Muscles are defined by linear segments connecting a series of Landmarks. The Landmarks can be created using any of the rules for creating landmarks in Visual3D.

Muscle Tab

Muscles are created and edited from the **Muscle Tab** in Model Builder Mode.

From this tab muscles can be created, edited, and deleted.

Muscle Definition

Muscles are defined as a connect series of linear segments, passing from Landmark to Landmark.

The user can add or delete the landmarks in the list box. The first landmark is always considered to be the **Origin** of the muscle, and the last landmark is always considered to be the **Insertion** of the muscle. All other landmarks are considered to be **Tether (Via)** points and are connected in the order they appear in the list box.

Terry Database

Kepple TM, Sommer HJ, Siegel KL, Standhope SJ (1998) A three-dimensional musculoskeletal database for the lower extremities. Journal of Biomechanics 31, pp 77-80

The locations of idealized muscle attachments on the pelvis, both femurs, both tibias and fibulas, and both feet were accurately digitized for 52 dried skeletal specimens….Statistical accumulation and scaling techniques were used to generate highly representative normative models, which were divided into groups and tested for differences based on gender and race….Containing over **12000 anatomical landmarks** digitized from 52 dried skeletons, this study represents an improvement over previous databases by an order of magnitude

Note that the limitation of the data set is that because the data collection was from bones, there is

little information on muscle path. For example, it was not possible to identify tether (or via) points related to, for example, attachments to the patella. Careful estimation of these via points is possible, but it is difficult to verify the accuracy of these estimates. This challenge is most serious for the estimate of the moment arms around some joints, and for the estimate of length of muscles that are short relative to the actual path.

If the purpose the muscle representation is visualization (e.g. mapping EMG to the color of the rendered muscles) these issues are not relevant.

The original data set can be downloaded Here.

The landmarks are stored in ASCII files. The structure of the data set is described in the files. An excerpt from the femur landmarks is presented here:

Description of landmarks digitized on the femur Each landmark is listed in the same order as they appear in the corresponding model files. The model file format is: (landmark #) x y z (# of specimens used to generate norm landmark) x is approximately anterior, y is superior, and z is right units are mm This file contains for each landmark:

1. landmark number followed by a description of where the landmark is located.
2. landmark type. The landmark type can be either externally palpable, muscle origin, muscle insertion, muscle connector (to wrap muscle around bone or through retinaculum), joint center (assumed to be a point of contact with the adjacent segment), or anthropometric (a point which may be of value for traditional anthropology measurements).
3. list of muscles associated with the point (origin, insertion or connector).

Affine Scaling of a Terry Landmark

Sommer H, Miller N, Pihanowske G (1982) Three-dimensional osteometric scaling and normative modeling of skeltal segments. Journal of Biomechanics 15, pp 171-180.

The linear algebra technique described in this article, **termed affine scaling**, scales the data based on all measured landmarks and allows for the statistical accumulation of landmark data in order to generate normative models.

Each landmark is defined relative to 3 or 4 landmarks that were selected to be palpable on living subjects (For example, the thigh landmarks are defined relative to the greater trochanter, the lateral epicondyle, and the medial epicondyle).

Visual3D Representation of a Terry Landmark

The following Visual3D command is used to define a landmark representing the **Origin of the Right Medial Gastrocnemius Muscle** based on **Affine Scaling**

Add_Landmark_Using_Affine_Scaling */VISUAL3D_LANDMARK_NAME=ORIGIN_RT_GASTROC_MED* //// /CALIBRATION_FILE=*model.mdh /LINKMODEL_MARKER_NAMES=RGT+RLK+RMK /LANDMARK_LOCATION_IN_LOCAL_COORDINATE_SYSTEM=-26.117+-381.432+-24.205

/SEGMENT_NAME=RTH /MARKER1_IN_LOCAL_COORDINATE_SYSTEM=0+0+0
/MARKER2_IN_LOCAL_COORDINATE_SYSTEM=0+-380.878+43.317
/MARKER3_IN_LOCAL_COORDINATE_SYSTEM=0+-394.841+-43.317 !
/MARKER4_IN_LOCAL_COORDINATE_SYSTEM= /SCALE_ML=FALSE /SCALE_AXIAL=TRUE *;* Note that the mocap markers/landmarks for the three homologous anatomical points must exist in the model file.

