IORFoot Tutorial Angles

Introduction

The IOR Foot analysis uses joint angles and planar angles to describe the motion of the foot.

****

The IOR Foot analysis has been described in the paper:

**** 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 [1]

**** **Modifications to the IOR Foot Analysis are described in the paper:**

**** Portinaro, N., A. Leardini, A. Panou, V. Monzani, and P. Caravaggi. "Modifying the Rizzoli foot model to improve the diagnosis of pes-planus: application to kinematics of feet in teenagers." Journal of Foot and Ankle Research (2014) [2]

**** This tutorial describes the original analysis with all modifications from the 2014 paper.

****

The 2007 paper is described [https://wiki.has-motion.com/doku.php?id=visual3d:tutorials:modeling:ior_foot_model#introduction|here]].

Downloads

Sample data for this tutorial can be downloaded here.

The PPT images shown in this tutorial can be downloaded here.

Modifications

Three modifications were made between the first[1] and second[2] papers. These modifications are outlined below.

Mod 1: Hallux

Previously, varus & dorsiflexion at the first metatarso-phalangeal joint were represented by planar angles (F2Pt and F2Ps)[1].

The 2014 paper creates a hallux segment and calculates the F2Pt and F2Ps angles as joint angles between the Hallux & Metatarsus segments[2].

Mod 2: Calcaneus

The original paper [1] only contained one target on the posterior calcaneus. The 2014 modifications[2] contain two targets on the posterior calcaneus.

The 2007 paper[1] described the CA target as the:

- CA - upper central ridge of the calcaneus posterior surface, i.e. Achilles' tendon attachment

The 2014 paper[2] described the HL target as the:

- HL - most distal point of attachment area of the Achilles tendon on the calcaneus

The CA[1] target will be referred to as the FCP (calcaneus proximal - the proximal attachement of the tendon) for the remainder of this tutorial.

The HL[2] target will be referred to as the FCD (calcaneus distal - FCC[3] [pg. 162]) for the remainder of this tutorial.

The FCP target will be used to indicate the origin of the calcaneus segment, and the orientation of the FCP/FCD targets will be used to indicate inversion/eversion of the calcaneus (Sha_Cal_Fro Angle). When placing these targets, make sure there is enough distance between them so that your camera system can recognize them as two separate targets.

The FCD target should be removed after the static trial.

Mod 3: MLA Angle

Previously, the MLA angle was calculated using the CA target[1].

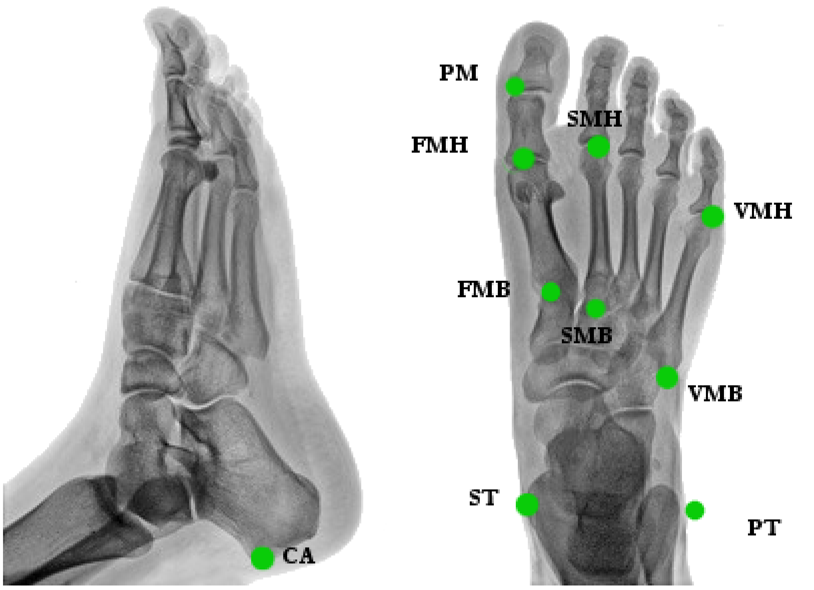
The 2014 paper projects the FCP target onto the ground during the static trial (FCP_proj), and tracks this projection using the calcaneus segment (FCP_proj_track)[2].

Target Placement

The following text contains a detailed explanation of how to palpate the necessary bony landmarks:

Serge van Sint Jan “Color Atlas of Skeletal Landmark Definitions: Guidelines for Reproducible Manual and Virtual Palpations” 2007 - Churchill Livingstone [3]

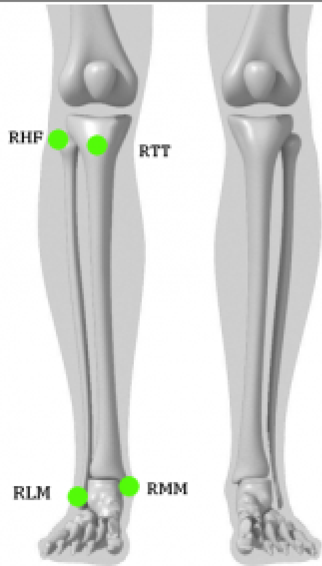
Foot Targets



- **CA[1] (FCP)** [3] : p. 162 = Proximal posterior Surface of Calcaneus. *
- **HL[2] (FCD)** [3] : p. 162 = Distal attachment of the Achilles' tendon. *
- **ST[1] (FST)** [3] : p.164 = Sustentaculum Tali of Calcaneus.
- **PT[1] (FPT)** [3] : p.171 = Lateral apex of the peroneal tubercle.
- **TN[1] (FNT)** [3] : p.165 = Medial apex of the tuberosity navicular.
- **FMH[1] (FM1)** [3] : p.173 = Head of 1st Metatarsus.
- **SMH[1] (FM2)** [3] : p.173 = Head of 2nd Metatarsus.
- **VMH[1] (FM5)** [3] : p.173 = Head of 5th Metatarsus.
- **VMB[1] (FMT)** [3] : p.172 = Tuberosity of 5th Metatarsal
- **PM[1] (PD6)** [3] : p.175 = Proximal Distal Phalanx. **
- **FMB[1]** = Base of First Metatarsal. ***
- **SMB[1]** = Base of Second Metatarsal. ***

* Serge Van Sint Jan describes palpation for the FCC landmark (which should be the FCD), and the FCP landmark should be placed proximal to this landmark.
** Serge Van Sint Jan describes palpation for the mediolateral borders of this landmark (PM6/PL6), the target should be placed at the midpoint.
*** There is no reference for this landmark in Serge Van Sint Jan text, please see the IOR Foot paper for further clarification

Shank Targets

HF[1] **(FAX)** [3] : p.154 = Apex of the styloid process **TT**[1] **(TTC)** [3] : p.144 = Tibial tuberosity **LM**[1] **(FAL)** [3] : p.158 = Apex of the Lateral malleolus **MM**[1] **(TAM)** [3] : p.148 = Apex of the Medial malleolus	

Segment Definition

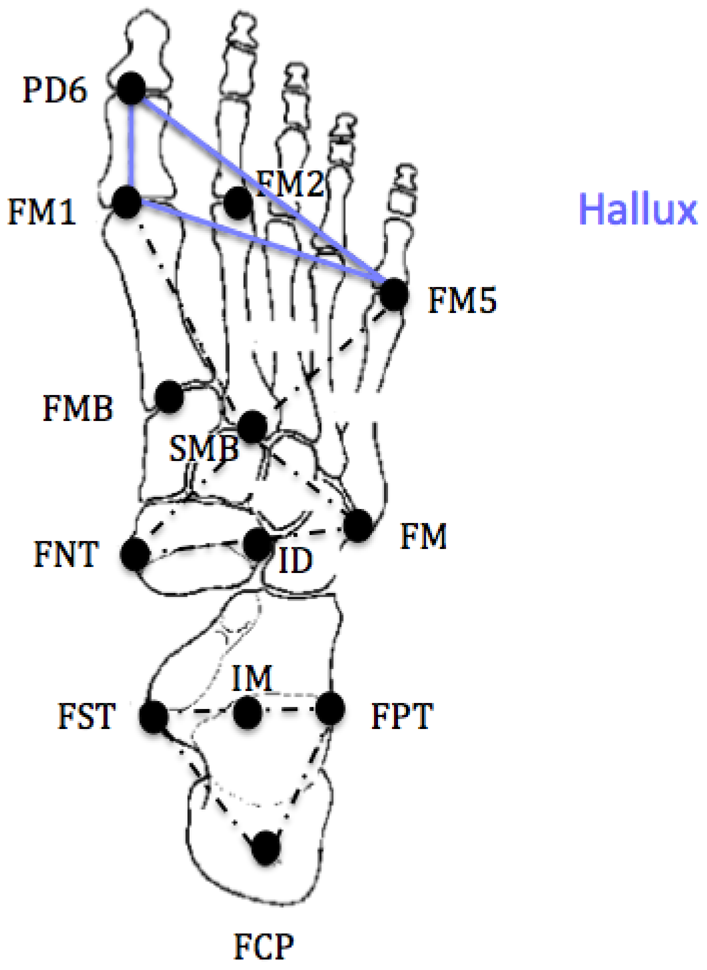
Hallux (Hal)

Segment Definition:

The FMH target is defined as the origin of Hal segment. The A/P (X) axis is defined from the FMH to PM target. The sagittal axis (Z axis) is along the plane defined by the FMH, FM, and VMH targets.

The Hal segment is a modification[2] to the original analysis[1]

Joint Angles:



- F2Pt[1]/ Y component of the Met-Hal Angle[2]
- F2Ps[1]/ Z component of the Met-Hal Angle[2]

Planar Angles:

- No planar angles

Hallux Landmarks:
1. Create RHal_Vert:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:**Landmark Name:** RHal_Vert
    1. **Define Orientation Using:**
        - **Starting Point:** RFMH
        - **Ending Point:** RPM
        - **Lateral Object:** RVMH
    2. Offset Using the Following **ML/AP/AXIAL** Offsets:
        - **ML:** 0.0 **AP:** DISTANCE(RFMH,RPM) **Axial:** 0.0
    3. **Do NOT Check:** Offset by Percent (1.0 = 100%)

4. **Do NOT Check:** Calibration Only Landmark

Hallux Definition
1. Create RHal Segment:

1. In the **Segments** tab, select *RHal* in the Segment Name box.
2. Select **Kinematic Only**
3. Click on the **Create Segment** button.
4. In the **RHal** tab, enter these values:
    1. **Define Proximal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RFMH*
        - **Medial:** *None*
        - **Radius:** *0.1*
    2. **Define Distal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RPM*
        - **Medial:** *None*
        - **Radius:** *0.1*
    3. **Extra Target to Define Orientation:**
        - **Location:** *Lateral RHal_Vert*
    4. **Select Tracking Targets:**
       RHal_Vert, *RFMH*, *RPM*
5. Click on **Build Model.**
6. Click on **Close Tab** before proceeding.

