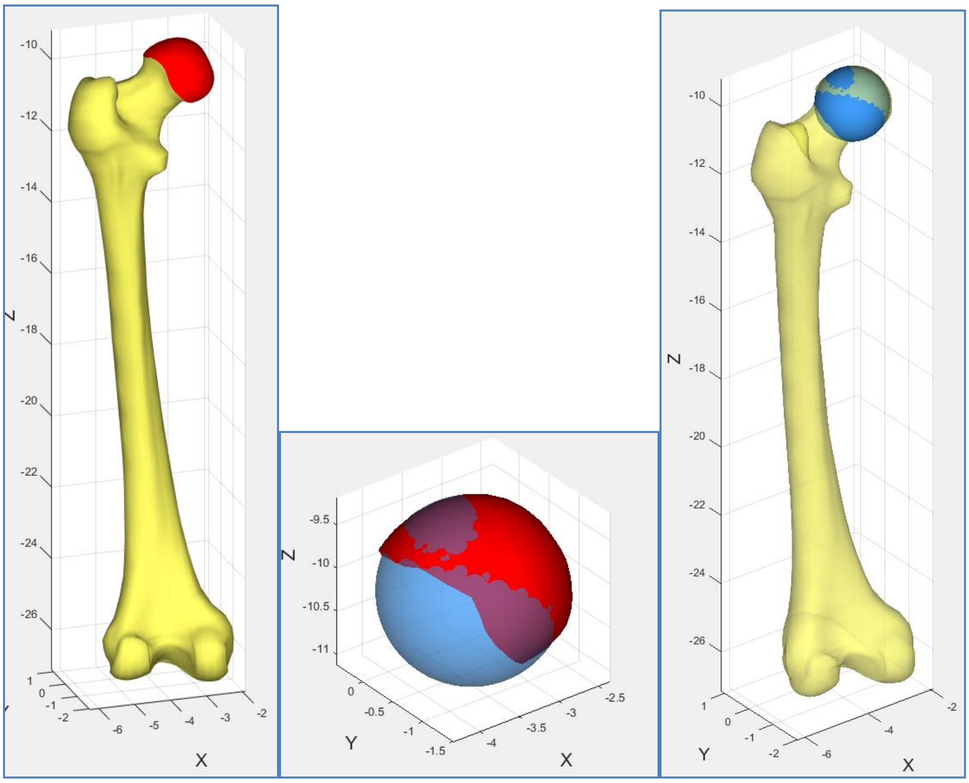
- For the left side, the X vector is also calculated as the vector from barycenter of the Humerus Condyle Medial region (in red on the figure describing the X vector of the Upper Arm section) to the barycenter of the Humerus Condyle Lateral region (in blue on the figure describing the X vector of the Upper Arm section), and then projected into the plane whose Y-vector is a normal to ensure that X and Y are exactly orthogonal, and finally normalized. The vector is in the opposite direction for the right side

- The Z vector is the cross product of X and Y vectors

8 Thighs

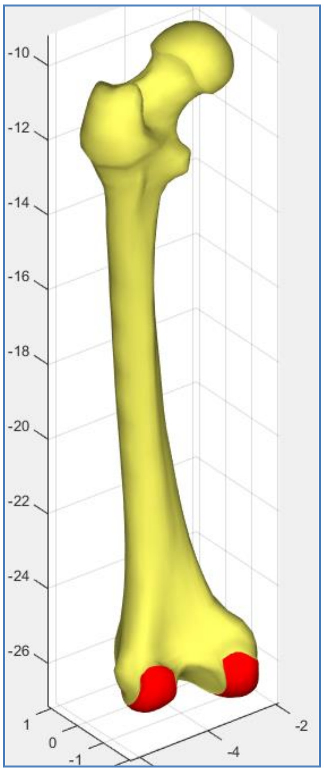
Rotation centre

Calculated as the centre of the sphere fitting at best (in the least square sense) the Femur Head region (in red below). The femur rotates around this head and the centre of the sphere should be therefore quite logically the centre of rotation:

