

# IOR Foot Model 2006

This tutorial has been updated to match the naming convention used in the 2007 IOR foot paper. The MODIFIED tutorial can be found [here](#).

In 2014, updates to the IOR foot model were published. The 2014 tutorial can be found [here](#).

Visual3D is a general tool capable of implementing many different foot models.

This tutorial focuses on the multi-segment foot model as described in the following article:



Available online at [www.sciencedirect.com](http://www.sciencedirect.com)



Gait & Posture 25 (2007) 453–462



[www.elsevier.com/locate/gaitpost](http://www.elsevier.com/locate/gaitpost)

## Rear-foot, mid-foot and fore-foot motion during the stance phase of gait

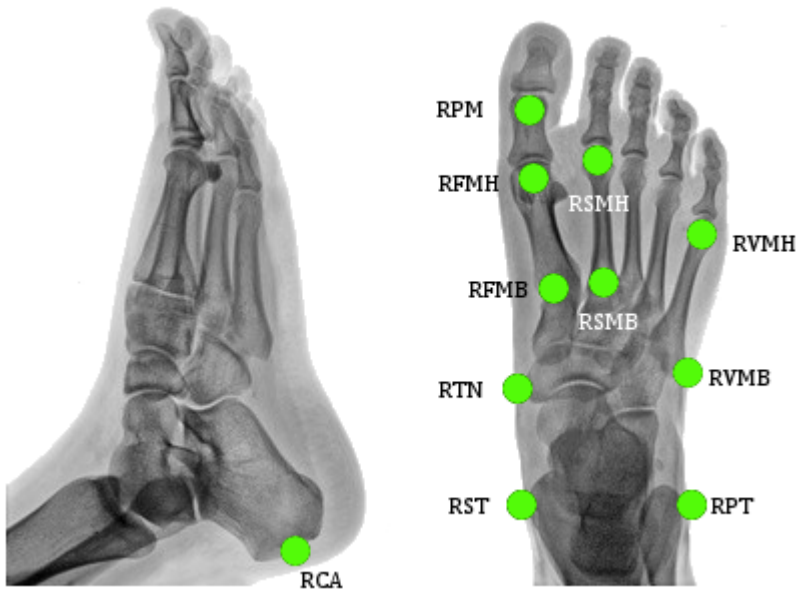
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Below is a tutorial demonstrating how this is done in Visual3D. If you would rather see a fully completed model you can simply download the following file [blank] and open it in Visual3D.

### Multi-Segment Foot Marker Set



CA<sup>[1]</sup>(FCC)<sup>[2]</sup>p. 160 = Posterior Surface of Calcaneus ST<sup>[1]</sup>(FST)<sup>[2]</sup> = Sustentaculum Tali of Calcaneus  
PT<sup>[1]</sup>(FPT)<sup>[2]</sup> = Lateral apex of the peroneal tubercle TN<sup>[1]</sup>(FNT)<sup>[2]</sup> = Medial apex of the tuberosity  
navicular. FMH<sup>[1]</sup>(FM1)<sup>[2]</sup> = Head of 1st Metatarsus SMH<sup>[1]</sup>(FM2)<sup>[2]</sup> = Head of 2nd Metatarsus  
VMH<sup>[1]</sup>(FM5)<sup>[2]</sup> = Head of 5th Metatarsus VMB<sup>[1]</sup>(FMT)<sup>[2]</sup> = Tuberosity of 5th Metatarsal PM<sup>[1]</sup>(PM6)<sup>[2]</sup> =  
Proximal Medial Phalanx FMB<sup>[1]</sup> = Base of First Metatarsal SMB<sup>[1]</sup> = Base of Second Metatarsal

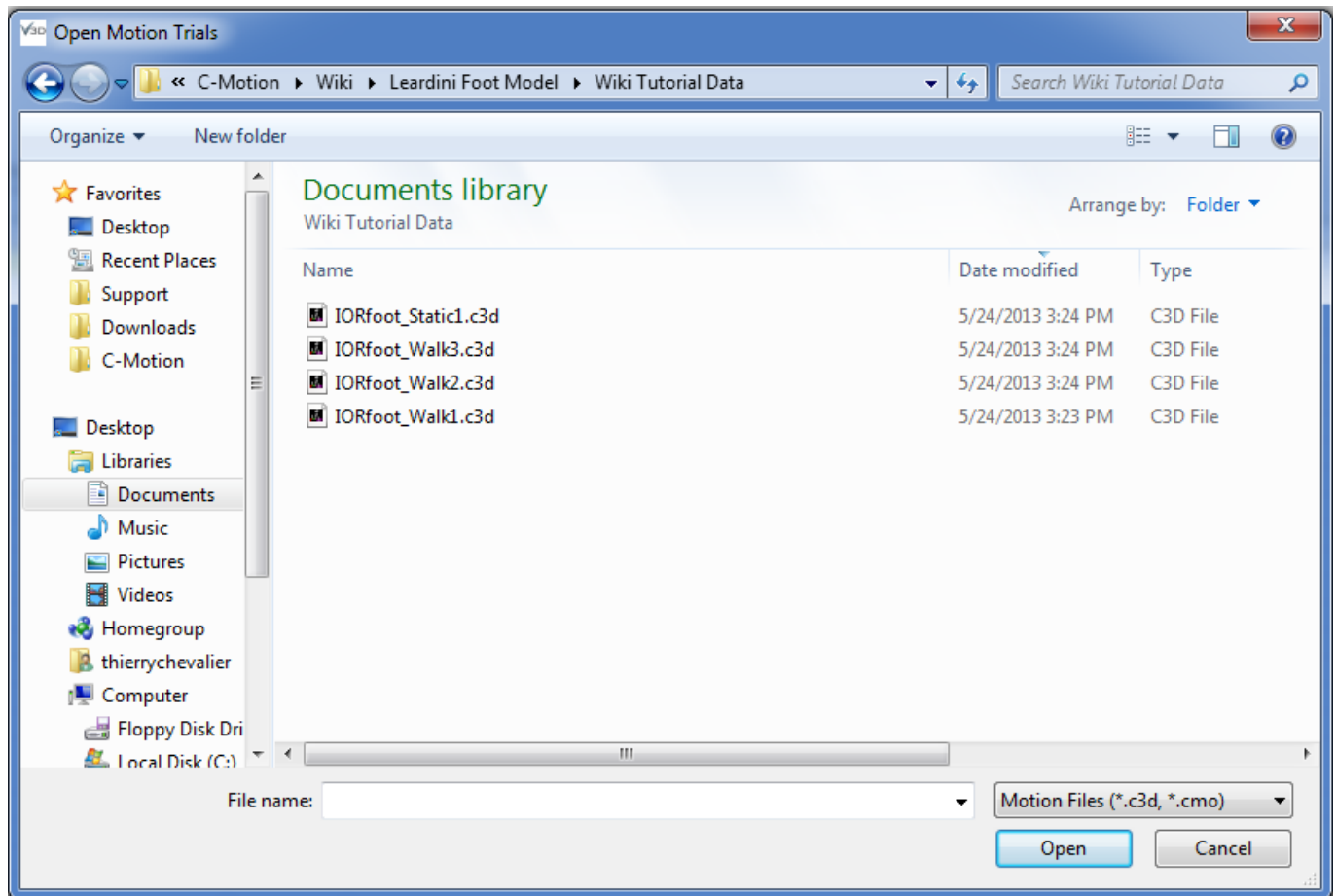
## Download and open the c3d files in Visual3D

Download the zip file [IORfoot\\_Tutorial.zip](#) containing the .c3d files.

Unzip this file in a location of your choice.

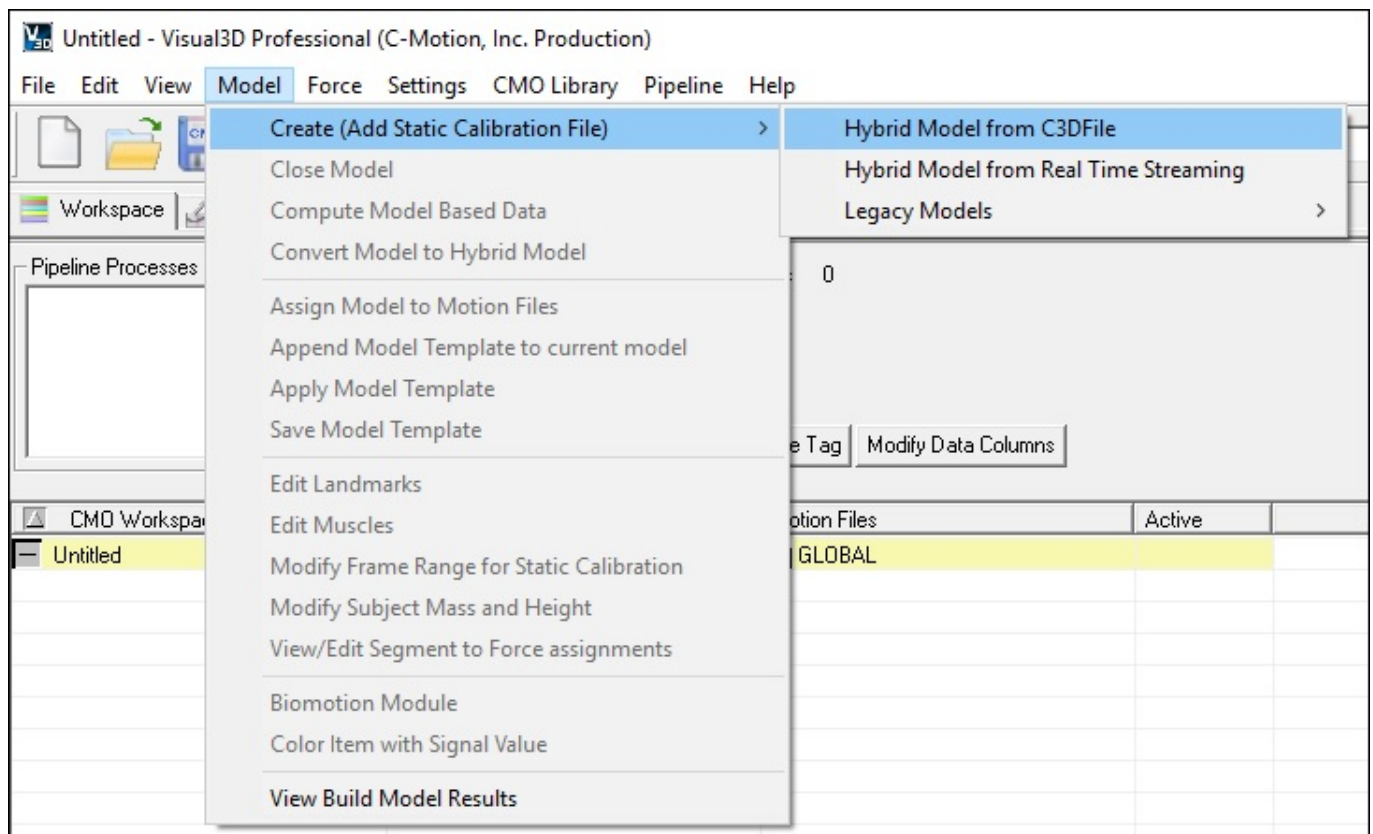
From the **File** menu select **Open**.