2. Modify the Segment Coordinate System:

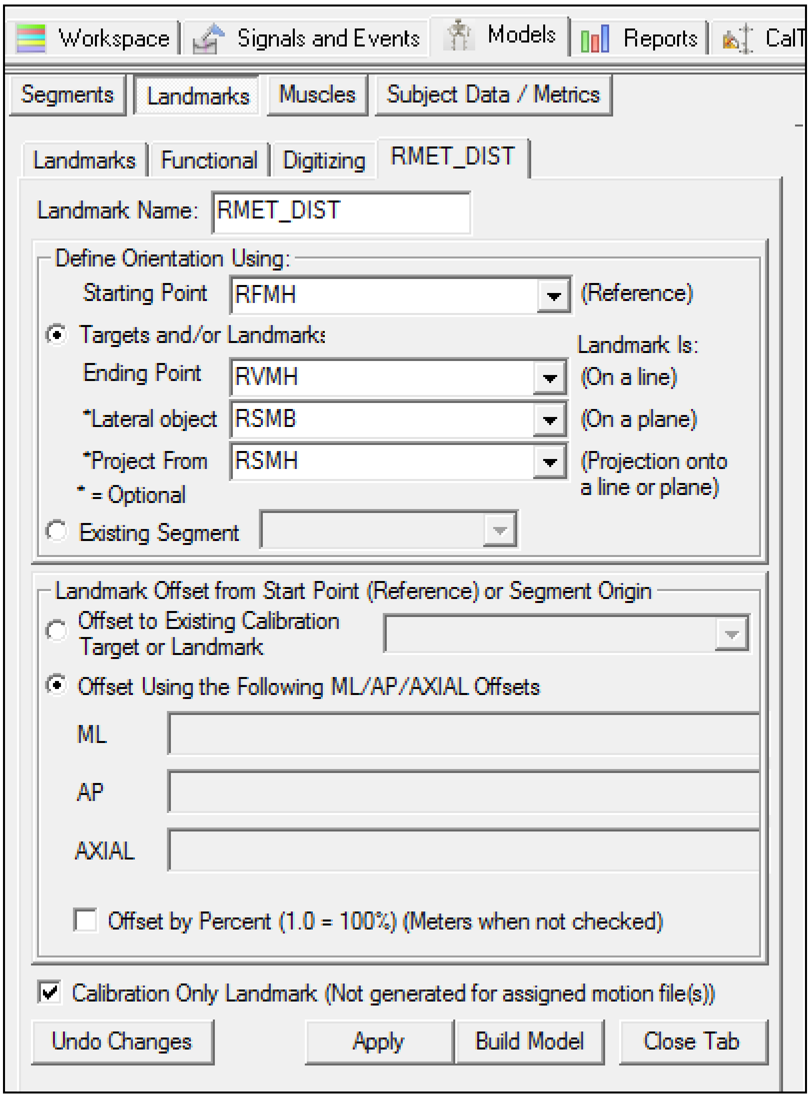
1. Define the Segment Orientation as:
    - **A/P Axis:** -Z
    - **Distal to Proximal:** -X

The image to the right (and all other images in this tutorial) show a mediolateral view of the segment coordinate system after it has been modified.

Metatarsus (Met)

Segment Definition:

The FM2 landmark is projected onto the plane defined by the FM1, FM5, and SMB landmarks. The line from the SMB to FM2 projection are used to define the X axis (A/P) axis of the Met segment. The sagittal axis (Z axis) is along the plane defined by the FM1, FM5, and SMB targets.
The FMB target is not used to define the segment, but it will be used to track the segment (in addition to the other targets).
Joint Angles:



- Mid-Met Angle
- Cal_Met Angle
- F2Pt[1]/ Y component of the Met-Hal Angle[2]
- F2Ps[1]/ Z component of the Met-Hal Angle[2]

Planar Angles:

- S2F is projected onto the plane of the Met segment
- S2FV is projected onto the plane of the Met segment

Metatarsus Landmarks:

1. Create RMET_DIST:

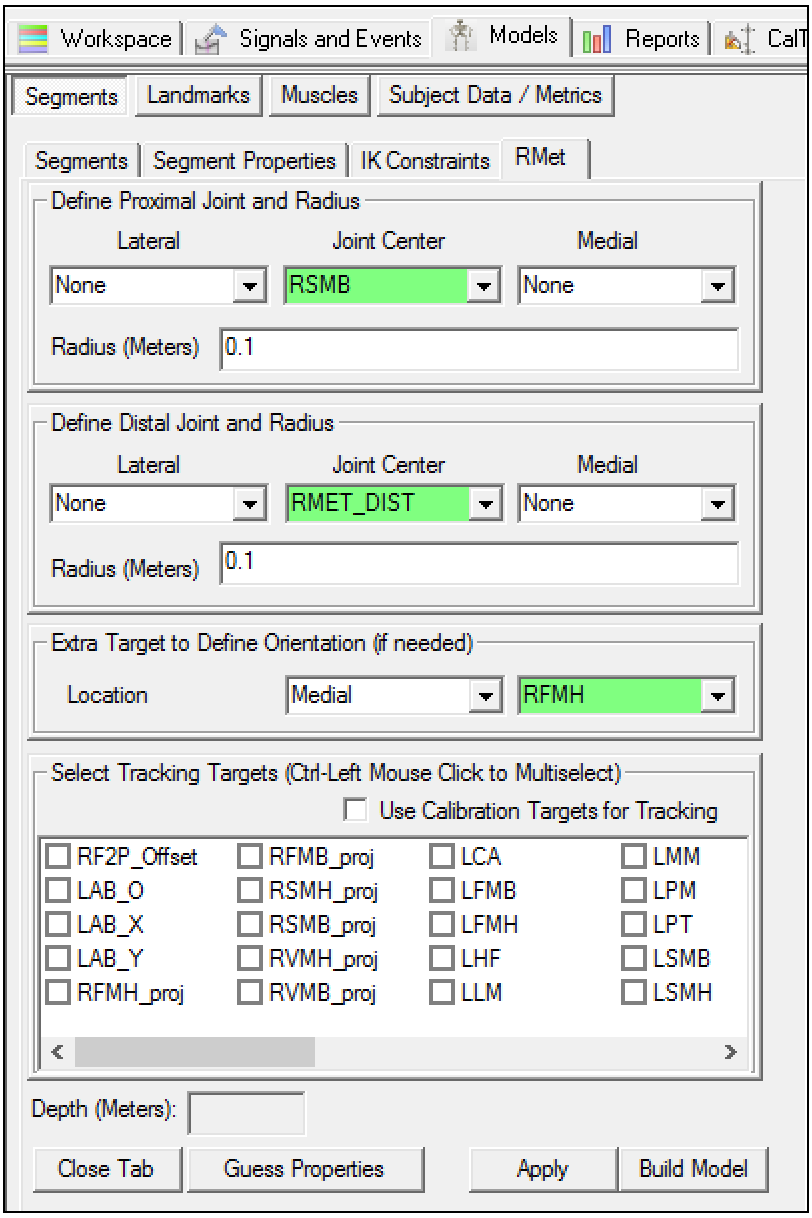
1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:**Landmark Name:** RMET_DIST
    1. **Define Orientation Using:**
        - **Starting Point:** RFMH
        - **Ending Point:** RVMH
        - **Lateral Object:** RSMB

- **Project From:** RSMH

2. **Do NOT Check:** Offset by Percent (1.0 = 100%)
3. **Check:** Calibration Only Landmark

Metatarsus Definition

1. Create RMet Segment:



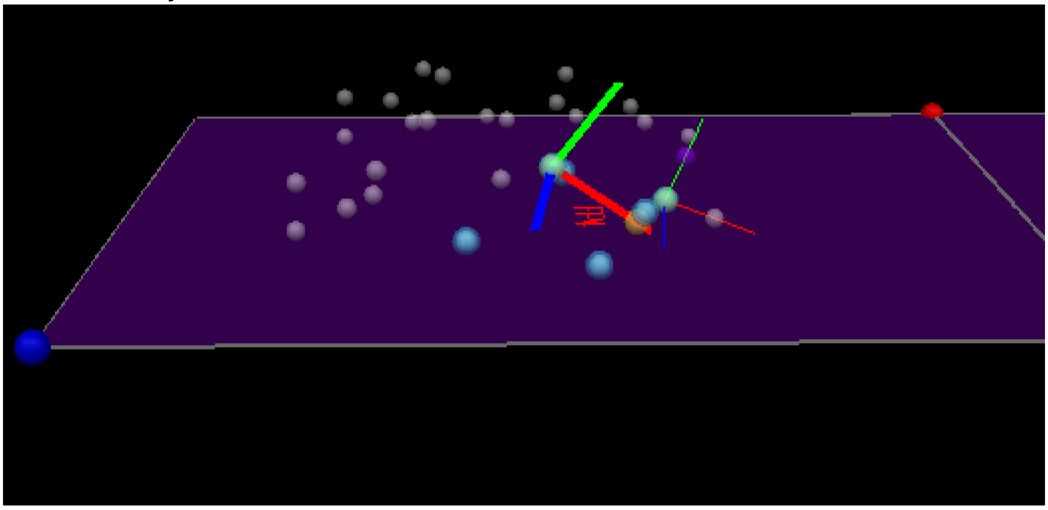
1. In the **Segments** tab, select *RMet* in the Segment Name box.
2. Select **Kinematic Only**
3. Click on the **Create Segment** button.
4. In the **RMet** tab, enter these values:
    1. **Define Proximal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RMSB*
        - **Medial:** *None*
        - **Radius:** *0.1*
    2. **Define Distal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RMET_DIST*

        - **Medial:** *None*
        - **Radius:** *0.1*
    3. **Extra Target to Define Orientation:**
        - **Location:** *Medial RFMH*
    4. **Select Tracking Targets:**
       RFMB, RFMH, RSMB, RSMH, RVMH
5. Click on **Build Model.**
6. Click on **Close Tab** before proceeding.

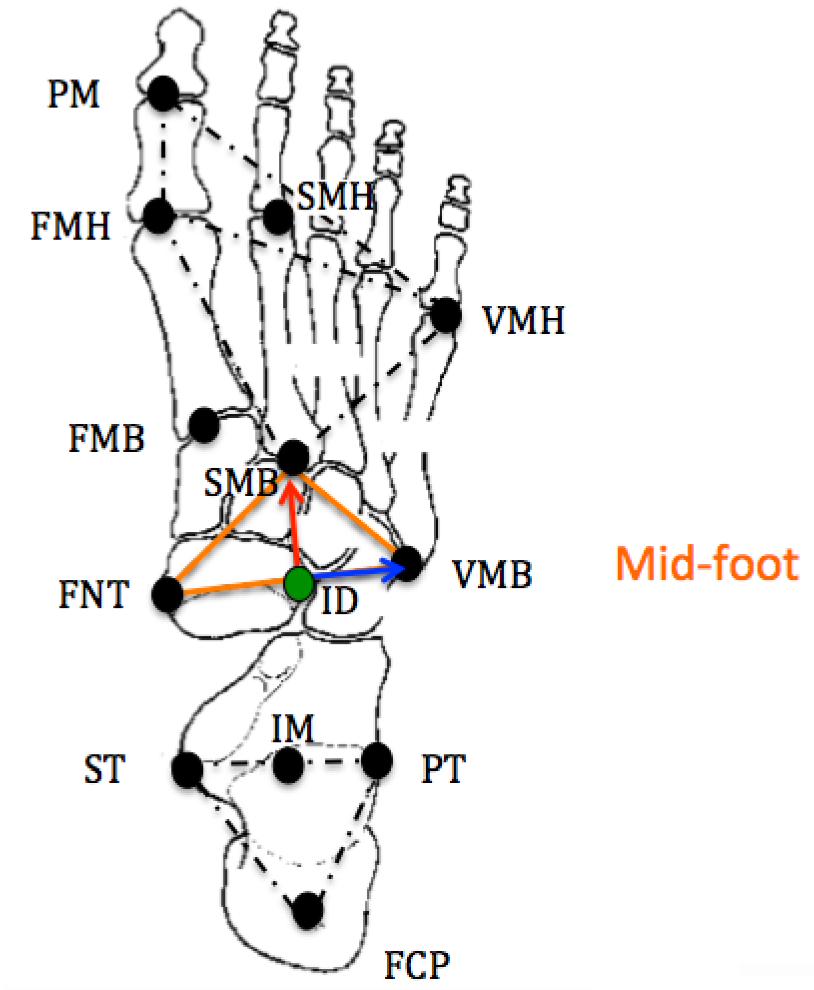
2. Modify the Segment Coordinate System:

1. Define the Segment Orientation as:
    - **A/P Axis:** +Y
    - **Distal to Proximal:** -X

The image below (and all other images in this tutorial) show a mediolateral view of the segment coordinate system after it has been modified.