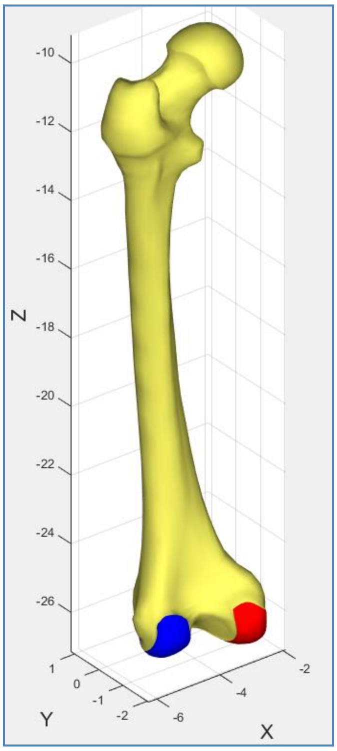


Basis vectors

- The Y vector is calculated as the vector from the Thigh coordinate system centre to the barycentre of the medial and lateral Femur condyles regions (in red on the figure below) and normalized



- For the left side, the X vector is also calculated as the vector from barycentre of the Femur Condyle Medial region (in red on the following figure) to the barycentre of the Femur Condyle Lateral region (in blue on the following figure), and then projected into the plane whose Y-vector is a normal to ensure that X and Y are exactly orthogonal, and finally normalized. The vector is in the opposite direction for the right side

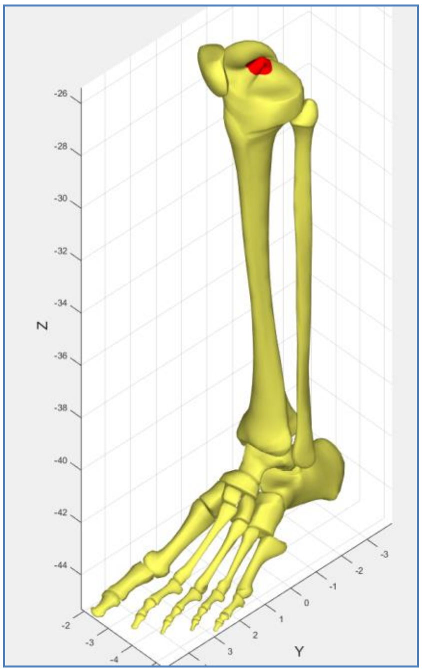


- The Z vector is the cross product of X and Y vectors

9 Shins

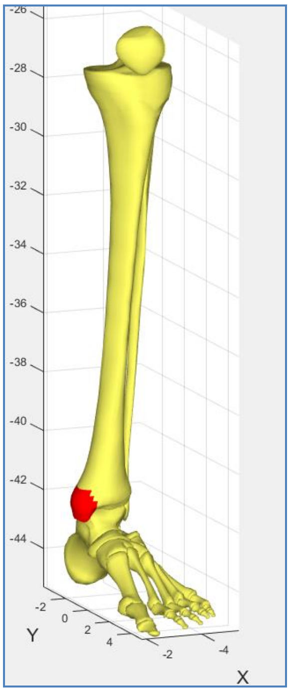
Centre

Calculated as the barycentre of the Intercondylar region of the tibia, highlighted in red on the following figure:



Basis vectors

- The Y vector is calculated as the vector from the Shin coordinate system centre to the barycentre of the Tibia Malleolus region (in red on the figure below) and normalized



- For the left side, the X vector is also calculated as the vector from barycentre of the Femur Condyle Medial region (in red on the figure describing the X vector of the Thigh section) to the barycentre of the Femur Condyle Lateral region (in blue on the figure describing the X vector of the Thigh section), and then projected into the plane whose Y-vector is a normal to ensure that X and Y are exactly orthogonal, and finally normalized. The vector is in the opposite direction for the right side

- The Z vector is the cross product of X and Y vectors

10 Adding new bones

We have added the bones listed above as a proof of concept. It must be highlighted that new bones could be added in a similar way.