From the "Open the movement trial" dialog navigate to the files you downloaded and select the file labeled *IORfoot\_Walk1.c3d*, *IORfoot\_Walk2.c3d* and *IORfoot\_Walk3.c3d*. Click **Open**.

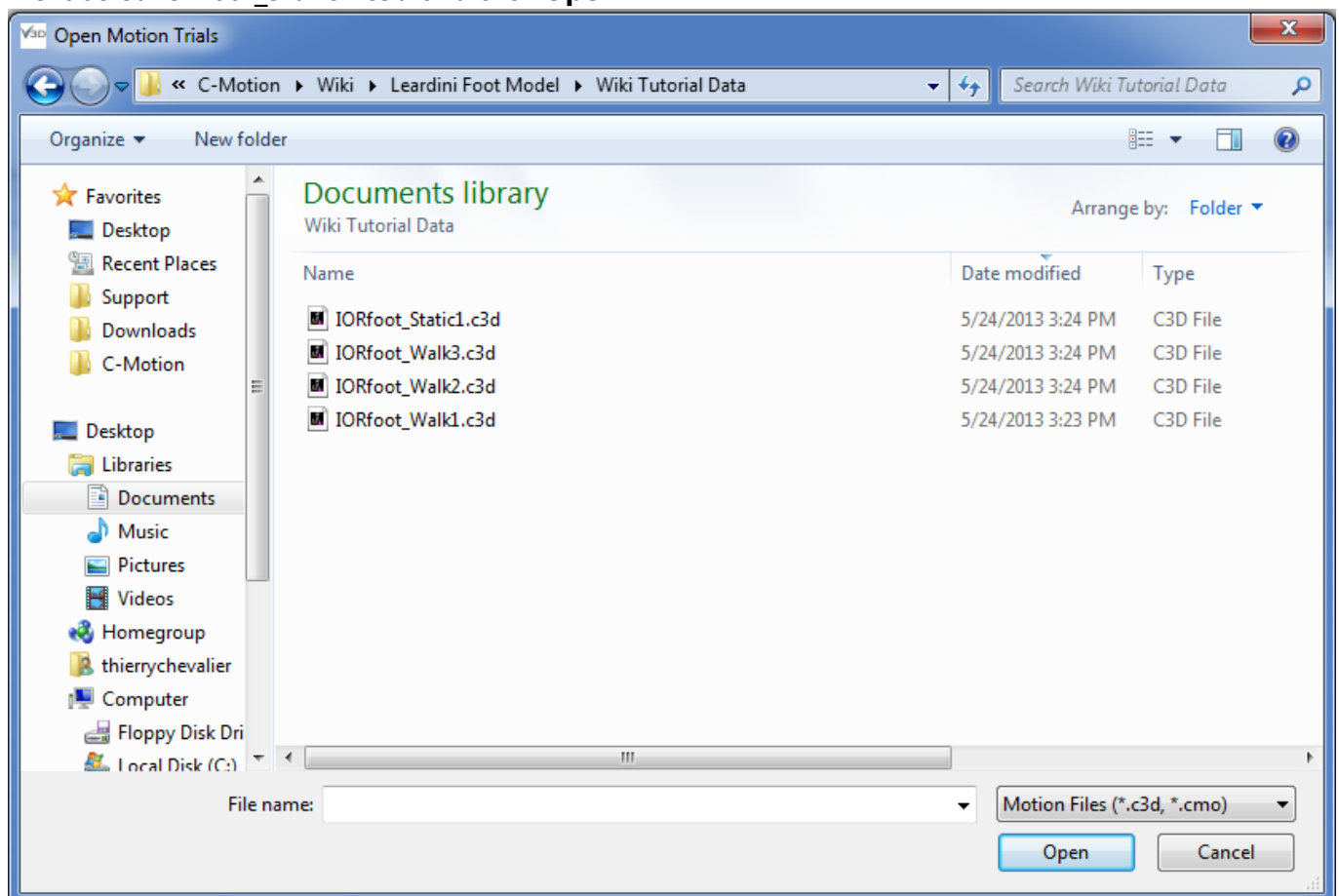


**Note:** If you would like to perform your own motion capture for this model, here is a list of the marker names in this file: [LFM\\_MARKERS.txt](#)

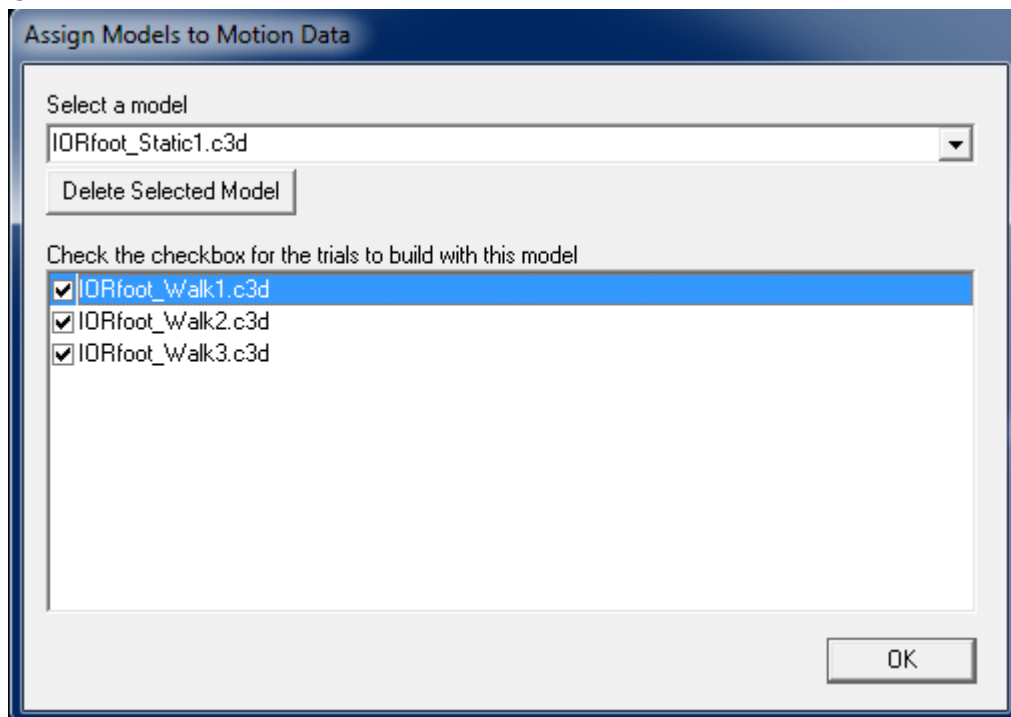
Create a hybrid model - From the **Model** menu open **Create (Add Static Calibration File)** and select **Visual3D Hybrid Model**.



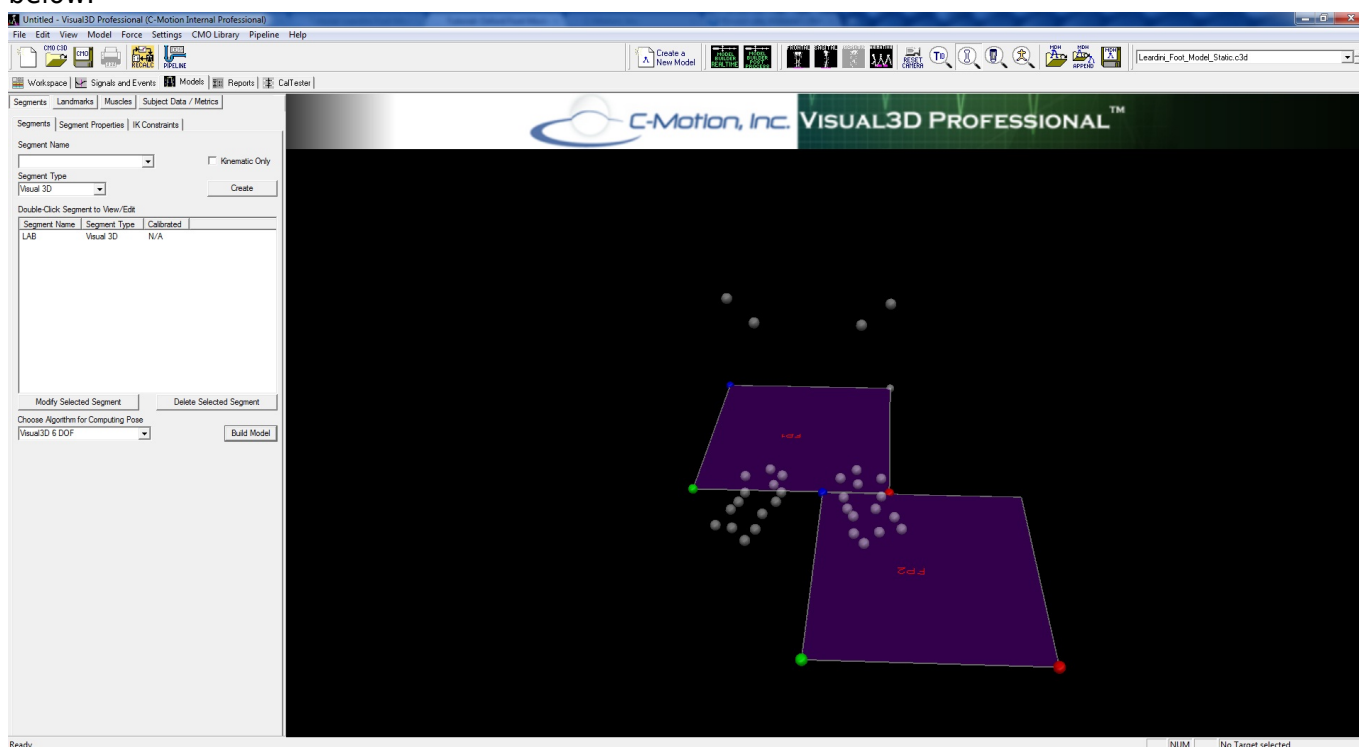
Load the standing trial - From the “Select the calibration file for the new model” dialog box select the file labeled *IORfoot\_Static1.c3d* and click **Open**.