Mid-foot (Mid)



Segment Definition:

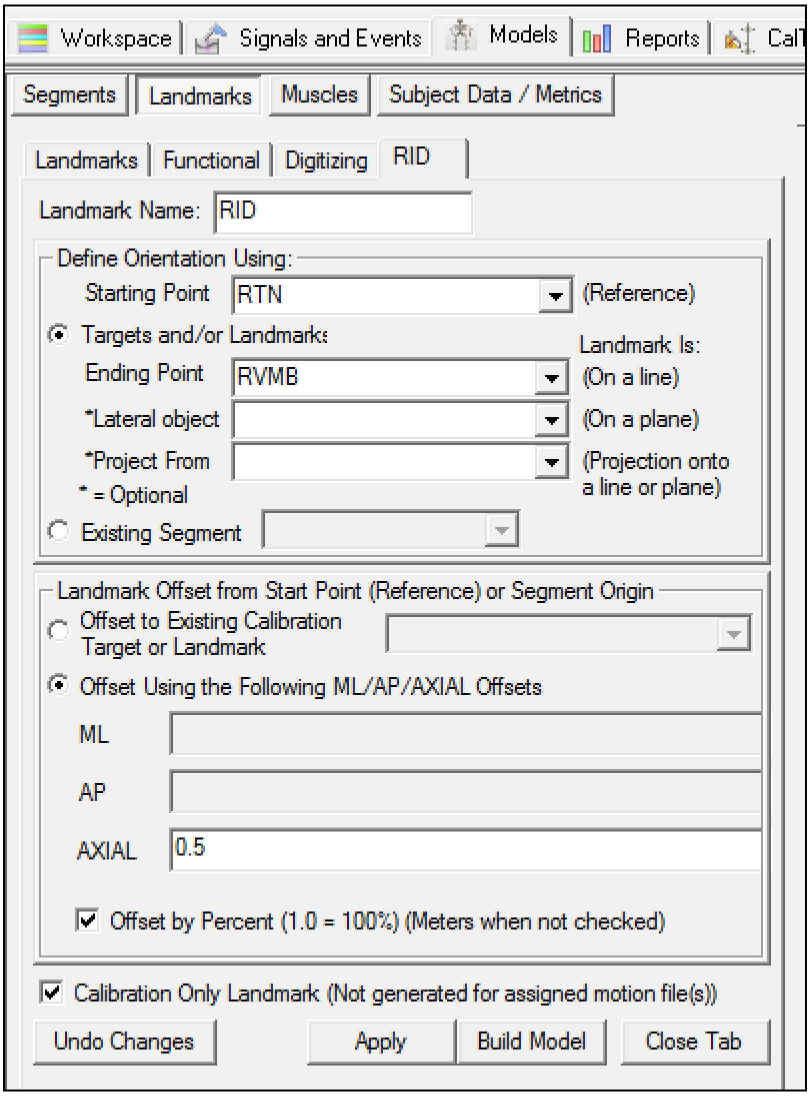
The midpoint between the TN and VMB targets is used to define the origin of the Mid segment. The A/P (X) axis is defined along the line from this midpoint to the SMB target. The sagittal (Z) axis is along the plane defined by the ID, TN and SMB targets.
Joint Angles:

- Cal-Mid Angle
- Mid-Met Angle

Planar Angles:

- Not used for planar angles.

Mid-foot Landmarks:



1. Create RID:

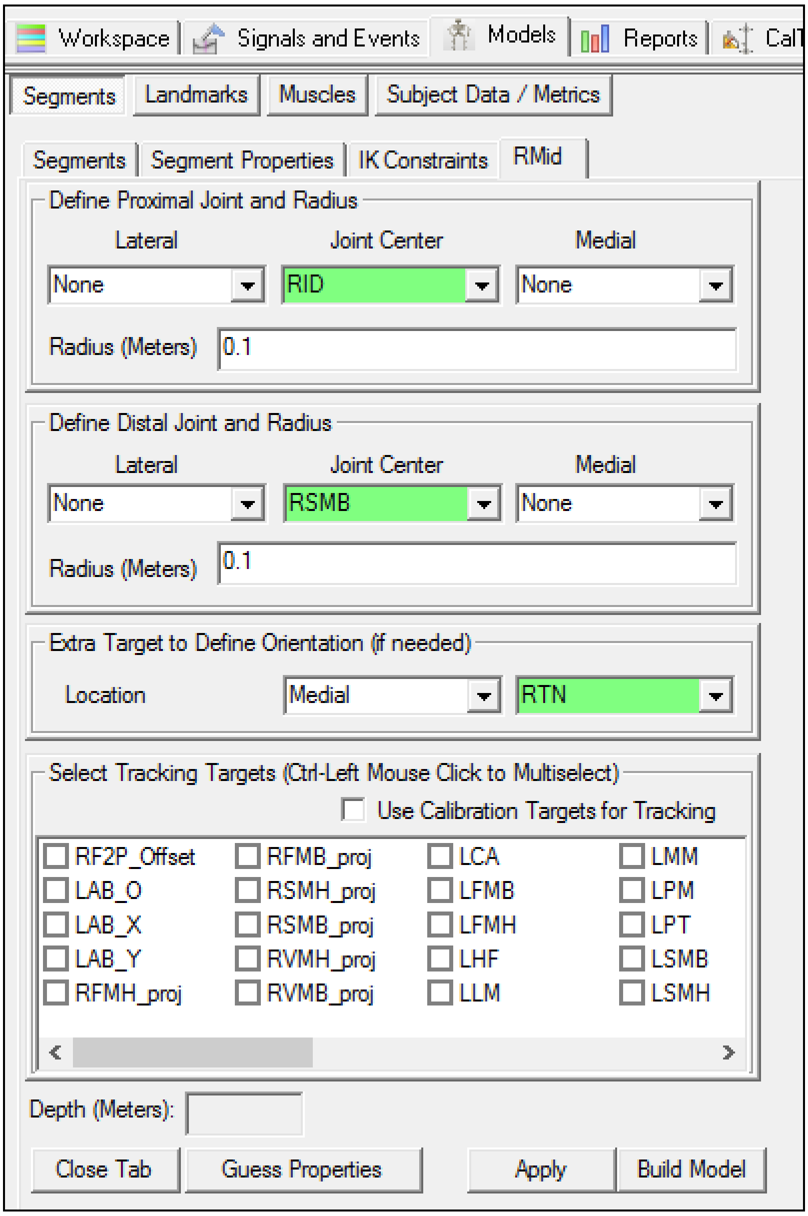
1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:**Landmark Name:** RID
    1. **Define Orientation Using:**
        - **Starting Point:** RTN
        - **Ending Point:** RVMB
    2. Offset Using the Following **ML/AP/AXIAL** Offsets:
        - **Axial:** 0.5
    3. **Check:** Offset by Percent (1.0 = 100%)
    4. **Check:** Calibration Only Landmark

Mid-Foot Definition

1. Create RMid Segment:

1. In the **Segments** tab, select *RMid* in the Segment Name box.
2. Select **Kinematic Only**
3. Click on the **Create Segment** button.
4. In the **RMet** tab, enter these values:
    1. **Define Proximal Joint and Radius:**

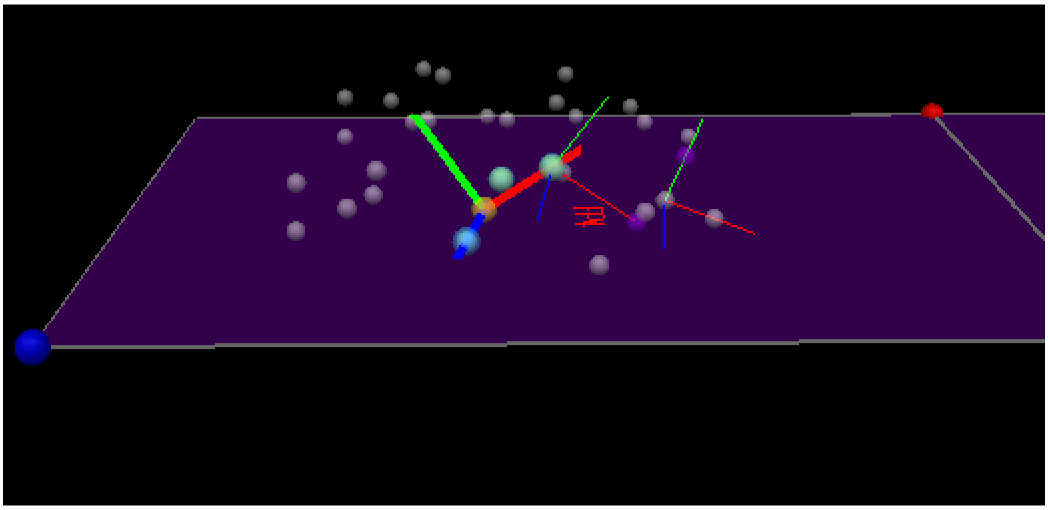
        - **Lateral:** *None*
        - **Joint:** *RID*
        - **Medial:** *None*
        - **Radius:** *0.1*
    2. **Define Distal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RMSB*
        - **Medial:** *None*
        - **Radius:** *0.1*
    3. **Extra Target to Define Orientation:**
        - **Location:** *Medial RTN*
    4. **Select Tracking Targets:**
        RSMB, RTN, RVMB
5. Click on **Build Model.**
6. Click on **Close Tab** before proceeding.



2. Modify the Segment Coordinate System:

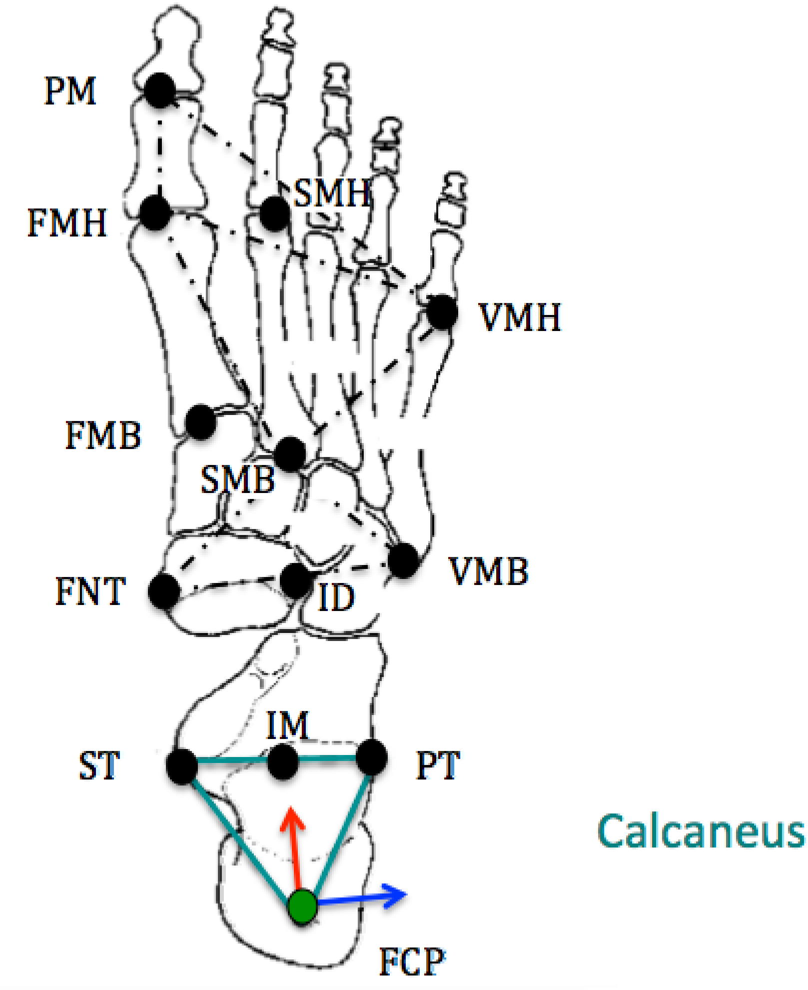
1. Define the Segment Orientation as:
    - **A/P Axis:** +Y

- **Distal to Proximal:** -X



Calcaneus (Cal)

Segment Definition:



The origin is at the FCP target. The A/P (X) axis is along the line from the FCP to midpoint of the ST

and PT targets (IC landmark). The sagittal (Z) axis is along the plane defined by the FCP, ST and TN targets.
Joint Angles:

- Sha-Cal Angle
- Cal-Mid Angle Z rotation & Y Rotation*
- Cal-Met Angle

* The 2014 paper[2] modified the definition of inversion/eversion for the calcaneus segment relative to the shank segment. This is now calculated as the Sha_Cal_Fro angle which is a four point planar angle.