LGT= Left Greater Trochanter

LLK= Left Lateral Knee (epicondyle)

LMK= Left Lateral Knee (epicondyle) In the above example, the Terry information for the thigh segments (femur.txt) required are the following:

1) most lateral point on greater trochanter type:palpable landmark muscle: 2) most lateral point on lateral epicondyle type: palpable landmark muscle: 3) most medial point on medial epicondyle type: palpable landmark muscle: 30) most superior point on medial condyle type: muscle origin muscle: origin of Gastrocnemius medial head The numerical values associated with these locations for a **White Male** are stored in the file femur.mod

FEMUR - right and left - 26 males, 26 females 41 LANDMARKS

1	0.000	0.000	0.000	104.000
2	0.000	-380.878	43.317	104.000
3	0.000	-394.841	-43.317	104.000
.....				
30	-26.117	-381.432	-24.205	104.000

Example Data Set with Meta Commands and Pipeline

This is an example data set compatible with the Terry Database.

Download the Meta-Commands and place them in a folder labeled Meta-Commands inside the Visual3D plugins folder

Download the example Visual3D pipeline. Note to download this file, right mouse click on the link and save the link to your computer.

Load the cmo file into Visual3D

Execute the pipeline to create Visual3D representations of a collection of the Terry Database muscle.

Note that the first command of this example pipeline specifies the FOLDER containing the data. You will need to recreate this folder path or specify the path on your computer.

Visual3D Meta-Command for a Terry Muscle

As an example, the Gastrocnemius muscle can be defined using the following Meta-Command

! BEGIN_META
! META_CMD_NAME=Terry_Rt_Plantar_Flexors_Group

```
! META_PARAM= MODEL_NAME : string ::yes
! META_PARAM= RIGHT_THIGH_MARKERS : string ::yes
! META_PARAM= RIGHT_SHANK_MARKERS: string ::yes
! META_PARAM= RIGHT_FOOT_MARKERS: string ::yes
! END_META


! ————————————————————————-
! Gastrocnemius
! ————————————————————————-
```

Add_Landmark_Using_Affine_Scaling

```
/VISUAL3D_LANDMARK_NAME=ORIGIN_RT_GASTROC_MED
/CALIBRATION_FILE=::MODEL_NAME
/LINKMODEL_MARKER_NAMES=::RIGHT_THIGH_MARKERS
/LANDMARK_LOCATION_IN_LOCAL_COORDINATE_SYSTEM=-26.117+-381.432+-24.205
/SEGMENT_NAME=RTH
/MARKER1_IN_LOCAL_COORDINATE_SYSTEM=0+0+0
/MARKER2_IN_LOCAL_COORDINATE_SYSTEM=0+-380.878+43.317
/MARKER3_IN_LOCAL_COORDINATE_SYSTEM=0+-394.841+-43.317
! /MARKER4_IN_LOCAL_COORDINATE_SYSTEM=
/SCALE_ML=FALSE
/SCALE_AXIAL=TRUE
;
```

Add_Landmark_Using_Affine_Scaling

```
/VISUAL3D_LANDMARK_NAME=TETHER_RT_GASTROC_MED
/CALIBRATION_FILE=::MODEL_NAME
/LINKMODEL_MARKER_NAMES=::RIGHT_THIGH_MARKERS
/LANDMARK_LOCATION_IN_LOCAL_COORDINATE_SYSTEM=-37.929+-401.247+-20.216
/SEGMENT_NAME=RTH
/MARKER1_IN_LOCAL_COORDINATE_SYSTEM=0+0+0
/MARKER2_IN_LOCAL_COORDINATE_SYSTEM=0+-380.878+43.317
/MARKER3_IN_LOCAL_COORDINATE_SYSTEM=0+-394.841+-43.317
! /MARKER4_IN_LOCAL_COORDINATE_SYSTEM=
/SCALE_ML=FALSE
/SCALE_AXIAL=TRUE
;
```

Add_Landmark_Using_Affine_Scaling

```
/VISUAL3D_LANDMARK_NAME=INSERTION_RT_GASTROC_MED
/CALIBRATION_FILE=::MODEL_NAME
/LINKMODEL_MARKER_NAMES=::RIGHT_FOOT_MARKERS
/LANDMARK_LOCATION_IN_LOCAL_COORDINATE_SYSTEM=-0.529+1.120+-0.726
/SEGMENT_NAME=RFT
/MARKER1_IN_LOCAL_COORDINATE_SYSTEM=0+0+0
/MARKER2_IN_LOCAL_COORDINATE_SYSTEM=85.524+0+-35.699
/MARKER3_IN_LOCAL_COORDINATE_SYSTEM=88.645+0+35.699
! /MARKER4_IN_LOCAL_COORDINATE_SYSTEM=
/SCALE_ML=FALSE
/SCALE_AXIAL=FALSE
```

;

Add_Landmark_Based_Muscle
/MUSCLE_NAME=RT_GASTROC_MEDIALIS
/LANDMARK_ORIGIN=ORIGIN_RT_GASTROC_MED
/LANDMARK_TETHERS=TETHER_RT_GASTROC_MED
/LANDMARK_INSERTION=INSERTION_RT_GASTROC_MED
/LINK_MODEL_NAME=::MODEL_NAME
;