Assign the model to the movement trial - When the “Assign Models to Motion Data” window opens select the movement files *IORfoot\_Walk1.c3d*, *IORfoot\_Walk2.c3d* and *IORfoot\_Walk3.c3d* and click **OK**.



Visual3D will automatically open the Model Builder mode and your screen should look like the image below.



## Creating the landmarks

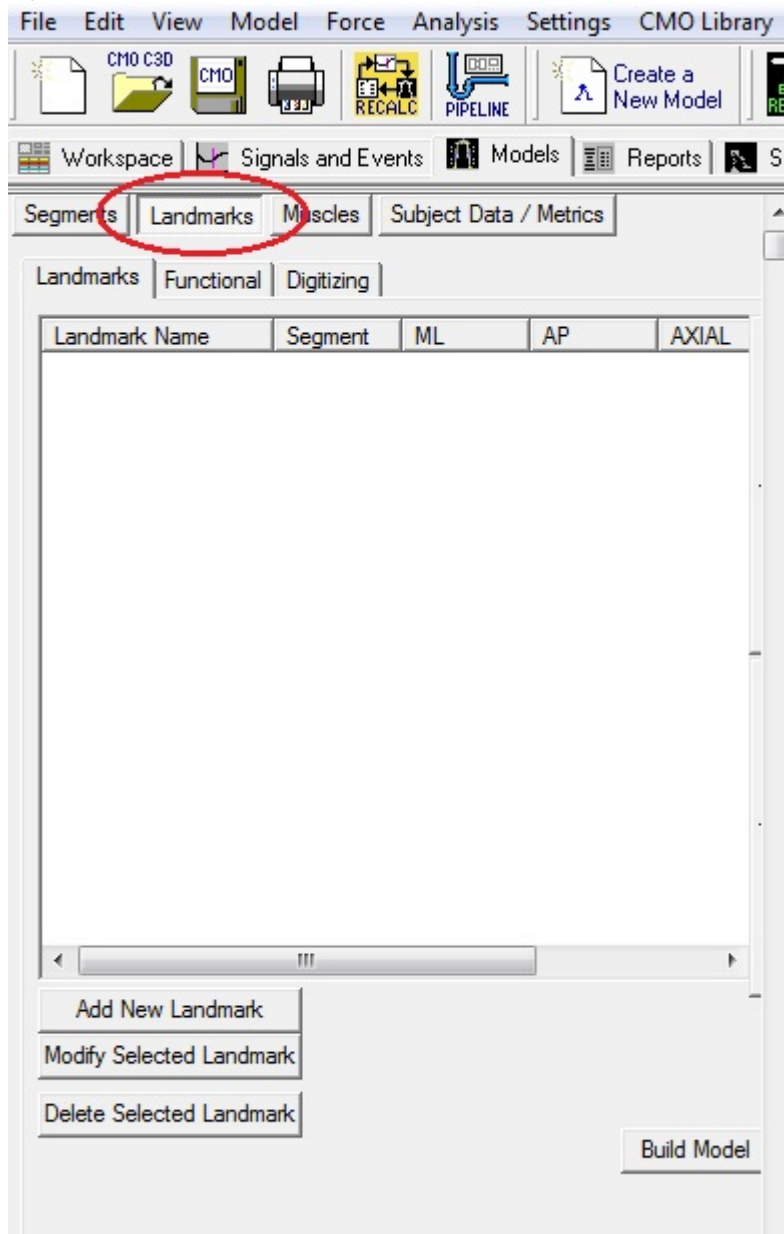
The Leardini Foot Model is built using landmarks and motion capture markers. Landmarks are defined relative to motion capture markers, other landmarks, or to existing segment coordinate systems.

**Note:** As you go through this exercise, you will notice that the marker names in our example are slightly different than those shown above.

### Project TARGET onto the Laboratory Floor

In order to calculate the sagittal planar angles, certain markers/targets must be projected onto the floor.

Open the **Landmarks** Tab



1. Click **Add a New Landmark**

2. In the box labeled **Landmark Name**, enter *LFM\_FLOOR*
3. Leave all boxes empty, except for the box labeled **Existing Segment** select *Lab* (it should already be selected)
4. Click the radio button labeled **Offset Using the Following ML/AP/AXIAL offsets**
5. Enter LFM::X, LFM::Y and 0 for the X, Y and Z offsets respectively.
6. Click **Apply**. when all the information (listed below) has been entered
7. Click **Close Tab**.

The same steps should be repeated to create all subsequent landmarks representing floor projection of the following markers/targets, only replacing the name of the landmark's name \*\*\*\_FLOOR and the X and Y offsets to the corresponding target:

LFM, LFMB, LSM, LSMB, LVM, LVMB, RFM, RFMB, RSM, RSMB, RVM, RVMB.

### Creating other LANDMARKS

Other landmarks are also required to create certain segments.

Workspace | Signals and Events | Models | Reports | Ca

Segments | Landmarks | Muscles | Subject Data / Metrics

Landmarks | Functional | Digitizing

Landmark Name:

Define Orientation Using:

Starting Point  (Reference)

☐ Targets and/or Landmarks

Ending Point  (On a line)

\*Lateral object  (On a plane)

\*Project From  (Projection onto a line or plane)

\* = Optional

☒ Existing Segment

Landmark Offset from Start Point (Reference) or Segment Origin

☐ Offset to Existing Calibration Target or Landmark

☒ Offset Using the Following ML/AP/AXIAL Offsets

X  Y  Z

☐ Offset by Percent (1.0 = 100%) (Meters when not checked)

☐ Calibration Only Landmark (Not generated for assigned motion file(s))

Undo Changes | Apply | Build Model | Close Tab

The following landmarks need to be created:

LIC, RIC, LID, RID, LIM, RIM, LF2P, RF2P, LSM\_FT, RSM\_FT, LST\_MET, RSM\_MET, LCAB\_MLA, RCAB\_MLA, LIC\_VIRTUAL, RIC\_VIRTUAL, LST\_VIRTUAL, RST\_VIRTUAL, LSHANK\_ORIGIN, RSHANK\_ORIGIN.

**Note:** The contralateral landmarks have been paired together so that the parameters for the right landmarks included within parentheses next to the corresponding left parameter.

### LIC (RIC):

**Note:** The *LIC (RIC)* landmarks defines the midpoint between the *LST (RST)* and the *LPT (RPT)* targets.

1. Click **Add a New Landmark**
2. In the field. labeled **Landmark Name** enter the name of the marker/target *LIC (RIC)*.
3. From the list box labeled **Starting Point** select *LST (RST)*.
4. Click the radio button labeled **Targets and/or Landmarks**.
5. From the list box labeled **Ending Point** select *LPT (RPT)*.
6. Click the radio button labeled **Offset Using the Following AP/ML/AXIAL Offsets**
7. In the field labeled AXIAL enter 0.5.
8. Check the checkbox labeled **Offset by Percent (1.0 = 100%) (Meters when not checked)**.
9. Click **Apply**.
10. Click **Close Tab**.

### LID (RID):

**Note:** The *LID (RID)* landmark defines the midpoint between the *LTN (RTN)* and the *LVMB (RVMB)* targets.

1. Click **Add a New Landmark**
2. In the field. labeled **Landmark Name** enter the name of the marker/target *LID (RID)*.
3. From the list box labeled **Starting Point** select *LTN (RTN)*.
4. Click the radio button labeled **Targets and/or Landmarks**.
5. From the list box labeled **Ending Point** select *LVMB (RVMB)*.
6. Click the radio button labeled **Offset Using the Following AP/ML/AXIAL Offsets**
7. In the field labeled AXIAL enter 0.5.
8. Check the checkbox labeled **Offset by Percent (1.0 = 100%) (Meters when not checked)**.
9. Click **Apply**.
10. Click **Close Tab**.

### LIM (RIM):

**Note:** The *LIM (RIM)* landmark defines the ankle joint centre based on the midpoint between the *LLM (RLM)* and the *LMM (RMM)* targets.

1. Click **Add a New Landmark**
2. In the field. labeled **Landmark Name** enter the name of the marker/target *LIM (RIM)*.
3. From the list box labeled **Starting Point** select *LLM (RLM)*.
4. Click the radio button labeled **Targets and/or Landmarks**.
5. From the list box labeled **Ending Point** select *LMM (RMM)*.
6. Click the radio button labeled **Offset Using the Following AP/ML/AXIAL Offsets**
7. In the field labeled AXIAL enter 0.5.

8. Check the checkbox labeled **Offset by Percent (1.0 = 100%) (Meters when not checked)**.
9. Click **Apply**.
10. Click **Close Tab**.

### LSM\_MET (RSM\_MET):

**Note:** The *LSM\_MET (RSM\_MET)* landmark is the projection of the *LSM (RSM)* target onto the plane defined by the *LSMB (RSMB)*, *LFM (RFM)* and the *LVM (RVM)* targets.

1. Click **Add a New Landmark**
2. In the field. labeled **Landmark Name** enter the name of the marker/target *LSM\_MET (RSM\_MET)*.
3. From the list box labeled **Starting Point** select *LSMB (RSMB)*.
4. Click the radio button labeled **Targets and/or Landmarks**.
5. From the list box labeled **Ending Point** select *LFM (RFM)*.
6. From the list box labeled **\*Lateral object** select *LVM (RVM)*.
7. From the list box labeled **\*Projected From** select *LSM (RSM)*.
8. Click **Apply**.
9. Click **Close Tab**.

### LSM\_FT (RSM\_FT):

**Note:** The *LSM\_FT (RSM\_FT)* landmark is the projection of the *LSM (RSM)* target onto the plane defined by the *LCA(RCA)*, *LFM (RFM)* and the *LVM (RVM)* targets.