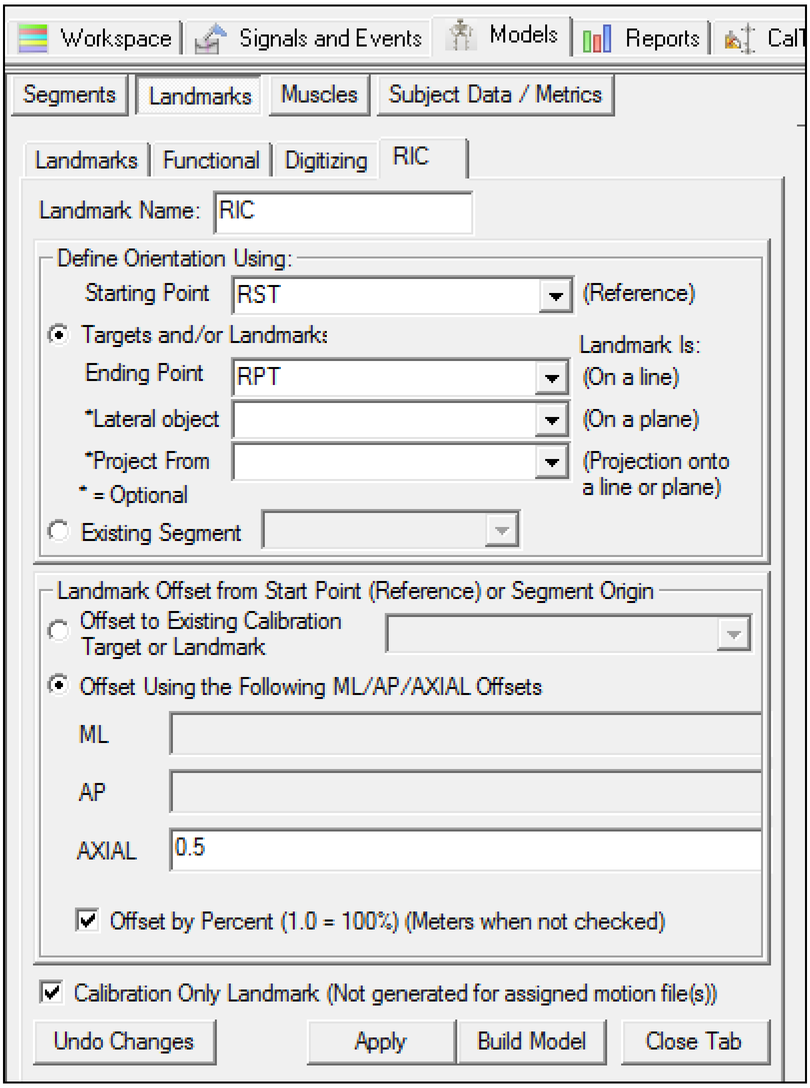
Planar Angles:

- Not used for planar angles.

Calcaneus Landmarks:

1. Create RIC:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RIC
    2. **Define Orientation Using:**
        - **Starting Point:** RST
        - **Ending Point:** RPT
    3. Offset Using the Following **ML/AP/AXIAL** Offsets:
        - **Axial:** 0.5
    4. **Check:** Offset by Percent (1.0 = 100%)
    5. **Check:** Calibration Only Landmark



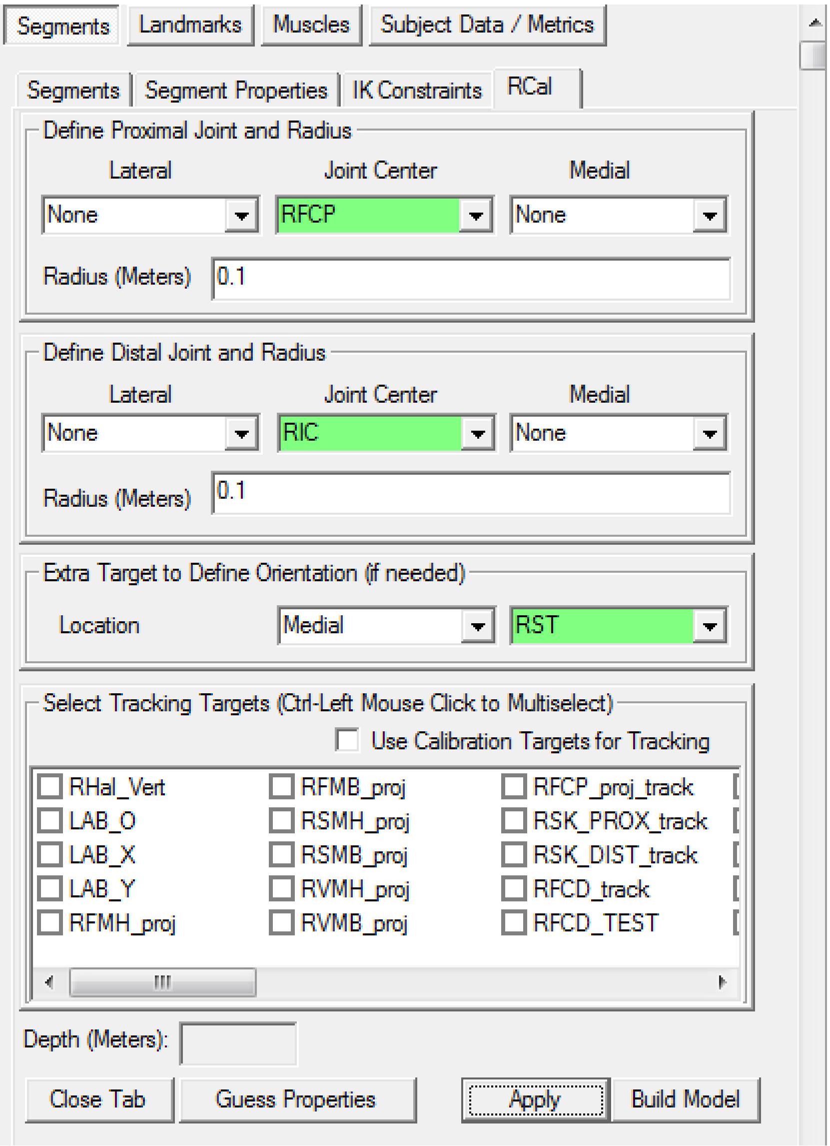
Calcaneus Definition

1. Create RMid Segment:

1. In the **Segments** tab, select *RCal* in the Segment Name box.
2. Select **Kinematic Only**
3. Click on the **Create Segment** button.
4. In the **RCal** tab, enter these values:
    1. **Define Proximal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RFCP*
        - **Medial:** *None*
        - **Radius:** *0.1*
    2. **Define Distal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RIC*
        - **Medial:** *None*
        - **Radius:** *0.1*
    3. **Extra Target to Define Orientation:**
        - **Location:** *Medial RST*
    4. **Select Tracking Targets:**

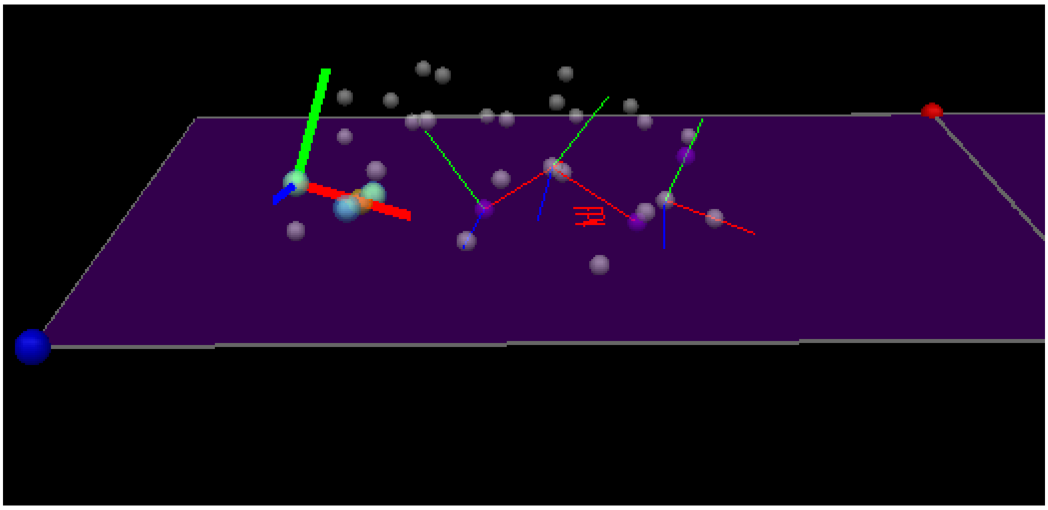
RFCP, RPT, RST

5. Click on **Build Model.**
6. Click on **Close Tab** before proceeding.



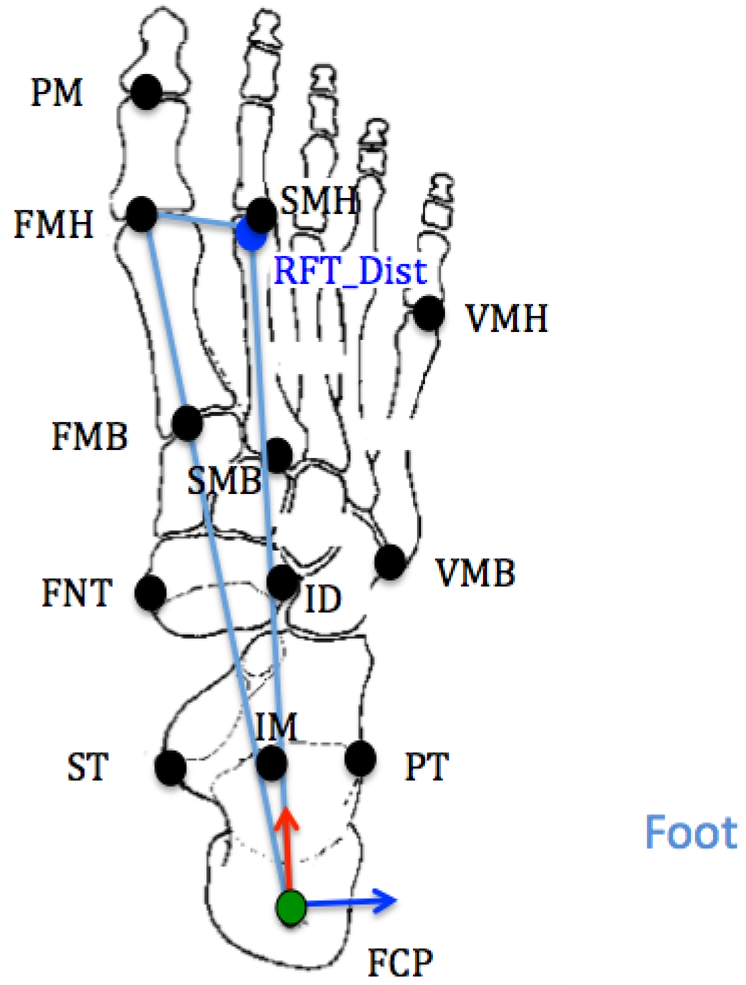
2. Modify the Segment Coordinate System:

1. Define the Segment Orientation as:
   - **A/P Axis:** +Y
   - **Distal to Proximal:** -X



Virtual Foot (Foo)

Segment Definition:



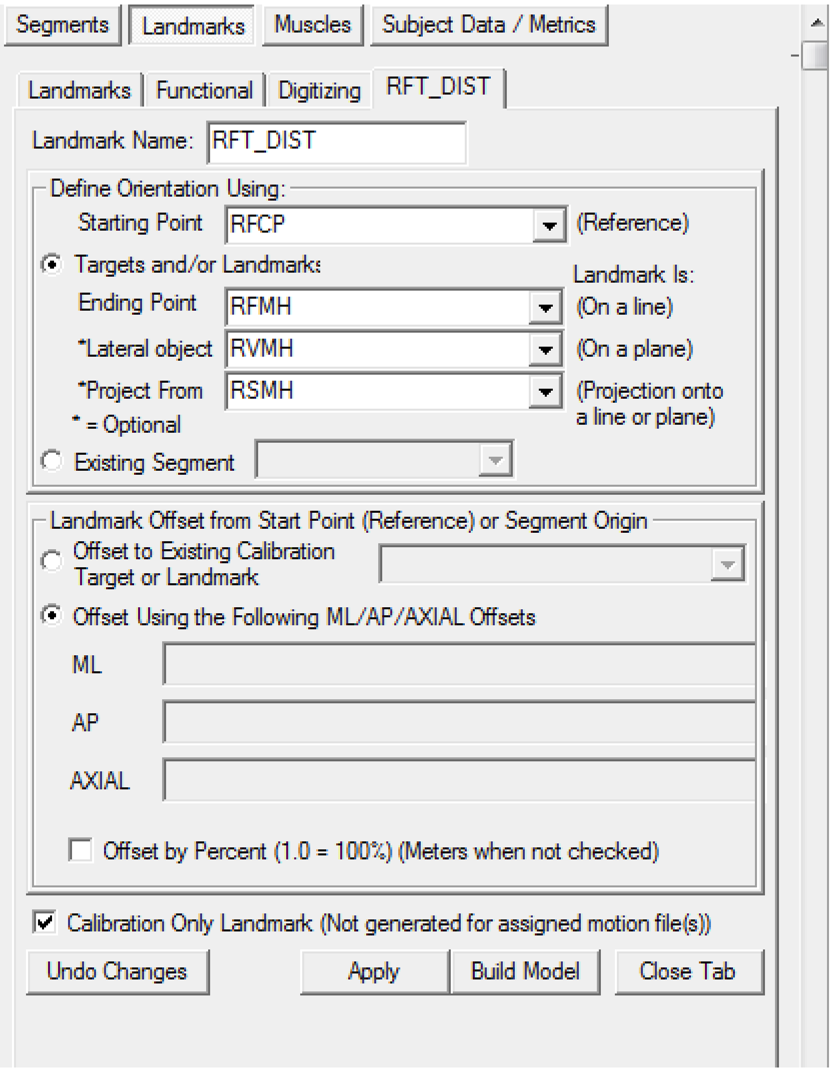
The origin is at the FCP target. The A/P (X) axis is along the line from the FCP to RFT_DIST landmark. The sagittal (Z) axis is along the plane defined by the FCP, FMH and VMH targets.
This foot segment should be set to "kinematic only" since the origin is not at the point of rotation (the

mid point of the RIMM & RLM targets. The IORFoot analysis does not calculate kinetics, so no kinetic foot segment is described in this model. To create gait events, you will need a kinetic foot segment. An example of a kinetic foot segment is created in the sample download files for this tutorial.

Foot Landmarks:

1. Create RFT_DIST:

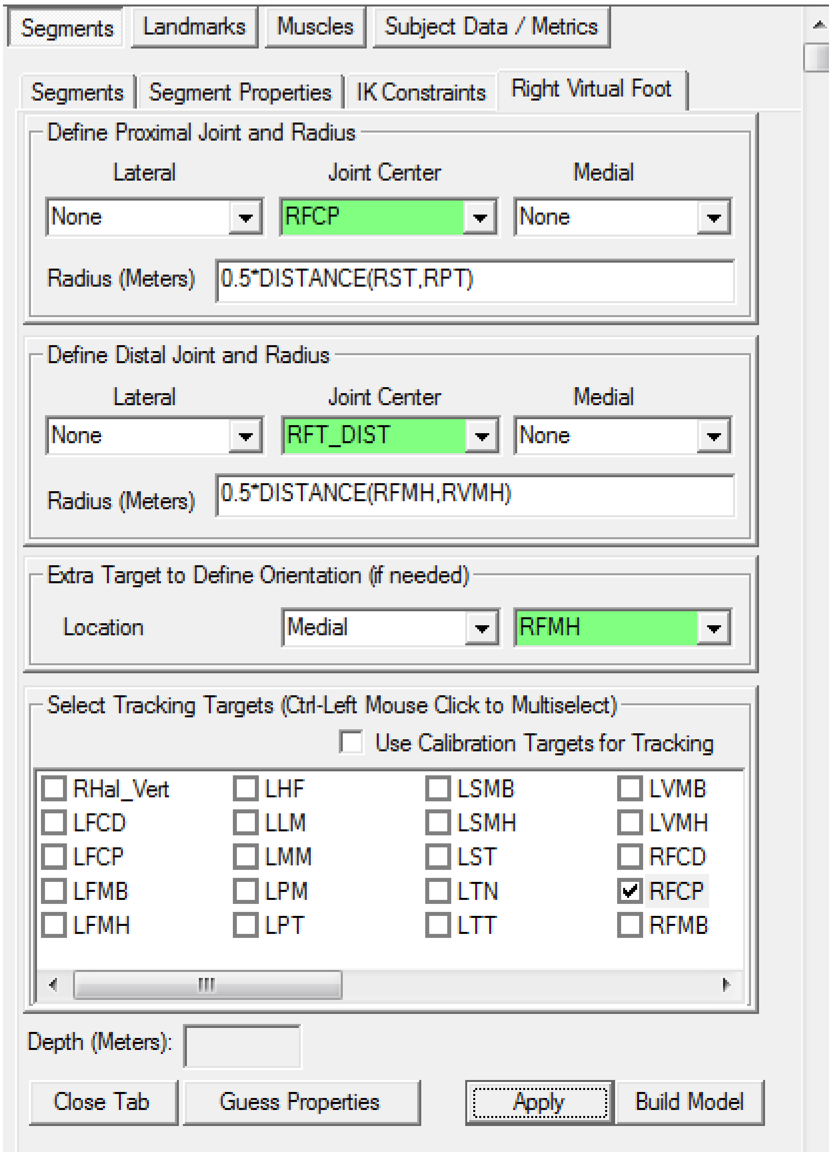
1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RFT_DIST
    2. **Define Orientation Using:**
        - **Starting Point:** RCA
        - **Ending Point:** RFMH
        - **Lateral Object:** RVMH
        - **Project From:** RSMH
    3. **Do Not Check:** Offset by Percent (1.0 = 100%)
    4. **Check:** Calibration Only Landmark



Foot Definition

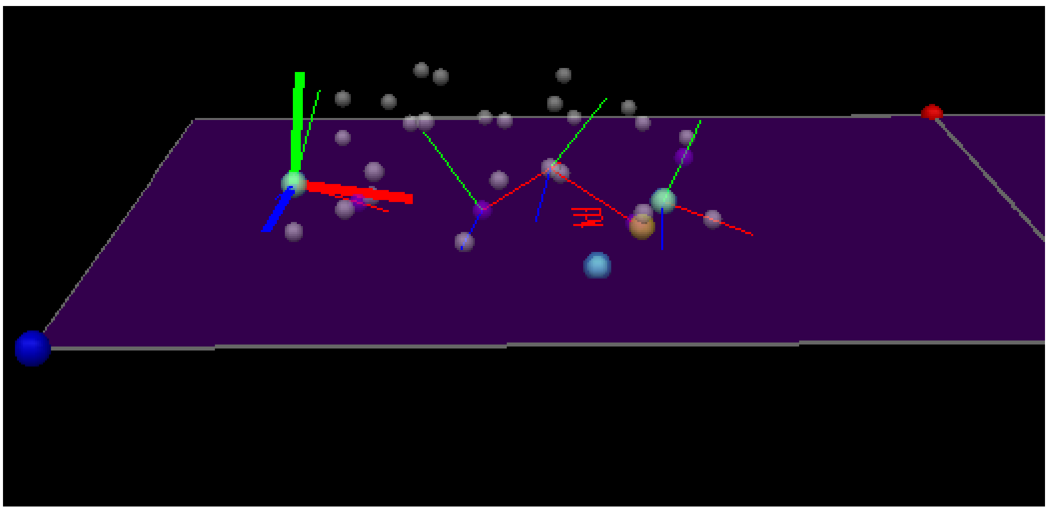
1. Create Right Virtual Foot Segment:

1. In the **Segments** tab, select *Right Virtual Foot* in the Segment Name box.
2. Select **Kinematic Only**
3. Click on the **Create Segment** button.
4. In the **Right Virtual Foot** tab, enter these values:
    1. **Define Proximal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RFCP*
        - **Medial:** *None*
        - **Radius:** *0.5*DISTANCE(RST,RPT)*
    2. **Define Distal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RFT_DIST*
        - **Medial:** *None*
        - **Radius:** *0.5*DISTANCE(RFMH,RVMH)*
    3. **Extra Target to Define Orientation:**
        - **Location:** *Medial RFMH*
    4. **Select Tracking Targets:**
       RFCP, RFMH, RVMH
5. Click on **Build Model.**
6. Click on **Close Tab** before proceeding.



2. Modify the Segment Coordinate System:

1. Define the Segment Orientation as:
    - **A/P Axis:** +Y
    - **Distal to Proximal:** -X

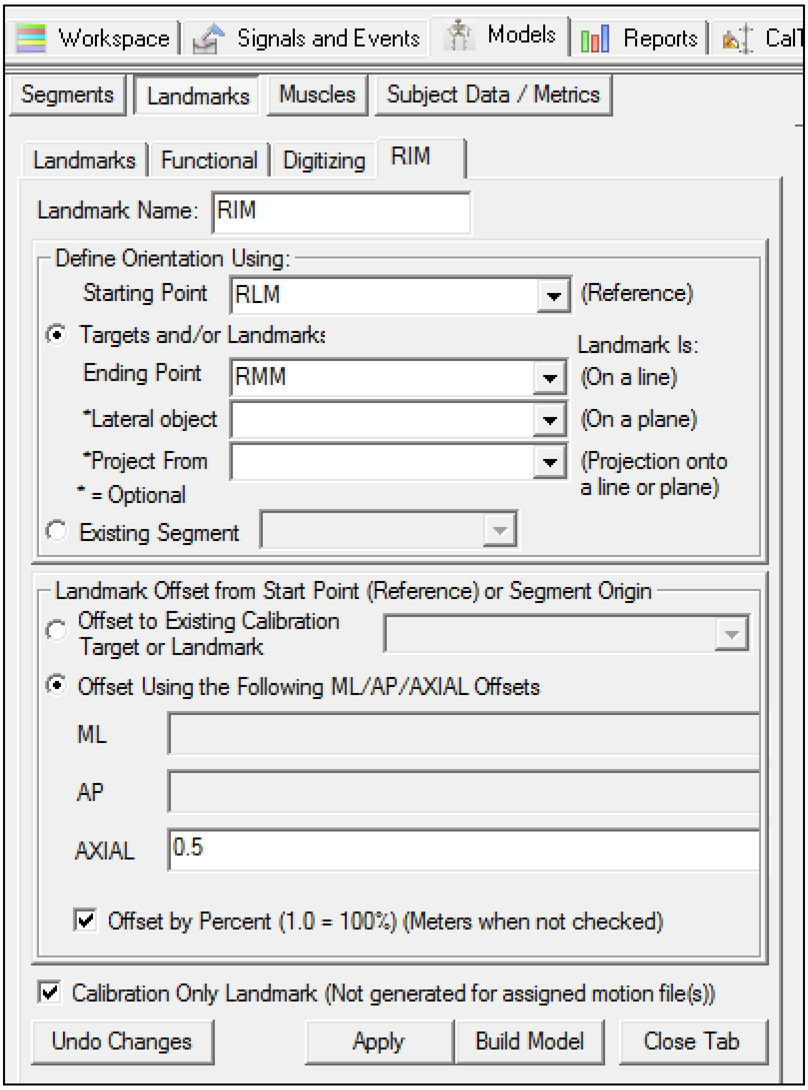


Shank (Sha)