Add_Landmark_Using_Affine_Scaling
/VISUAL3D_LANDMARK_NAME=ORIGIN_RT_GASTROC_LAT_PLANTARIS
/CALIBRATION_FILE=::MODEL_NAME
/LINKMODEL_MARKER_NAMES=::RIGHT_THIGH_MARKERS
/LANDMARK_LOCATION_IN_LOCAL_COORDINATE_SYSTEM=-20.936+-373.101+18.664
/SEGMENT_NAME=RTH
/MARKER1_IN_LOCAL_COORDINATE_SYSTEM=0+0+0
/MARKER2_IN_LOCAL_COORDINATE_SYSTEM=0+-380.878+43.317
/MARKER3_IN_LOCAL_COORDINATE_SYSTEM=0+-394.841+-43.317
! /MARKER4_IN_LOCAL_COORDINATE_SYSTEM=
/SCALE_ML=FALSE
/SCALE_AXIAL=TRUE
;

Add_Landmark_Using_Affine_Scaling
/VISUAL3D_LANDMARK_NAME=TETHER_RT_GASTROC_LAT_PLANTARIS
/CALIBRATION_FILE=::MODEL_NAME
/LINKMODEL_MARKER_NAMES=::RIGHT_THIGH_MARKERS
/LANDMARK_LOCATION_IN_LOCAL_COORDINATE_SYSTEM=-30.662+-390.245+23.209
/SEGMENT_NAME=RTH
/MARKER1_IN_LOCAL_COORDINATE_SYSTEM=0+0+0
/MARKER2_IN_LOCAL_COORDINATE_SYSTEM=0+-380.878+43.317
/MARKER3_IN_LOCAL_COORDINATE_SYSTEM=0+-394.841+-43.317
! /MARKER4_IN_LOCAL_COORDINATE_SYSTEM=
/SCALE_ML=FALSE
/SCALE_AXIAL=TRUE
;

Add_Landmark_Using_Affine_Scaling
/VISUAL3D_LANDMARK_NAME=INSERTION_RT_GASTROC_LAT_PLANTARIS
/CALIBRATION_FILE=::MODEL_NAME
/LINKMODEL_MARKER_NAMES=::RIGHT_FOOT_MARKERS
/LANDMARK_LOCATION_IN_LOCAL_COORDINATE_SYSTEM=-0.529+1.120+-0.726
/SEGMENT_NAME=RFT
/MARKER1_IN_LOCAL_COORDINATE_SYSTEM=0+0+0
/MARKER2_IN_LOCAL_COORDINATE_SYSTEM=85.524+0+-35.699
/MARKER3_IN_LOCAL_COORDINATE_SYSTEM=88.645+0+35.699
! /MARKER4_IN_LOCAL_COORDINATE_SYSTEM=
/SCALE_ML=FALSE
/SCALE_AXIAL=FALSE
;

Add_Landmark_Based_Muscle
/MUSCLE_NAME=RT_GASTROC_LATERALIS
/LANDMARK_ORIGIN=ORIGIN_RT_GASTROC_LAT_PLANTARIS
/LANDMARK_TETHERS=TETHER_RT_GASTROC_LAT_PLANTARIS
/LANDMARK_INSERTION=INSERTION_RT_GASTROC_LAT_PLANTARIS
/LINK_MODEL_NAME=::MODEL_NAME
;

Pipeline Command for Above Meta-Command

A meta-command is a Visual3D pipeline into which **Parameters can be passed**

The meta-command should be stored in a folder labeled **Meta-Commands**, which is located in the Visual3D **Plugins** Folder.

The header in the meta-command defines the data that should be passed:

! BEGIN_META ! META_CMD_NAME=Terry_Rt_Plantar_Flexors_Group ! META_PARAM= MODEL_NAME : string ::yes ! META_PARAM= RIGHT_THIGH_MARKERS : string ::yes ! META_PARAM= RIGHT_SHANK_MARKERS: string ::yes ! META_PARAM= RIGHT_FOOT_MARKERS: string ::yes ! END_META This command will appear in the Visual3D Pipeline Dialog list box in a folder labeled **Meta_Commands.** The command will be similar to the following:

Terry_Rt_Plantar_Flexors_Group /MODEL_NAME= *model.mdh /RIGHT_THIGH_MARKERS= RGT+RLK+RMK /RIGHT_SHANK_MARKERS= LTT +RLA+RMA /RIGHT_FOOT_MARKERS= RHL+RFT2+RFT1 ;

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