1. Click **Add a New Landmark**
2. In the field. labeled **Landmark Name** enter the name of the marker/target *LSM\_FT (RSM\_FT)*.
3. From the list box labeled **Starting Point** select *LCA (RCA)*.
4. Click the radio button labeled **Targets and/or Landmarks**.
5. From the list box labeled **Ending Point** select *LFM (RFM)*.
6. From the list box labeled **\*Lateral object** select *LVM (RVM)*.
7. From the list box labeled **\*Projected From** select *LSM (RSM)*.
8. Click **Apply**.
9. Click **Close Tab**.

### LF2P (RF2P):

**Note:** The *LF2P (RF2P)* is a landmark onto the line define by the *LFMB (RFMB)* and the *LFM (RFM)* targets.

1. Click **Add a New Landmark**
2. In the field. labeled **Landmark Name** enter the name of the marker/target *LF2P (RF2P)*.
3. From the list box labeled **Starting Point** select *LFMB (RFMB)*.
4. Click the radio button labeled **Targets and/or Landmarks**.
5. From the list box labeled **Ending Point** select *LFM (RFM)*.
6. Click the radio button labeled **Offset Using the Following AP/ML/AXIAL Offsets**
7. In the field labeled **AXIAL** enter *1.5*.

8. Check the checkbox labeled **Offset by Percent (1.0 = 100%) (Meters when not checked)**.
9. Click **Apply**.
10. Click **Close Tab**.

### LSHANK\_ORIGIN (RSHANK\_ORIGIN):

1. Click **Add a New Landmark**
2. In the field. labeled **Landmark Name** enter the name of the marker/target *LSHANK\_ORIGIN* (*RSHANK\_ORIGIN*).
3. In the list box labeled **Starting Point**, enter *LHF* (*RHF*).
4. In the list box labeled **Ending Point**, enter *LLM* (*RLM*).
5. In the list box labeled **Lateral Object**, enter *LMM* (*RMM*).
6. In the list box labeled **Projected From**, enter *LTT* (*RTT*).
7. Click **Apply**.
8. Click **Close Tab**.

### LCAB\_MLA (RCAB\_MLA):

**Note:** This landmark can only be created once the LT\_CALC (RT\_CALC) segment has been created.

**Note:** The *LCAB\_MLA* (*RCAB\_MLA*) landmark recreates the LCAB marker which is normally removed after the standing trial.

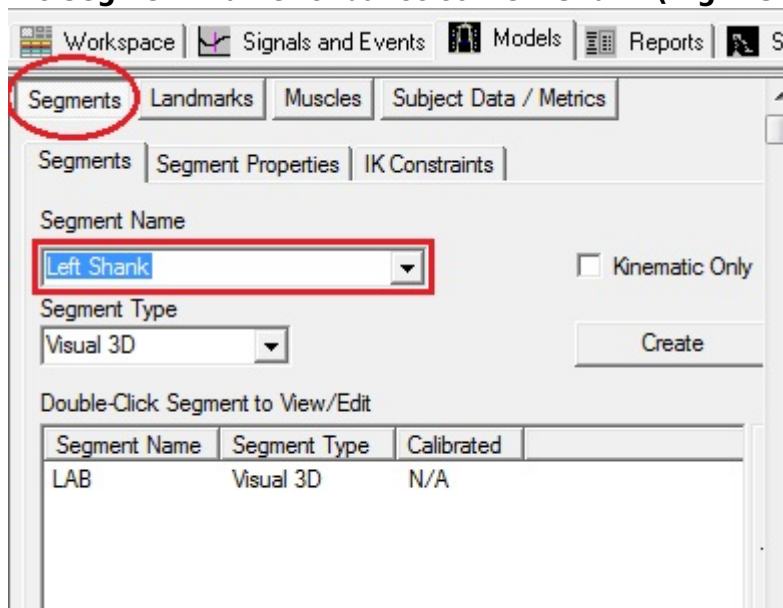
1. Click **Add a New Landmark**
2. In the field. labeled **Landmark Name** enter the name of the marker/target *LCAB\_MLA* (*RCAB\_MLA*).
3. From the list box labeled **Starting Point** select *LCAB* (*RCAB*).
4. Click the radio button labeled **Existing Segment**.
5. From the list box, select *LT\_CALC* (*RT\_CALC*).
6. Click **Apply**.
7. Click **Close Tab**.

## Defining the segments

### Defining the Shank

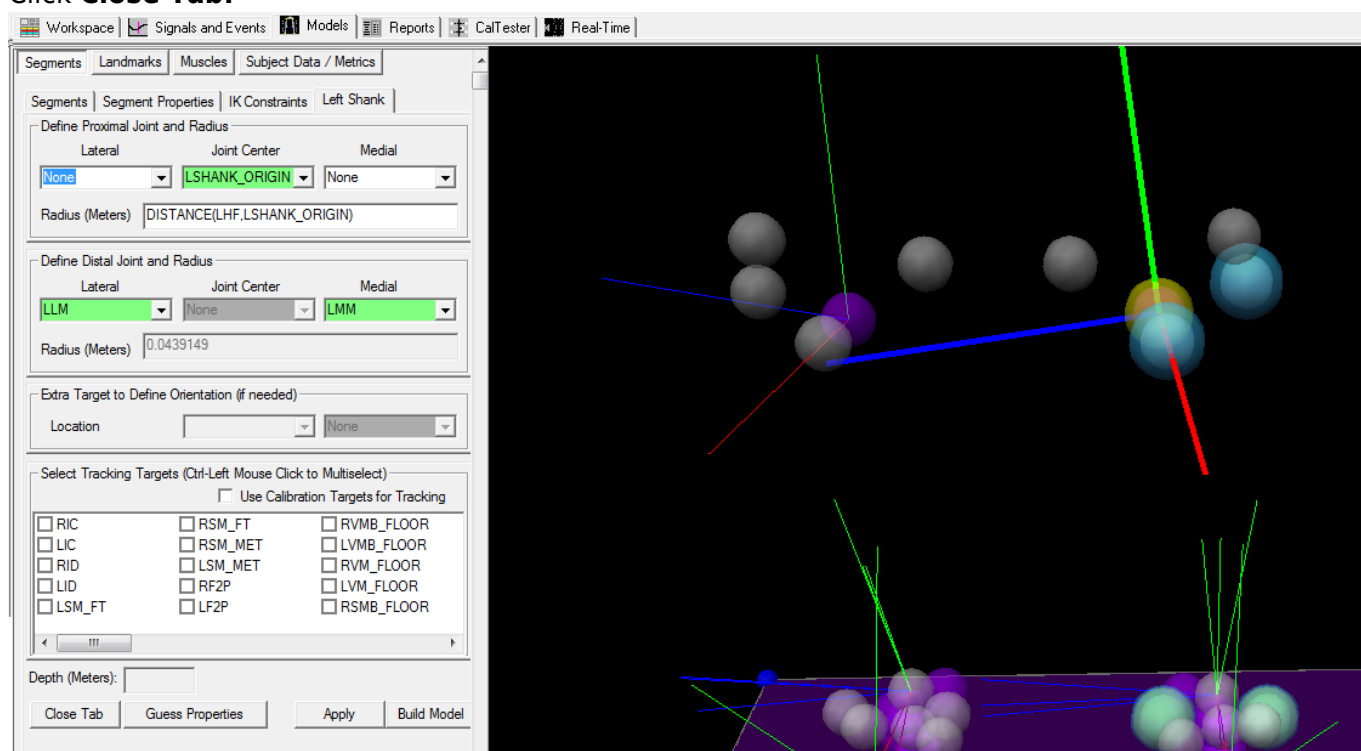
Follow the sub-steps below to create the shank segments using the following properties. The Shank segments are created by defining the KNEE (LT\_KNEE/RT\_KNEE) landmark as the proximal segment endpoint and the ANKLE joint centre (LIM/RIM) as the distal segment endpoint. The frontal plane is defined using the segment endpoints and the lateral malleolus (LLM/RLM) targets. The segment is

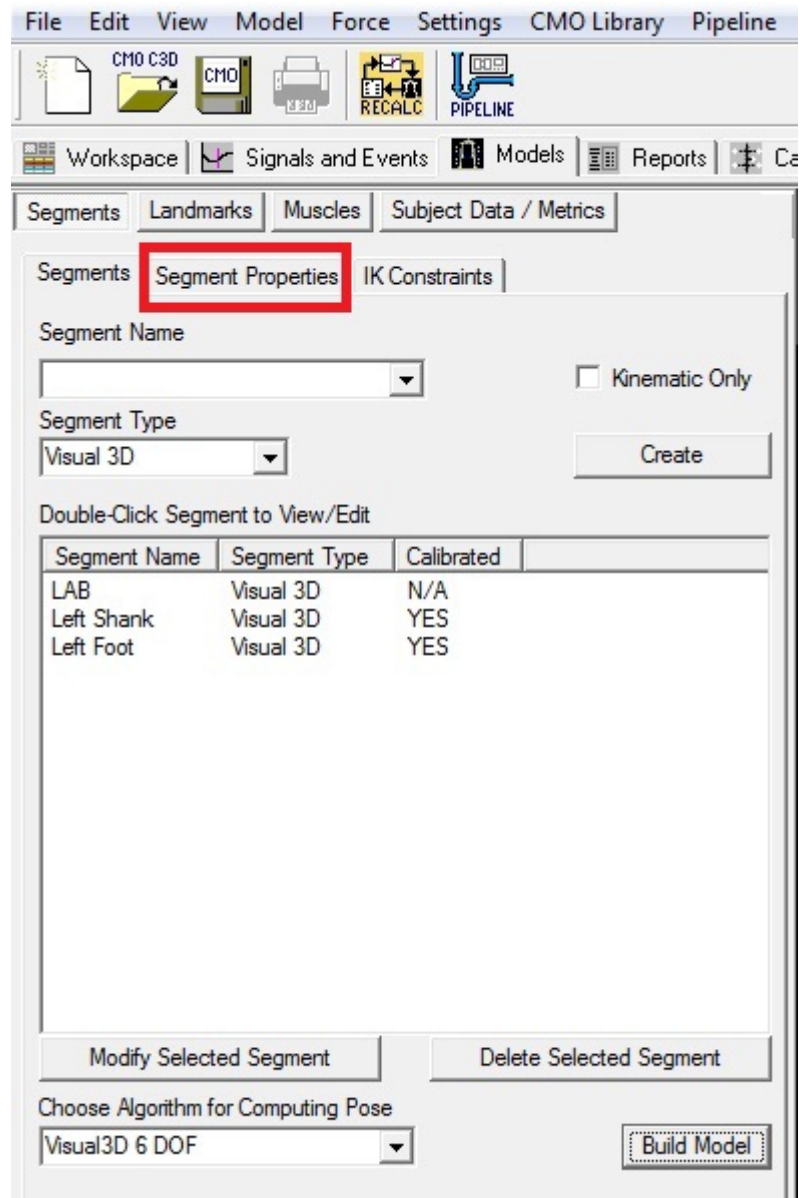
tracked using the four shank markers. Click the **Segments** button to open the **Segments** tab. From the **Segment Name** list box select **Left Shank (Right Shank)**.