Shank Landmarks:

1. Create RIM:

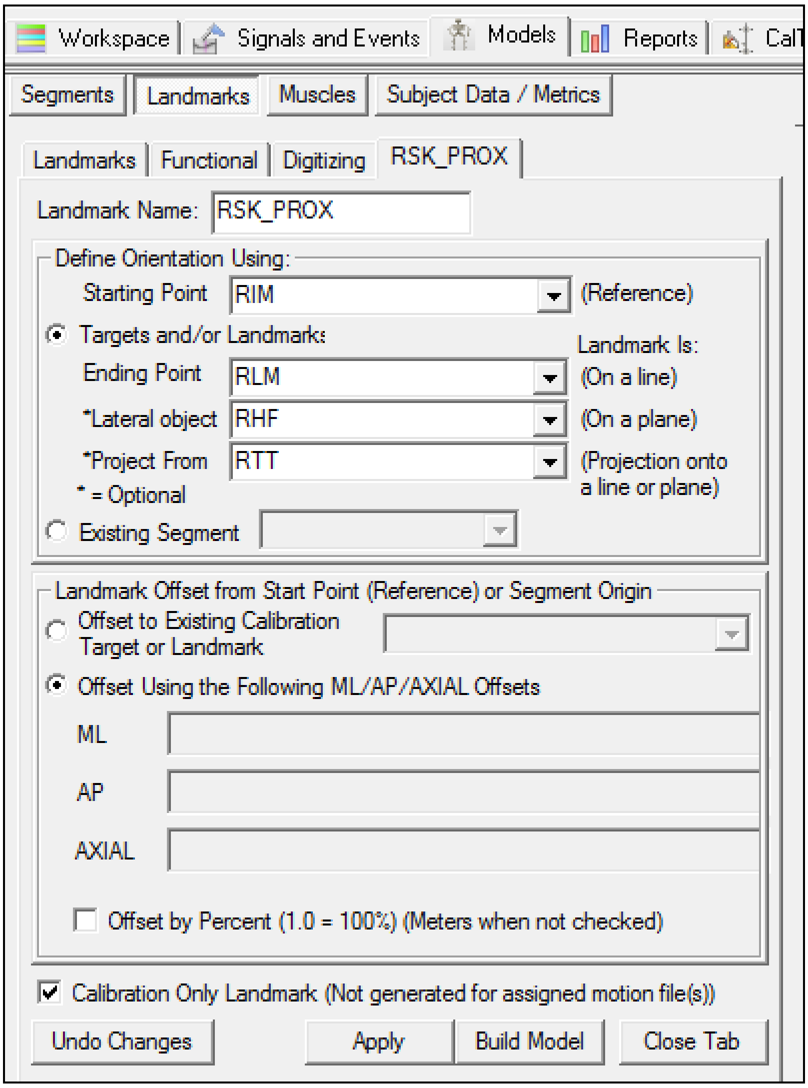
1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RIM
    2. **Define Orientation Using:**
        - **Starting Point:** RLM
        - **Ending Point:** RMM
    3. **Check:** Offset by Percent (1.0 = 100%)
    4. **Check:** Calibration Only Landmark



2. Create RSK_PROX:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:

1. **Landmark Name:** RSK_PROX
2. **Define Orientation Using:**
    - **Starting Point:** RIM
    - **Ending Point:** RLM
    - **Lateral Object:** RHF
    - **Project From:** RTT
3. **Do Not Check:** Offset by Percent (1.0 = 100%)
4. **Check:** Calibration Only Landmark

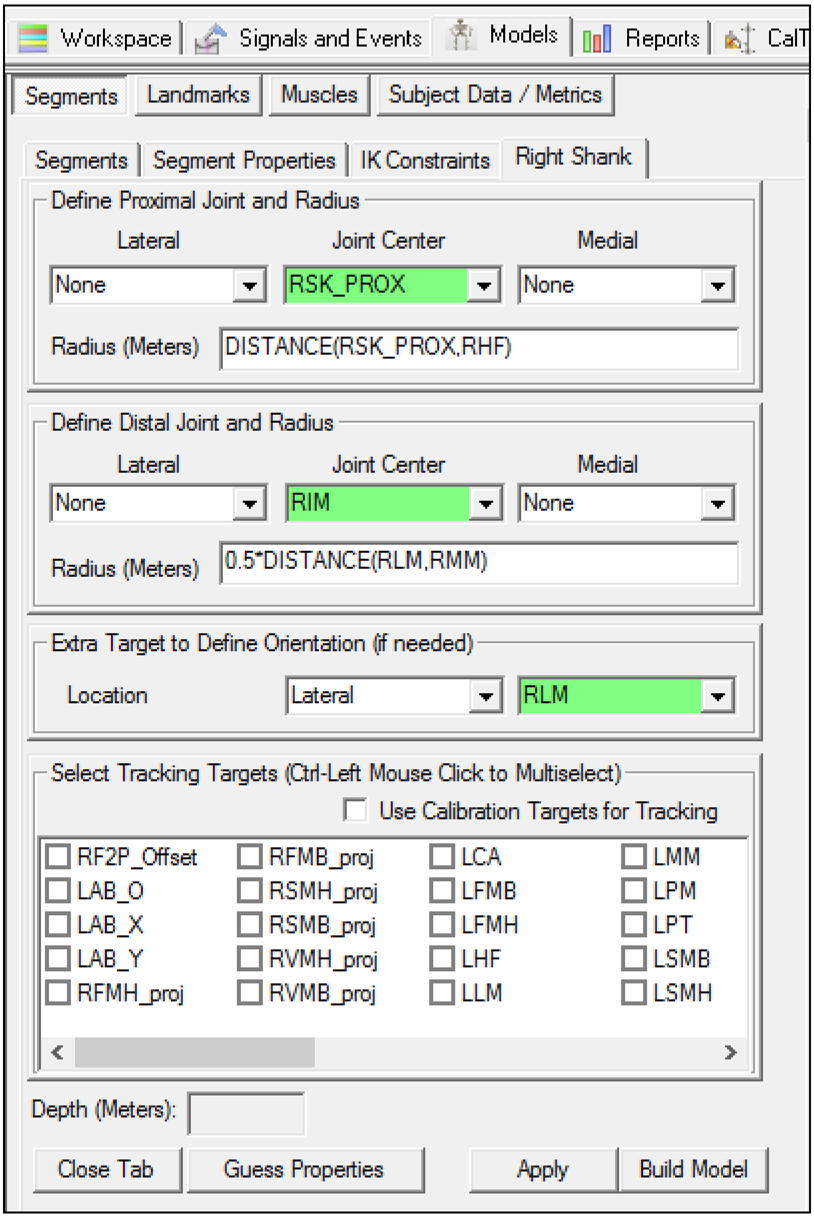


Shank Definition

1. Create Right Virtual Foot Segment:

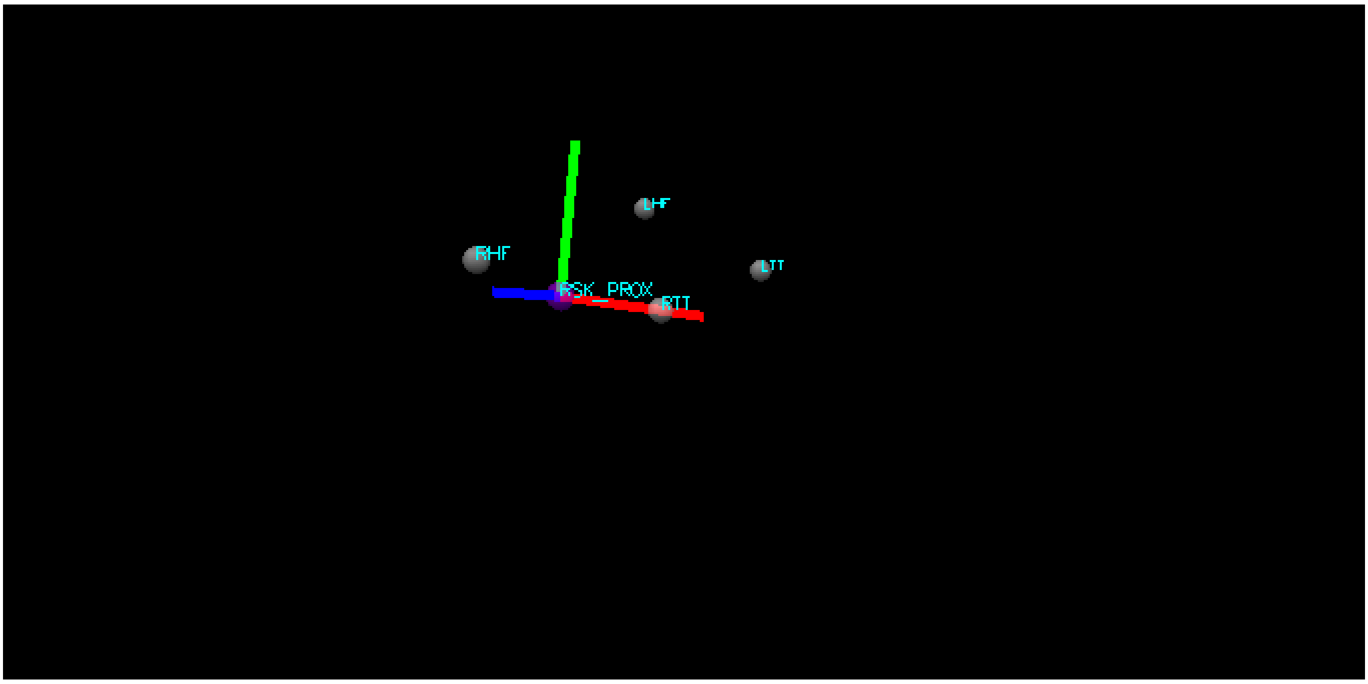
1. In the **Segments** tab, select *Right Shank* in the Segment Name box.
2. Select **Kinematic Only**
3. Click on the **Create Segment** button.
4. In the **Right Shank** tab, enter these values:
    1. **Define Proximal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RSK_PROX*
        - **Medial:** *None*

        - **Radius:** *DISTANCE(RSK_PROX,RHF)*
    2. **Define Distal Joint and Radius:**
        - **Lateral:** *None*
        - **Joint:** *RIM*
        - **Medial:** *None*
        - **Radius:** *0.5*DISTANCE(RLM,RMM)*
    3. **Extra Target to Define Orientation:**
        - **Location:** *Lateral RLM*
    4. **Select Tracking Targets:**
        RHF, RLM, RMM, RTT
5. Click on **Build Model.**
6. Click on **Close Tab** before proceeding.



2. Modify the Segment Coordinate System:

1. Define the Segment Orientation as:
    - **A/P Axis:** +X
    - **Distal to Proximal:** +Y

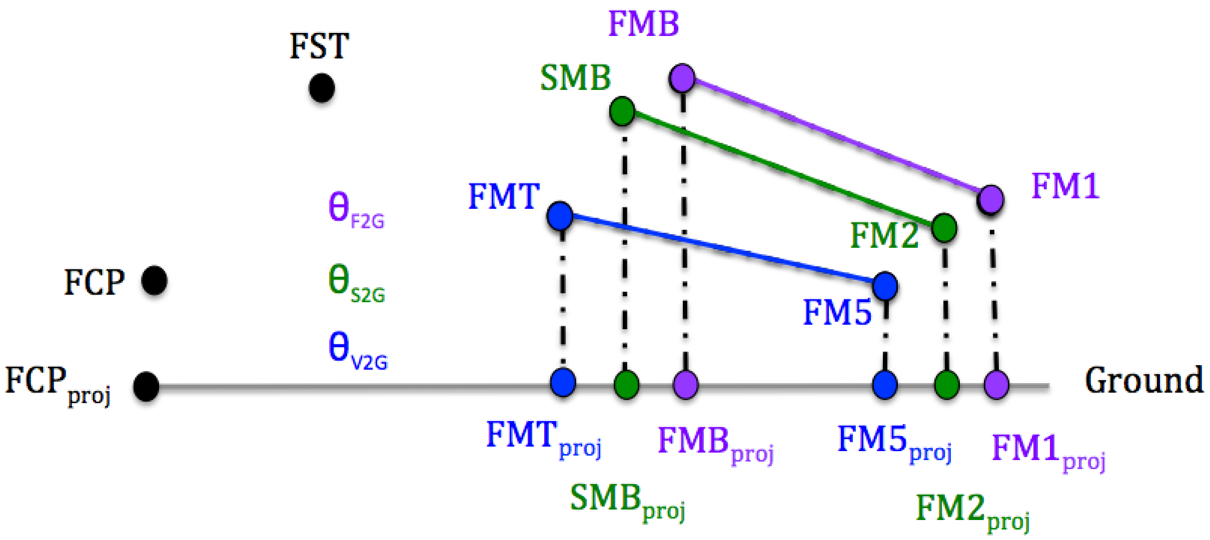


Sagittal Planar Angles

The F2G, S2G, and V2G angles are planar angles relative to the ground.
The MLA angle is the angle between the Medial Longitudinal Arch/Navicular drop.

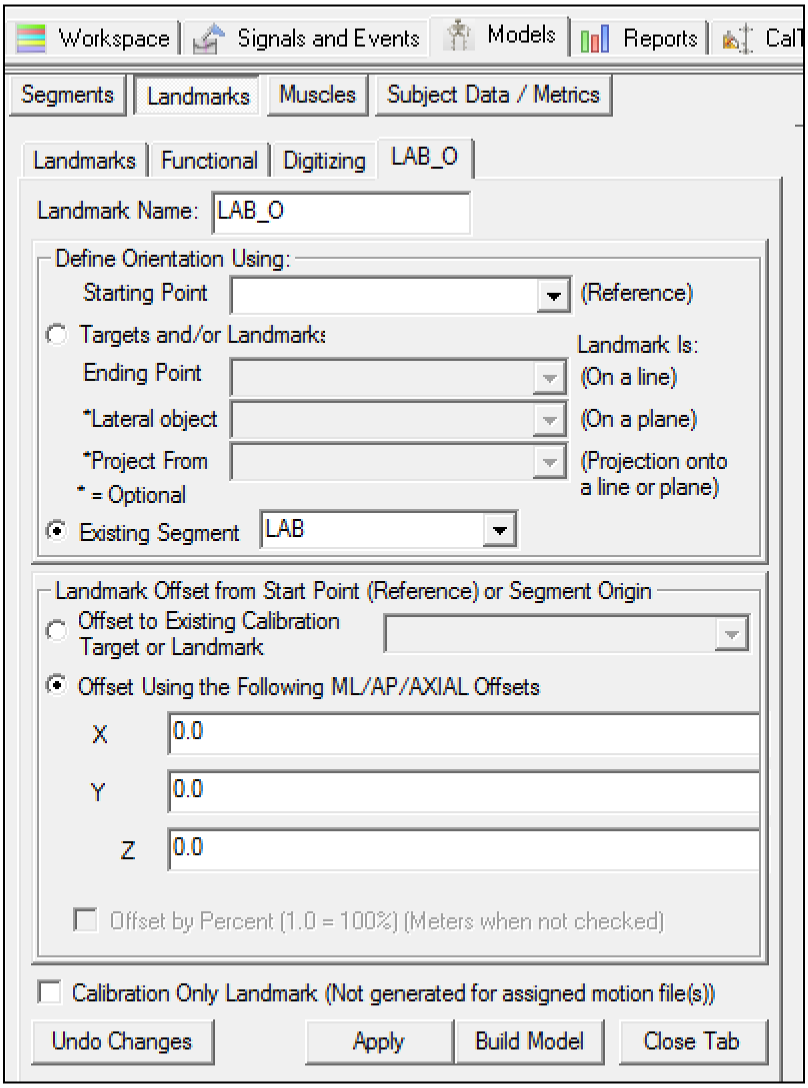
F2G, S2G, and V2G Landmarks:

The F2G, S2G and V2G angles are calculated in the plane orthogonal to the ground. These landmarks will need to be projected onto the ground. To project landmarks onto the ground, the Lab_O, Lab_X and Lab_Y landmarks will need to be created to identify the plane of the ground.



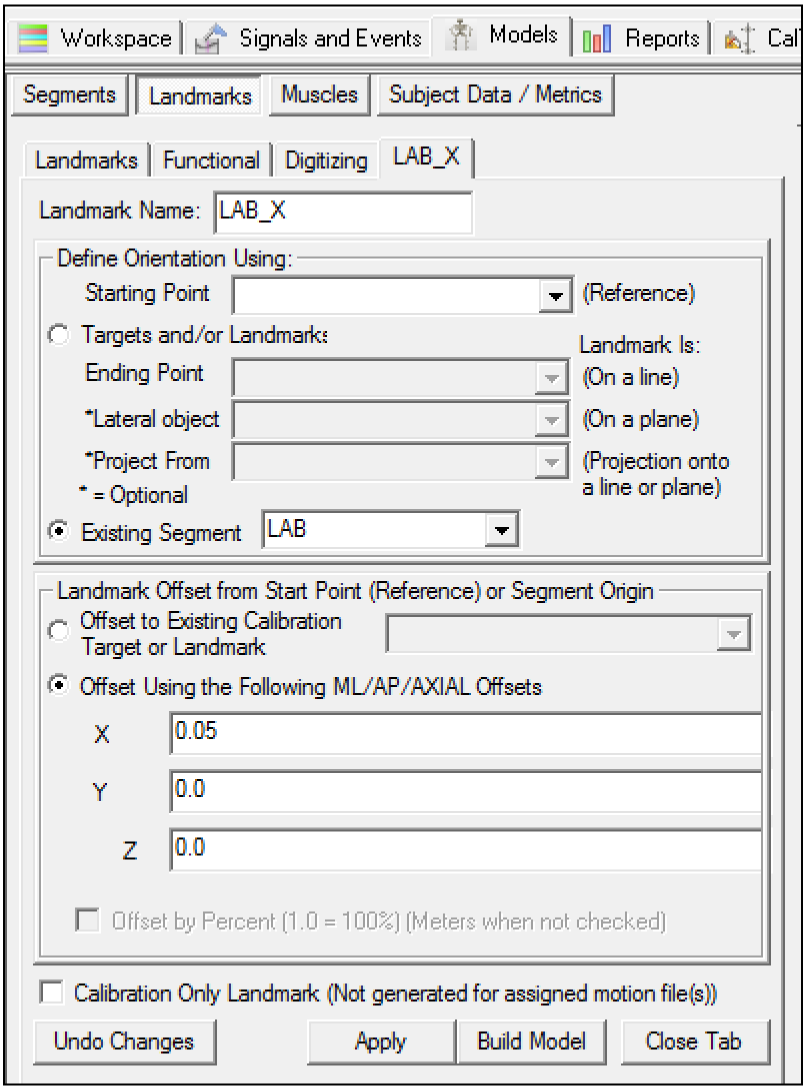
1. Create Lab_O:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** Lab_O
    2. Offset Using the Following **ML/AP/AXIAL** Offsets:
        - **ML:** 0.0 **AP:** 0.0 **Axial:** 0.0
    3. **Do Not Check:** Offset by Percent (1.0 = 100%)
    4. **Do Not Check:** Calibration Only Landmark



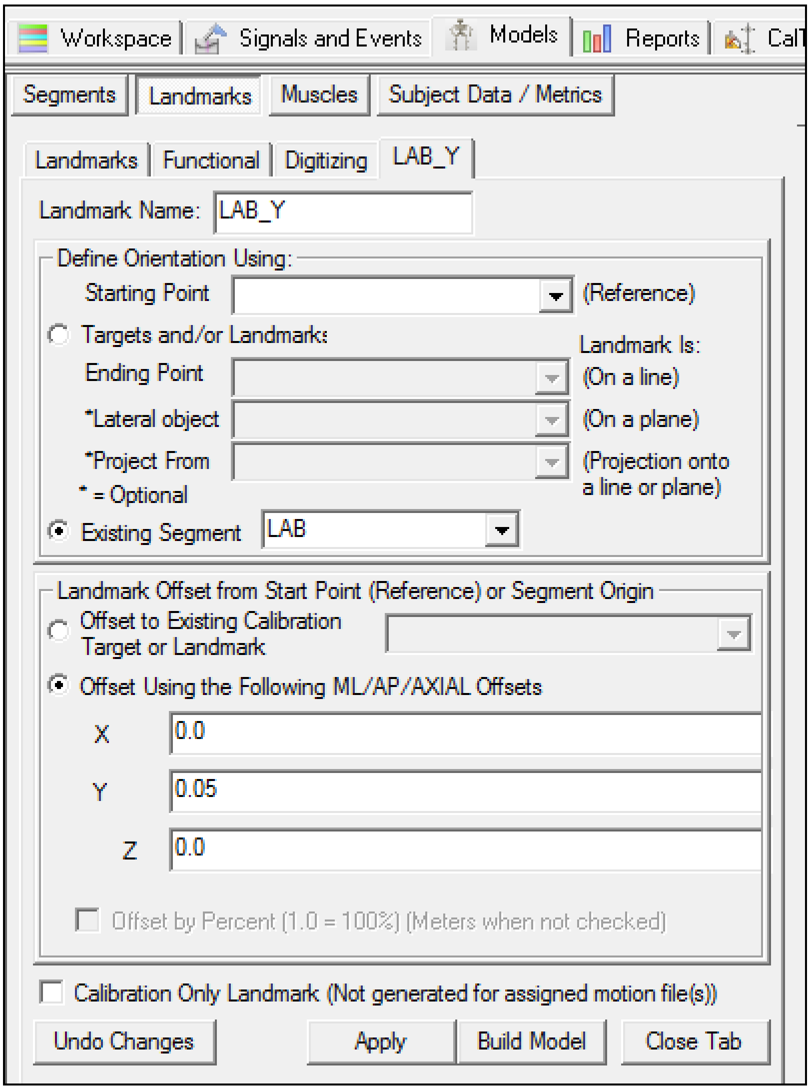
2. Create Lab_X:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** Lab_X
    2. Offset Using the Following **ML/AP/AXIAL** Offsets:
        - **ML:** 0.05 **AP:** 0.0 **Axial:** 0.0
    3. **Do Not Check:** Offset by Percent (1.0 = 100%)
    4. **Do Not Check:** Calibration Only Landmark