Click **Create**. The segment will be created and the Left Shank tab will open. In the section labeled **Define Proximal Joint and Radius**, select *LSHANK\_ORIGIN* (*RSHANK\_ORIGIN*) from the list box labeled **Joint Center** and enter *DISTANCE(LHF,LSHANK\_ORIGIN)* (*DISTANCE(RHF,RSHANK\_ORIGIN)*) in the **Radius (Meters)** field. In the section labeled **Define Distal Joint and Radius**, select *LLM* (*RLM*) from the list box labeled **Lateral** and *LMM* (*RMM*) in the list box labeled **Medial**. In the section labeled **Select Tracking Targets**, select the following targets: *LHF* (*RHF*), *LLM* (*RLM*), *LMM* (*RMM*) and *LTT* (*RTT*).

**Note:** Use the ctrl key on your keyboard while you click to select multiple targets. Click **Build Model**. Click **Close Tab**.





Click the **Segment Properties** button.

From the *Segment Name* list box select **Left Shank**.

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Segments | Landmarks | Muscles | Subject Data / Metrics

Segments | Segment Properties | IK Constraints

Segment Name: **Left Shank** ☐ Kinematic Only

Segment Mass:  = 0.0465 kgs

Segment Length:  Meters

Segment Geometry:

| Inertial Values* |                                                        | Center of Mass (Meters)* |                                                           |
|------------------|--------------------------------------------------------|--------------------------|-----------------------------------------------------------|
| Expression       | Value                                                  | Expression               | Value                                                     |
| IXX:             | <input type="text" value="0.000622614"/> 0.000622614   | ML :                     | <input type="text" value="0*LSK_SEG_I"/> 0                |
| IYY:             | <input type="text" value="6.52589e-005"/> 6.52589e-005 | AP :                     | <input type="text" value="0*LSK_SEG_I"/> 0                |
| IZZ:             | <input type="text" value="0.000622614"/> 0.000622614   | Axial :                  | <input type="text" value="0.448812*LSK_SEG_I"/> -0.177366 |

\*May be modified for custom geometry

Model File:

Material File:

Click the **Modify Segment Coordinate System** button.

For the **A/P Axis**, select +X, and for the **Distal to Proximal**, select +Y.

Segment Orientation (Relative to Lab) X

|                                     |                                     |
|-------------------------------------|-------------------------------------|
| A/P Axis                            | Distal to Proximal                  |
| <input checked="" type="radio"/> +X | <input type="radio"/> +X            |
| <input type="radio"/> -X            | <input type="radio"/> -X            |
| <input type="radio"/> +Y            | <input checked="" type="radio"/> +Y |
| <input type="radio"/> -Y            | <input type="radio"/> -Y            |
| <input type="radio"/> +Z            | <input type="radio"/> +Z            |
| <input type="radio"/> -Z            | <input type="radio"/> -Z            |

Then click **OK**. Then click **Apply**.

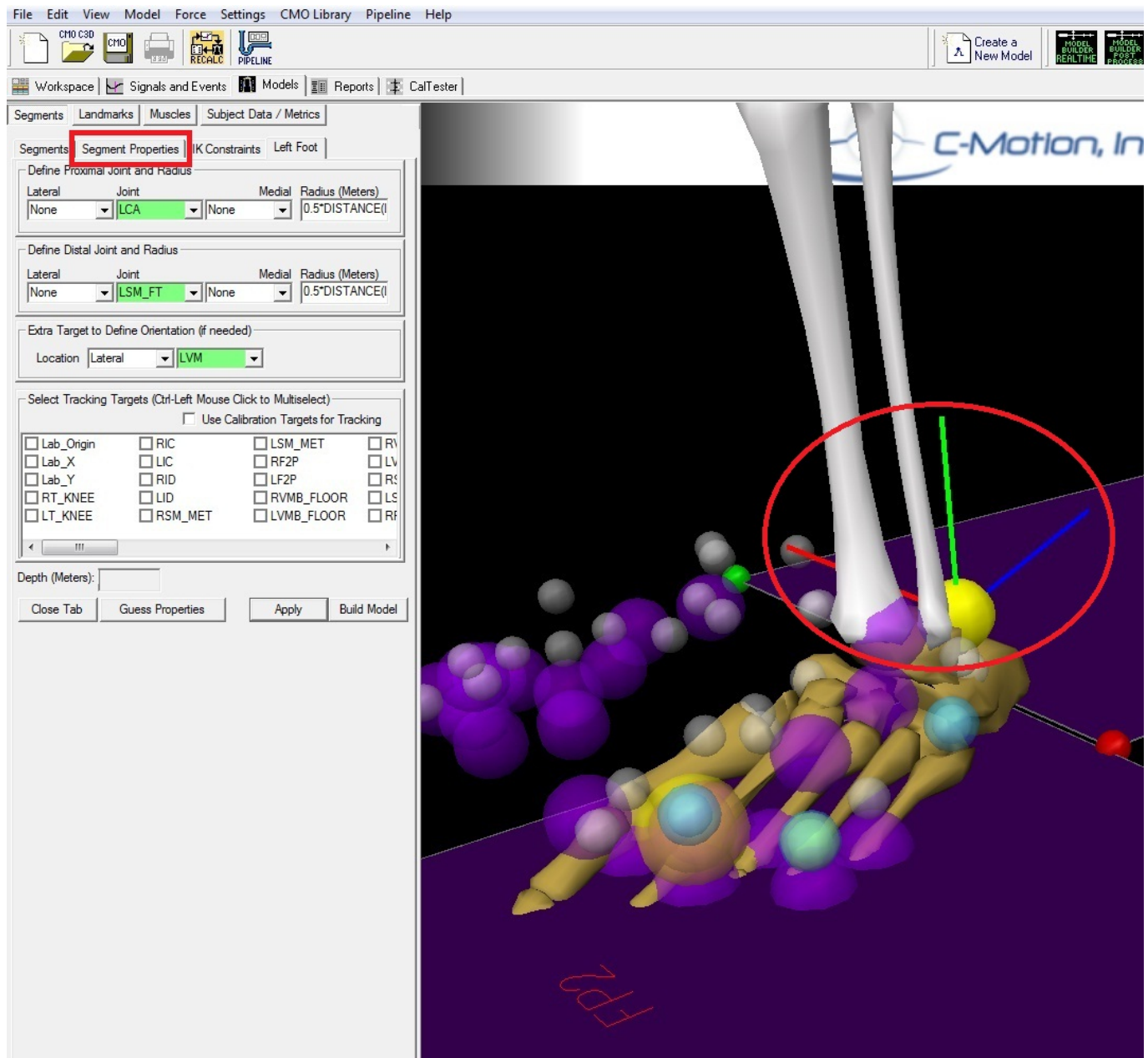
## Defining the Foot (single segment)

Follow the sub-steps below to create the foot segments (rigid segment) using the following properties. The Foot segments are created by defining the Calcaneus (LCA/RCA) targets as the proximal segment endpoint and the second metatarsal distal head (LSM/RSM) as the distal segment endpoint. The transverse plane is defined using the segment endpoints and the fifth metatarsal head (LVM/RVM) targets. The segment is tracked using three markers.

Click the **Segments** button to open the **Segments** tab. From the **Segment Name** list box select *Left Foot (Right Foot)*.

Click **Create**. The segment will be created and the Left Foot tab will open. In the section labeled **Define Proximal Joint and Radius**, select *LCA (RCA)* from the list box labeled **Joint** and enter  $0.5 * \text{DISTANCE}(LPT, LST)$  ( $0.5 * \text{DISTANCE}(RPT, RST)$ ) in the **Radius (Meters)** field. In the section labeled **Define Distal Joint and Radius**, select *LSM\_FT (RSM\_FT)* from the list box labeled **Joint** and enter  $0.5 * \text{DISTANCE}(LST, LPT)$  ( $0.5 * \text{DISTANCE}(RPT, RST)$ ) in the **Radius (Meters) field**. In the section labeled **Extra Target to Define Orientation (if needed)**, select *Lateral* and *LVM (RVM)* from the list boxes labeled **Location**. In the section labeled **Select Tracking Targets**, select the following targets: *LSM\_FT (RSM\_FT)*, *LCA (RCA)* and *LFM (RFM)*.

**Note:** Use the ctrl key on your keyboard while you click to select multiple targets. Click **Build Model**. Click **Close Tab**.



Click the **Segment Properties** button. Click the **Modify Segment Coordinate System** button.

File Edit View Model Force Settings CMO Library Pipeline

Workspace Signals and Events Models Reports Ca

Segments Landmarks Muscles Subject Data / Metrics

Segments Segment Properties IK Constraints

Segment Name: Left Foot ☐ Kinematic Only

Segment Mass: 0.0145\*Mass = 0.0145 kgs

Segment Length: 0.198005 Meters

Segment Geometry: CONE

| Inertial Values*  |              | Center of Mass (Meters)* |           |
|-------------------|--------------|--------------------------|-----------|
| Expression        | Value        | Expression               | Value     |
| IXX: 5.35404e-005 | 5.35404e-005 | ML: 0*LFT_SEG_1          | 0         |
| IYY: 5.35404e-005 | 5.35404e-005 | AP: 0*LFT_SEG_1          | 0         |
| IZZ: 1.2333e-005  | 1.2333e-005  | Axial: 0.5*LFT_SEG       | -0.099002 |

\*May be modified for custom geometry

Model File: lfoot.v3g

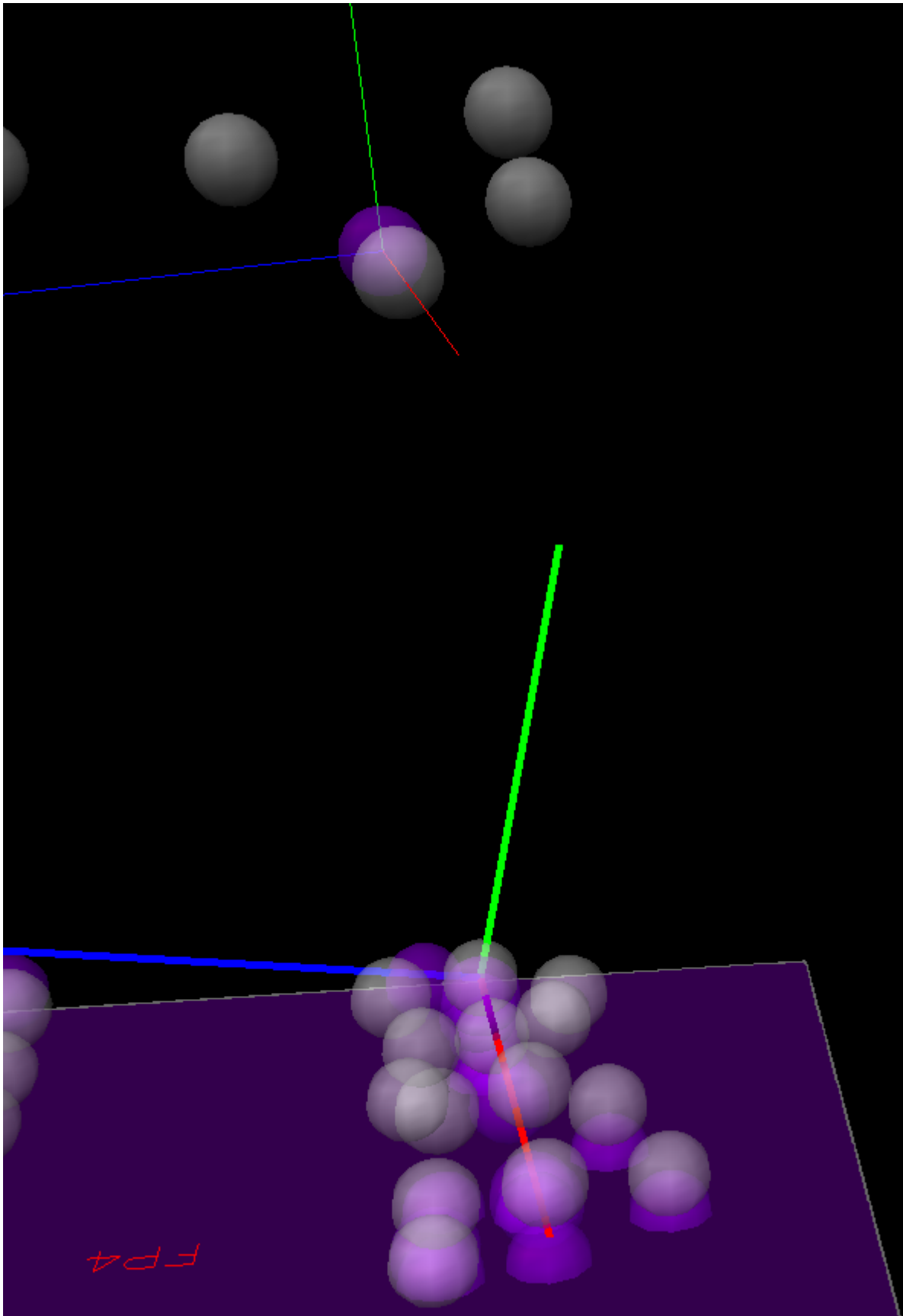
Material File:

For the **A/P Axis**, select +Y, and for the **Distal to Proximal**, select -X.

Segment Orientation (Relative to Lab)

| A/P Axis                            | Distal to Proximal                  |
|-------------------------------------|-------------------------------------|
| <input type="radio"/> +X            | <input type="radio"/> +X            |
| <input type="radio"/> -X            | <input checked="" type="radio"/> -X |
| <input checked="" type="radio"/> +Y | <input type="radio"/> +Y            |
| <input type="radio"/> -Y            | <input type="radio"/> -Y            |
| <input type="radio"/> +Z            | <input type="radio"/> +Z            |
| <input type="radio"/> -Z            | <input type="radio"/> -Z            |

Then click **OK**. Then click **Apply**. The Foot Segment Coordinate system should now be similar to the Shank one.



### Defining the Foot Segments

The definition of the foot segments are as followed:

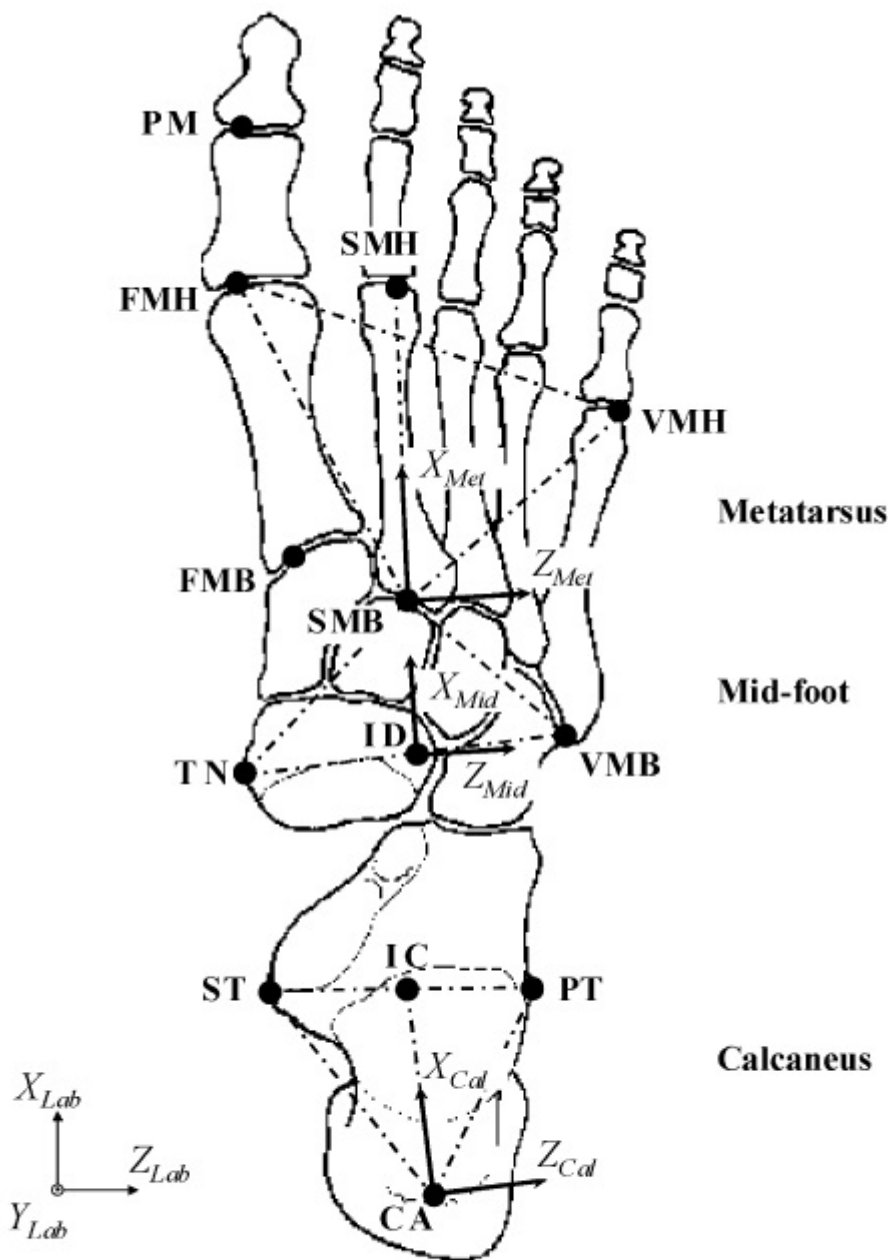


Fig. 1. Diagram of the foot with relevant assumed rigid segments, anatomical landmarks and frames depicted. Transverse planes (dash-dot triangles) and X- and Z-axes (solid arrows) on these planes are shown, corresponding Y-axes pointing proximally.

= Defining the Calcaneus =

Follow the sub-steps below to create the Calcaneus segments using the following properties.

1. Click the **Segments** button to open the **Segments** tab.
2. In the **Segment Name** box write **LT\_CALC (RT\_CALC)**, and check the **"Kinematic Only"** box.
3. Click **Create**. The segment will be created and the **LT\_CALC (RT\_CALC)** tab will open.
4. In the section labeled **Define Proximal Joint and Radius**, select **LCA (RCA)** from the list box

- labeled **Joint** and enter *0.1* in the **Radius (Meters)** field..
5. In the section labeled **Define Distal Joint and Radius**, select *LIC (RIC)* from the list box labeled **Joint** and enter *0.1* in the **Radius (Meters)** field.
  6. In the section labeled **Extra Target to Define Orientation**, select *Medial* from the list box labeled **Location** and *LST (RST)* from the second list box.
  7. In the section labeled **Select Tracking Targets**, select the following targets: *LCA (RCA)*, *LPT (RPT)* and *LST (RST)*.

**Note:** Use the ctrl key on your keyboard while you click to select multiple targets.

1. Click the **Segment Properties** button.
2. Click the **Modify Segment Coordinate System** button.
3. For the **A/P Axis**, select *+Y*, and for the **Distal to Proximal**, select *-X*.
4. Then click **OK**.
5. Then click **Apply**.
6. Then click on the *LT\_CALC (RT\_CALC)* tab.
7. Click **Build Model**.
8. Click **Close Tab**.

= Defining the Mid-foot =

Follow the sub-steps below to create the Mid-Foot segments using the following properties. The Mid-Foot segments are created by defining the *LID (RID)* landmark as the proximal segment endpoint and the *LSMB (RSMB)* as the distal segment endpoint. The transverse plane is defined using the segment endpoints and the *LTN/RTN* targets. The segment is tracked using three markers.

1. Click the **Segments** button to open the **Segments** tab.
2. In the **Segment Name** box write *LT\_MID (RT\_MID)*, and check the **"Kinematic Only"** box.
3. Click **Create**. The segment will be created and the *LT\_MID (RT\_MID)* tab will open.
4. In the section labeled **Define Proximal Joint and Radius**, select *LID (RID)* from the list box labeled **Joint** and enter *0.1* in the **Radius (Meters)** field.
5. In the section labeled **Define Distal Joint and Radius**, select *LSMB (RSMB)* from the list box labeled **Joint** and enter *0.1* in the **Radius (Meters)** field.
6. In the section **Extra Target to Define Orientation (if needed)**, select *Medial* for the **Location** and *LTN (RTN)* as the target from the list box.
7. In the section labeled **Select Tracking Targets**, select the following targets: *LSMB (RSMB)*, *LTN (RTN)* and *LVMB (RVMB)*.

**Note:** Use the ctrl key on your keyboard while you click to select multiple targets.

1. Click the **Segment Properties** button.
2. Click the **Modify Segment Coordinate System** button.
3. For the **A/P Axis**, select *+Y*, and for the **Distal to Proximal**, select *-X*.
4. Then click **OK**.
5. Then click **Apply**.
6. Then click on the *LT\_MID (RT\_MID)* tab.
7. Click **Build Model**.
8. Click **Close Tab**.

= Defining the Metatarsus =

Follow the sub-steps below to create the Metatarsus segments using the following properties. The

Metatarsus segments are created by defining the *LSMB (RSMB)* landmark as the proximal segment endpoint, the *LSM\_MET (RSM\_MET)* as the distal segment joint and the *LVM/RVM* as the lateral distal endpoint. The segment is tracked using four markers.

1. Click the **Segments** button to open the **Segments** tab.
2. In the **Segment Name** box write *LT\_MET (RT\_MET)*, and check the **“Kinematic Only”** box.
3. Click **Create**. The segment will be created and the *LT\_MET (RT\_MET)* tab will open.
4. In the section labeled **Define Proximal Joint and Radius**, select *LSMB (RSMB)* from the list box labeled **Joint** and enter *0.1* in the **Radius (Meters)** field.
5. In the section labeled **Define Distal Joint and Radius**, select *LSM\_MET (RSM\_MET)* from the list box labeled **Joint** and select *LVM (RVM)* as the **Lateral** distal endpoint. The Radius will be automatically calculated based on those targets.
6. In the section labeled **Select Tracking Targets**, select the following targets: *LFM (RFM)*, *LSMB (RSMB)*, *LSM (RSM)* and *LVM (RVM)*.

**Note:** Use the ctrl key on your keyboard while you click to select multiple targets.

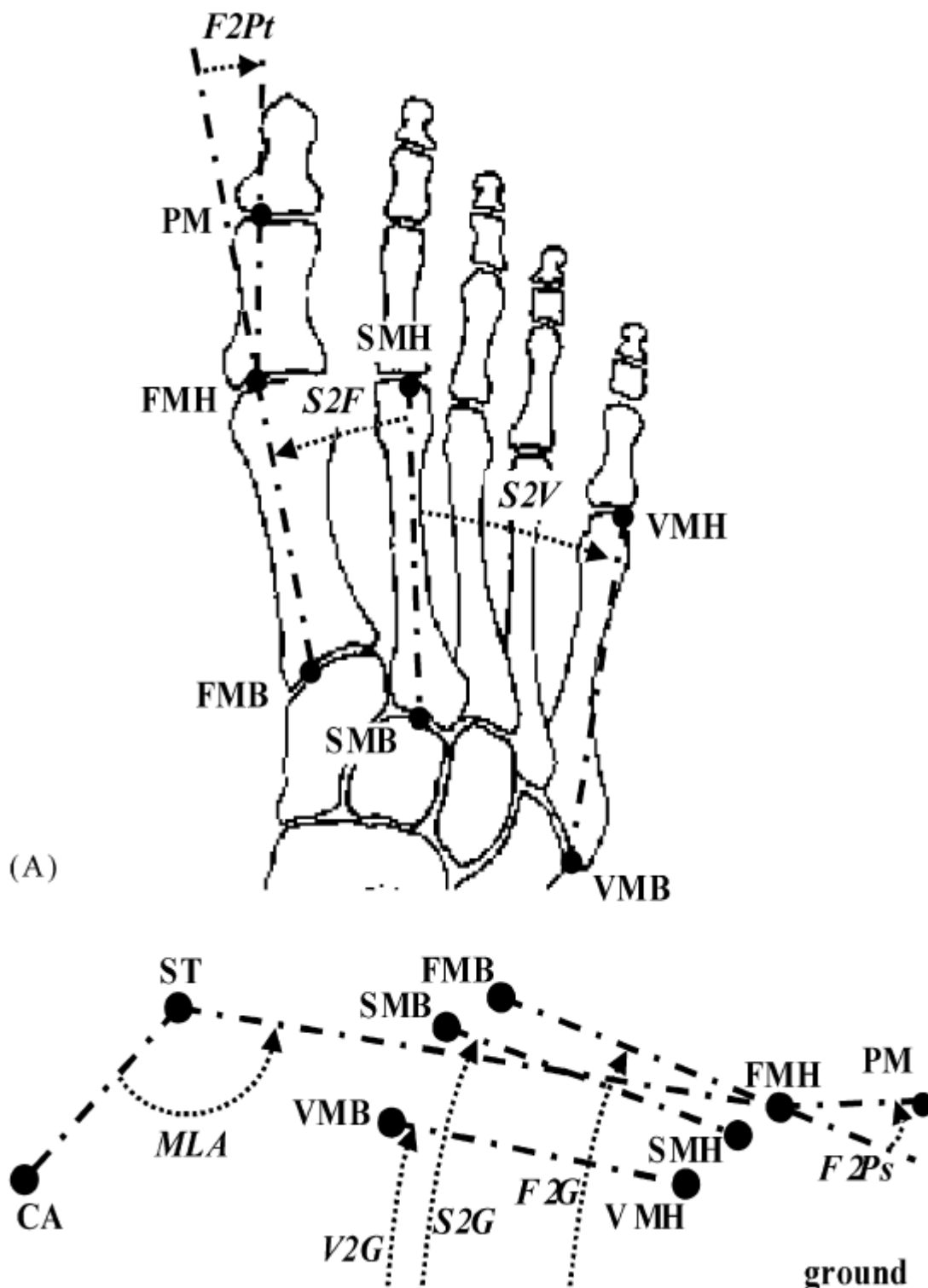
1. Click **Build Model**.
2. Click **Close Tab**.
3. Click the **Segment Properties** button.
4. Click the **Modify Segment Coordinate System** button.
5. For the **A/P Axis**, select **+Y**, and for the **Distal to Proximal**, select **-X**.
6. Then click **OK**.
7. Then click **Apply**.
8. Then click on the *LT\_MET (RT\_MET)* tab.
9. Click **Build Model**.
10. Click **Close Tab**.

## Computing Planar Angles

The IOR multi-segment foot model also offers a method to measure foot planar/anatomical angles, often measured through static load-bearing radiograms. In this case, these angles can also be measure dynamically. As per Leardini (2007) <sup>[1]</sup>, here a list of the different angles computed using this foot model:

**F2Pt** = angle between the projections of the line segments FMH-PM and FMB-FMH into the transverse plane of the metatarsus, positive angle with the former rotating laterally with respect to the latter, i.e. motion in valgus of the first metatarsophalangeal joint. **S2F** = angle between the projections of the line segments FMB-FMH and SMB-SMH into the transverse plane of the metatarsus, positive angle with the former rotating medially with respect to the latter. **S2V** = angle between the projections of the line segments VMB-VMH and SMB-SMH into the transverse plane of the metatarsus, positive angle with the former rotating laterally with respect to the latter. **F2G** = angle between the line segment FMB-FMH and the ground, i.e. in the plane orthogonal to the ground and containing FMB-FMH, positive angle with the downward rotation of the head. **S2G** = angle between the line segment SMB-SMH and the ground, positive angle with the downward rotation of the head. **V2G** = angle between the line segments VMB-VMH and the ground, positive angle with the downward rotation of the head. **F2Ps** = angle between the projections of the line segments FMH-PM and FMB-FMH into the sagittal plane of the metatarsus, positive angle with the former rotating upward, i.e. dorsiflexion of the first metatarsophalangeal joint. **MLA** = angle between the projections of the line segments CA-ST and ST-FMH into

the sagittal plane of the foot, positive angle with clockwise rotation of the former toward the latter, i.e. navicular drop being positive. This would replicate somehow what is known in radiography as the Moreau and Costa Bertani angle. To make sure all three markers (CA, ST and FMH) are not colinear, it is recommended to use the CAB marker instead of the CA since the CAB is lower than the CA marker, ensuring the angle is more acute.



Compute the angle between two vectors, represented by 3 or 4 points

Resulting Signal

Name

L\_F2Pt

Folder

PROCESSED

1

2

3

1

2

3

LANDMARK::ORIGINAL::LF2P

TARGET::ORIGINAL::LFM

TARGET::ORIGINAL::LPM

Specify 3 or 4 points

3 Point

4 Point

Angle Direction

Right Hand Rule

Left Hand Rule

Use Range

0 to 360 degrees

-180 to 180 degrees

Projected onto Plane

XY

☒ XZ

YZ

If the angle is projected onto one of the principle planes, the direction of the normal to the two vectors is the third principle axes. The Right Hand Rule and the Range are with respect to this normal.

3D Space

3D

Always 0 to 180 degrees (Unspecified Direction)

3D

Specify a Vector Normal to the Two Vectors

Example

With respect to the figure. Assume the two vectors lie in the XY plane; Rotation is about the Z-axis.

3D: Angle = 95 degrees

Projected onto XY: Use RHR: Use 0- to 360: Angle=265 degrees

Projected onto XY: Use RHR: Use -180 to 180: Angle=-95 degrees

Cancel

OK

Within the pipeline Workshop window, under **Signal Math**, double-click (or highlight and click on the right-pointing double arrows) **Compute\_Plantar\_Angle**. Once the **Compute\_Plantar\_Angle** is transferred in the *commands in Main pipeline* window, click on *Edit*.

The following are 3-point planar angles:

### L\_F2Pt (R\_F2Pt)

- 1- LANDMARK::ORIGINAL::LF2P (RF2P)
- 2- TARGET::ORIGINAL::LFM (RFM)
- 3- TARGET::ORIGINAL::LPM (RPM)

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Angle Direction: *LF2Pt* = Right Hand Rule; *RF2Pt* = Left Hand Rule

Use Range: -180 to 180 degrees

Projected onto Plane: XZ

**Note: The reference segment will need to be changed to *LT\_MET* (*RT\_MET*) within the text option.**

### **L\_F2Ps (R\_F2Ps)**

1- LANDMARK::ORIGINAL::LF2P (RF2P)

2- TARGET::ORIGINAL::LFM (RFM)

3- TARGET::ORIGINAL::LPM (RPM)

Angle Direction: Right Hand Rule

Use Range: -180 to 180 degrees

Projected onto Plane: XY

**Note: The reference segment will need to be changed to *LT\_MET* (*RT\_MET*) within the text option.**

### **L\_MLA (R\_MLA)**

1- LANDMARK::ORIGINAL::LCAB\_MLA (RCAB\_MLA)

2- TARGET::ORIGINAL::LST (RST)

3- TARGET::ORIGINAL::LFM (RFM)

Angle Direction: Right Hand Rule

Use Range: 0 to 360 degrees

Projected onto Plane: XY

**Note: The reference segment will need to be changed to *LFT* (*RFT*) within the text option.**

The following are 4-point planar angles:

### **L\_S2F (R\_S2F)**

1- TARGET::ORIGINAL::LSM (RSM)

2- TARGET::ORIGINAL::LSMB (RSMB)

3- TARGET::ORIGINAL::LFMB (RFMB)

4- TARGET::ORIGINAL::LFM (RFM)

Angle Direction:  $L\_S2F$  = Left Hand Rule;  $R\_S2F$  = Right Hand Rule

Use Range: -180 to 180 degrees

Projected onto Plane: XZ

**Note: The reference segment will need to be changed to  $LT\_MET$  ( $RT\_MET$ ) within the text option.**

### **L\_S2V (R\_S2V)**

1- TARGET::ORIGINAL::LSM (RSM)

2- TARGET::ORIGINAL::LSMB (RSMB)

3- TARGET::ORIGINAL::LVMB (RVMB)

4- TARGET::ORIGINAL::LVM (RVM)

Angle Direction:  $L\_S2V$  = Right Hand Rule;  $R\_S2V$  = Left Hand Rule

Use Range: -180 to 180 degrees

Projected onto Plane: XZ

**Note: The reference segment will need to be changed to  $LT\_MET$  ( $RT\_MET$ ) within the text option.**

### **L\_F2G (R\_F2G)**

1- TARGET::ORIGINAL::LFMB (RFMB)

2- TARGET::ORIGINAL::LFM (RFM)

3- LANDMARK::ORIGINAL::LFM\_FLOOR (RFM\_FLOOR)

4- LANDMARK::ORIGINAL::LFMB\_FLOOR (RFMB\_FLOOR)

Angle Direction: Left Hand Rule

Use Range: -180 to 180 degrees

3D Space: 3D - Always 0 to 180 degrees (Unspecified Direction)

## **L\_S2G (R\_S2G)**

1- TARGET::ORIGINAL::LSMB (RSMB)

2- TARGET::ORIGINAL::LSM (RSM)

3- LANDMARK::ORIGINAL::LSM\_FLOOR (RSM\_FLOOR)

4- LANDMARK::ORIGINAL::LSMB\_FLOOR (RSMB\_FLOOR)

Angle Direction: Left Hand Rule

Use Range: -180 to 180 degrees

3D Space: 3D - Always 0 to 180 degrees (Unspecified Direction)

**Note: The reference segment will need to be changed to *LT\_MET (RT\_MET)* within the text option.**

## **L\_S2Gs (R\_S2Gs)**

1- TARGET::ORIGINAL::LSMB (RSMB)

2- TARGET::ORIGINAL::LSM (RSM)

3- LANDMARK::ORIGINAL::LSM\_FLOOR (RSM\_FLOOR)

4- LANDMARK::ORIGINAL::LSMB\_FLOOR (RSMB\_FLOOR)

Angle Direction: Right Hand Rule

Use Range: -180 to 180 degrees

Projected onto Plane: XY

**Note: The reference segment will need to be changed to *LT\_MET (RT\_MET)* within the text option.**

## **LV2G (RV2G)**

1- TARGET::ORIGINAL::LVMB (RVMB)

2- TARGET::ORIGINAL::LVM (RVM)

3- LANDMARK::ORIGINAL::LVM\_FLOOR (RVM\_FLOOR)

4- LANDMARK::ORIGINAL::LVMB\_FLOOR (RVMB\_FLOOR)

Angle Direction: Left Hand Rule

Use Range: -180 to 180 degrees

3D Space: 3D - Always 0 to 180 degrees (Unspecified Direction)

## **L\_V2Gs (R\_V2Gs)**

1- TARGET::ORIGINAL::LVMB (RVMB)

2- TARGET::ORIGINAL::LVM (RVM)

3- LANDMARK::ORIGINAL::LVM\_FLOOR (RVM\_FLOOR)

4- LANDMARK::ORIGINAL::LVMB\_FLOOR (RVMB\_FLOOR)

Angle Direction: Left Hand Rule

Use Range: -180 to 180 degrees

Projected onto Plane: XY

**Note: The reference segment will need to be changed to *LT\_MET (RT\_MET)* within the text option.**

## **Computing Joint Angles**

The following joint angles describes the intrinsic foot movements between the different foot segments of the IOR foot model.

### ***Foot to Tibia Angle***

Z axis = Sagittal plane = Dorsiflexion (+)/Plantarflexion (-)

X axis = Frontal plane = Eversion (+)/Inversion (-)

Y axis = Transverse plane = Abduction (+)/ Adduction (-)

**Data Name=** LSHAFOO

**Folder=** ORIGINAL

**Model Based Item Properties=** JOINT\_ANGLE

**Negate X, Y, Z=** All Unchecked

**Normalization=** Normalization Off

**Segment=** LFT

**Reference Segment=** LSK

**Cardan Sequence=** Z-X-Y

**Data Name=** RSHAFOO

**Folder=** ORIGINAL

**Model Based Item Properties=** JOINT\_ANGLE

**Negate X, Y, Z=** Check X and Y

**Normalization**= Normalization Off

**Segment**= RFT

**Reference Segment**= RSK

**Cardan Sequence**= Z-X-Y

### ***Calcaneuss to Tibia Angle***

Z axis = Sagittal plane = Dorsiflexion (+)/Plantarflexion (-)

X axis = Frontal plane = Eversion (+)/Inversion (-)

Y axis = Transverse plane = Abduction (+)/ Adduction (-)

**Data Name**= LSHACAL

**Folder**= ORIGINAL

**Model Based Item Properties**= JOINT\_ANGLE

**Negate X, Y, Z**= All Unchecked

**Normalization**= Normalization Off

**Segment**= LT\_CALC

**Reference Segment**= LSK

**Cardan Sequence**= Z-X-Y

**Data Name**= RSHACAL

**Folder**= ORIGINAL

**Model Based Item Properties**= JOINT\_ANGLE

**Negate X, Y, Z**= Check X and Y

**Normalization**= Normalization Off

**Segment**= RT\_CALC

**Reference Segment**= RSK

**Cardan Sequence**= Z-X-Y

### ***Metatarsals to Mid-Foot Angle***

Z axis = Sagittal plane = Dorsiflexion (+)/Plantarflexion (-)

X axis = Frontal plane = Eversion (+)/Inversion (-)

Y axis = Transverse plane = Abduction (+)/ Adduction (-)

**Data Name**= LMIDMET

**Folder**= ORIGINAL

**Model Based Item Properties**= JOINT\_ANGLE

**Negate X, Y, Z**= All Unchecked

**Normalization**= Normalization Off

**Segment**= LT\_MET

**Reference Segment**= LT\_MID

**Cardan Sequence**= Z-X-Y

**Data Name**= RMIDMET

**Folder**= ORIGINAL

**Model Based Item Properties=** JOINT\_ANGLE

**Negate X, Y, Z=** Check X and Y

**Normalization=** Normalization Off

**Segment=** RT\_MET

**Reference Segment=** RT\_MID

**Cardan Sequence=** Z-X-Y

### ***Mid-Foot to Calcaneus Angle***

Z axis = Sagittal plane = Dorsiflexion (+)/Plantarflexion (-)

X axis = Frontal plane = Eversion (+)/Inversion (-)

Y axis = Transverse plane = Abduction (+)/ Adduction (-)

**Data Name=** LCALMID

**Folder=** ORIGINAL

**Model Based Item Properties=** JOINT\_ANGLE

**Negate X, Y, Z=** All Unchecked

**Normalization=** Normalization Off

**Segment=** LT\_MID

**Reference Segment=** LT\_CALC

**Cardan Sequence=** Z-X-Y

**Data Name=** RCALMID

**Folder=** ORIGINAL

**Model Based Item Properties=** JOINT\_ANGLE

**Negate X, Y, Z=** Check X and Y

**Normalization=** Normalization Off

**Segment=** RT\_MID

**Reference Segment=** RT\_CALC

**Cardan Sequence=** Z-X-Y

### ***Metatarsals to Calcaneus Angle***

Z axis = Sagittal plane = Dorsiflexion (+)/Plantarflexion (-)

X axis = Frontal plane = Eversion (+)/Inversion (-)

Y axis = Transverse plane = Abduction (+)/ Adduction (-)

**Data Name=** LCALMET

**Folder=** ORIGINAL

**Model Based Item Properties=** JOINT\_ANGLE

**Negate X, Y, Z=** All Unchecked

**Normalization=** Normalization Off

**Segment=** LT\_MET

**Reference Segment=** LT\_CALC

**Cardan Sequence=** Z-X-Y

**Data Name**= RCALMET  
**Folder**= ORIGINAL  
**Model Based Item Properties**= JOINT\_ANGLE  
**Negate X, Y, Z**= Check X and Y  
**Normalization**= Normalization Off  
**Segment**= RT\_MET  
**Reference Segment**= RT\_CALC  
**Cardan Sequence**= Z-X-Y

## References

1. ↑ [1.00 1.01 1.02 1.03 1.04 1.05 1.06 1.07 1.08 1.09 1.10 1.11](#) Leardini, A., M.G. Benedetti, L. Berti, D. Bettinelli, R. Nativo, and S. Giannini. "Rear-foot, Mid-foot and Fore-foot Motion during the Stance Phase of Gait." Gait & Posture 25 (2007): 453-55
2. ↑ [2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8](#) Serge van Sint Jan "Color Atlas of Skeletal Landmark Definitions: Guidelines for Reproducible Manual and Virtual Palpations" 2007 - Churchill Livingstone

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