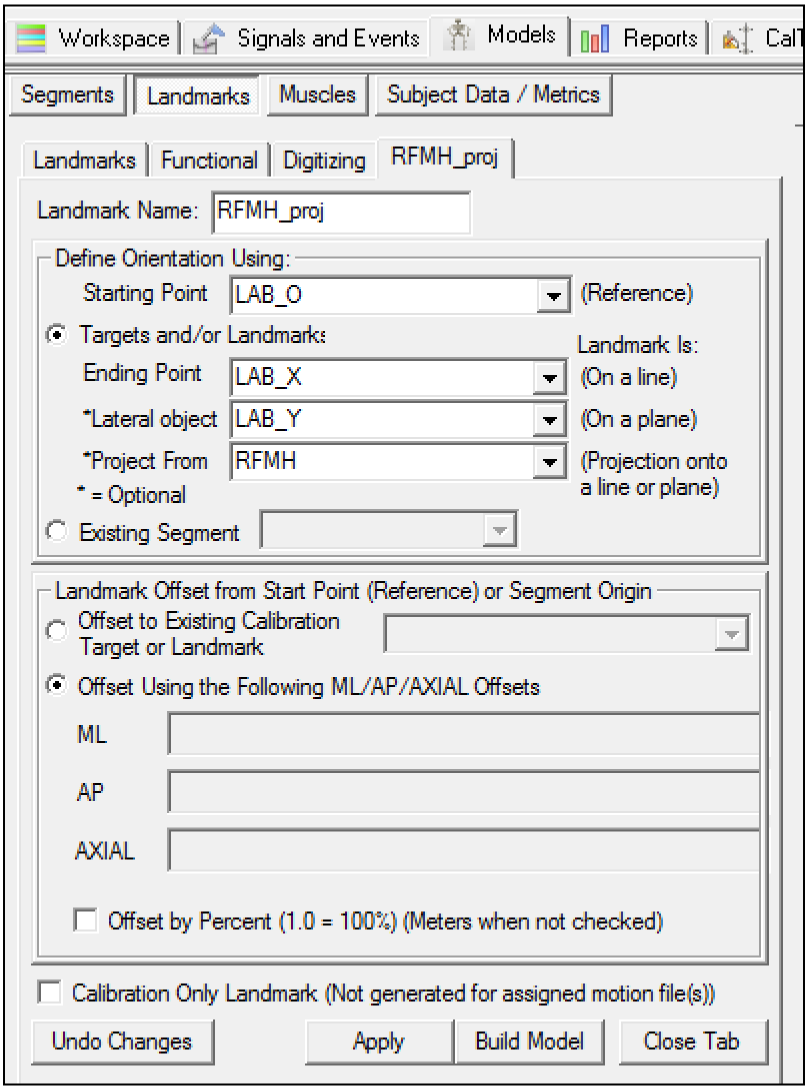
3. Create Lab_Y:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** Lab_Y
    2. Offset Using the Following **ML/AP/AXIAL** Offsets:
        - **ML:** 0.0 **AP:** 0.05 **Axial:** 0.0
    3. **Do Not Check:** Offset by Percent (1.0 = 100%)
    4. **Do Not Check:** Calibration Only Landmark



4. Create RFMH_proj:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RFMH_proj
    2. **Define Orientation Using:**
        - **Starting Point:** LAB_O
        - **Ending Point:** LAB_X
        - **Lateral Object:** LAB_Y
        - **Project From:** RFMH
    3. **Do Not Check:** Offset by Percent (1.0 = 100%)
    4. **Do Not Check:** Calibration Only Landmark

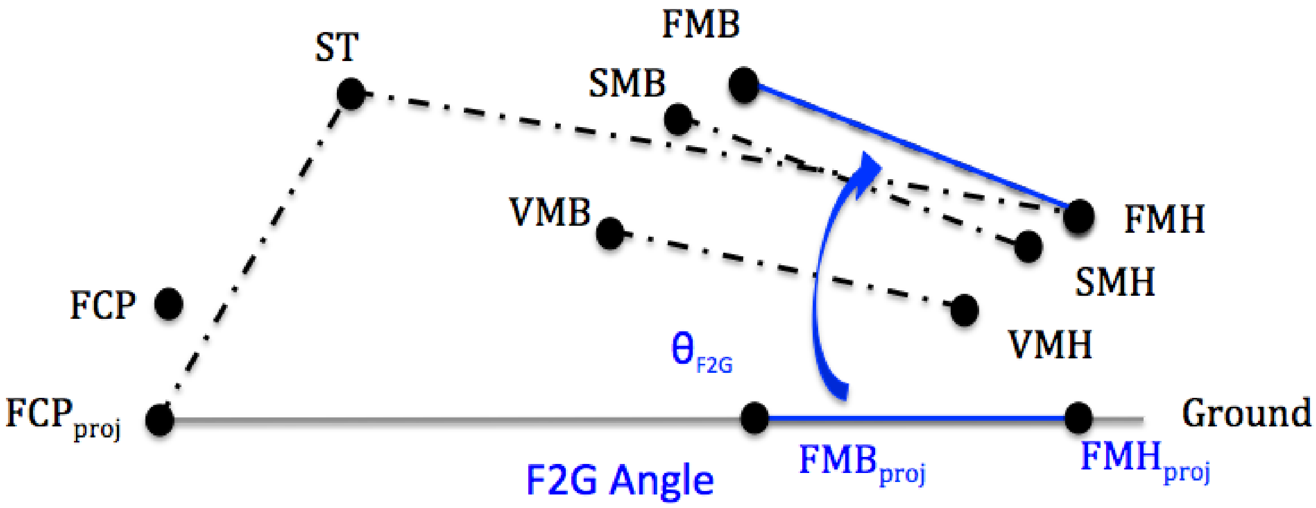


Create landmarks 7-17 by following the same format as the RFMH_proj landmark for:

- 5. RFMB 6. RSMH 7. RSMB 8. RVMH 9. RVMB 10. LFMH 11. LFMB 12. LSMH 13. LSMB 14. LVMH 15. LVMB

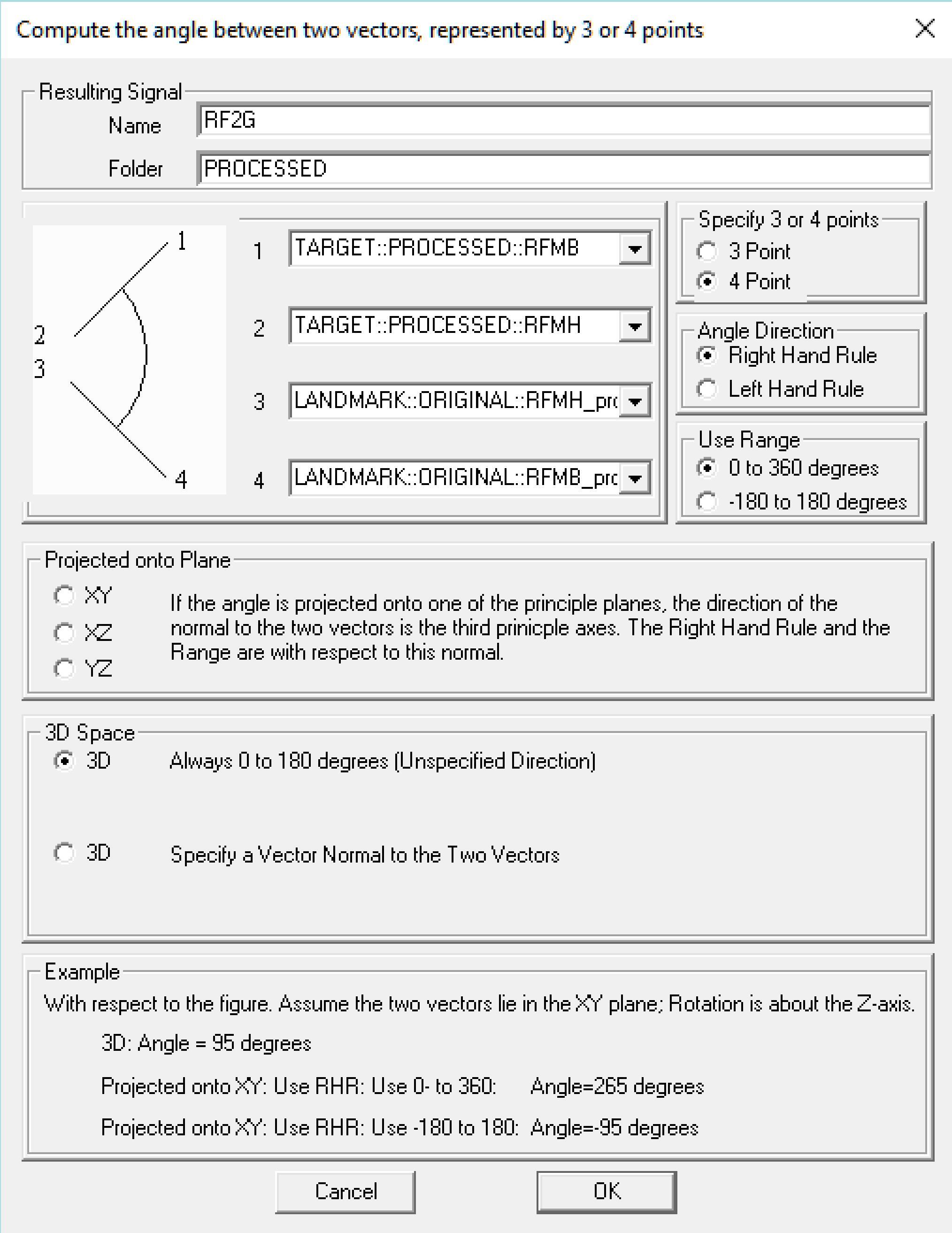
F2G Angle

F2G Angle – 3D angle of the first metatarsus relative to the ground



1. Create RF2G planar angle:

1. Define **Resulting Signal** Name: RF2G
2. Calculate a **4 point angle** between the following targets:
    1. TARGET::ORIGINAL::RFMB
    2. TARGET::ORIGINAL::RFMH
    3. TARGET::ORIGINAL::RFMH_proj
    4. TARGET::ORIGINAL::RFMB_proj
        - **Angle Direction:** Right Hand Rule
        - **3D Space:** Always 0 to 180 degrees



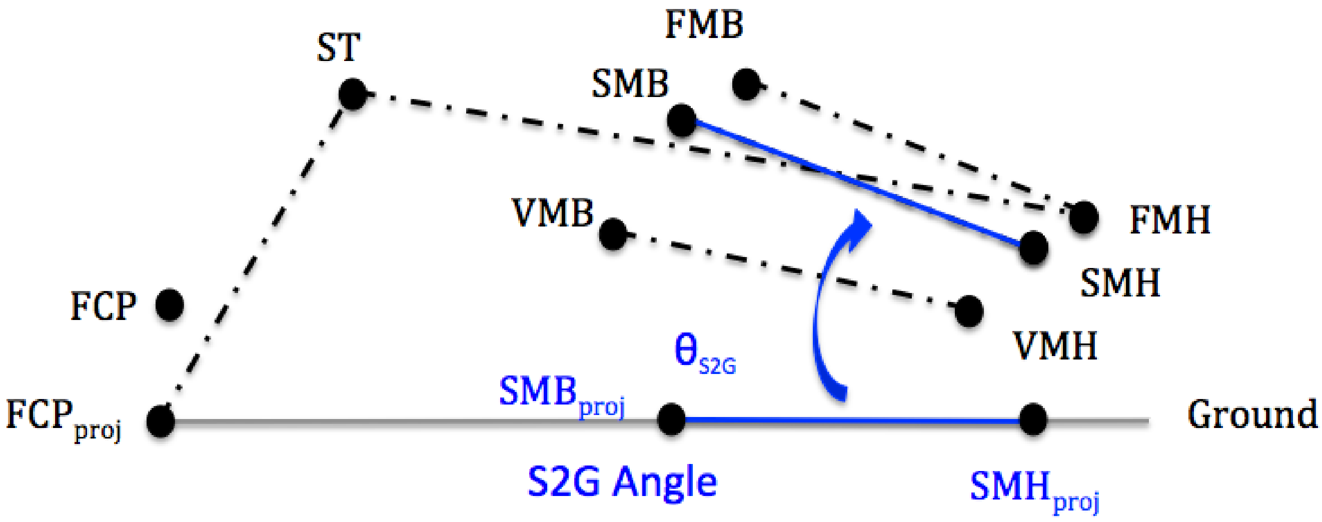
\\

2. Create LF2G planar angle:

1. When defining the left signal, use the same definitions as for the right angle.

S2G Angle

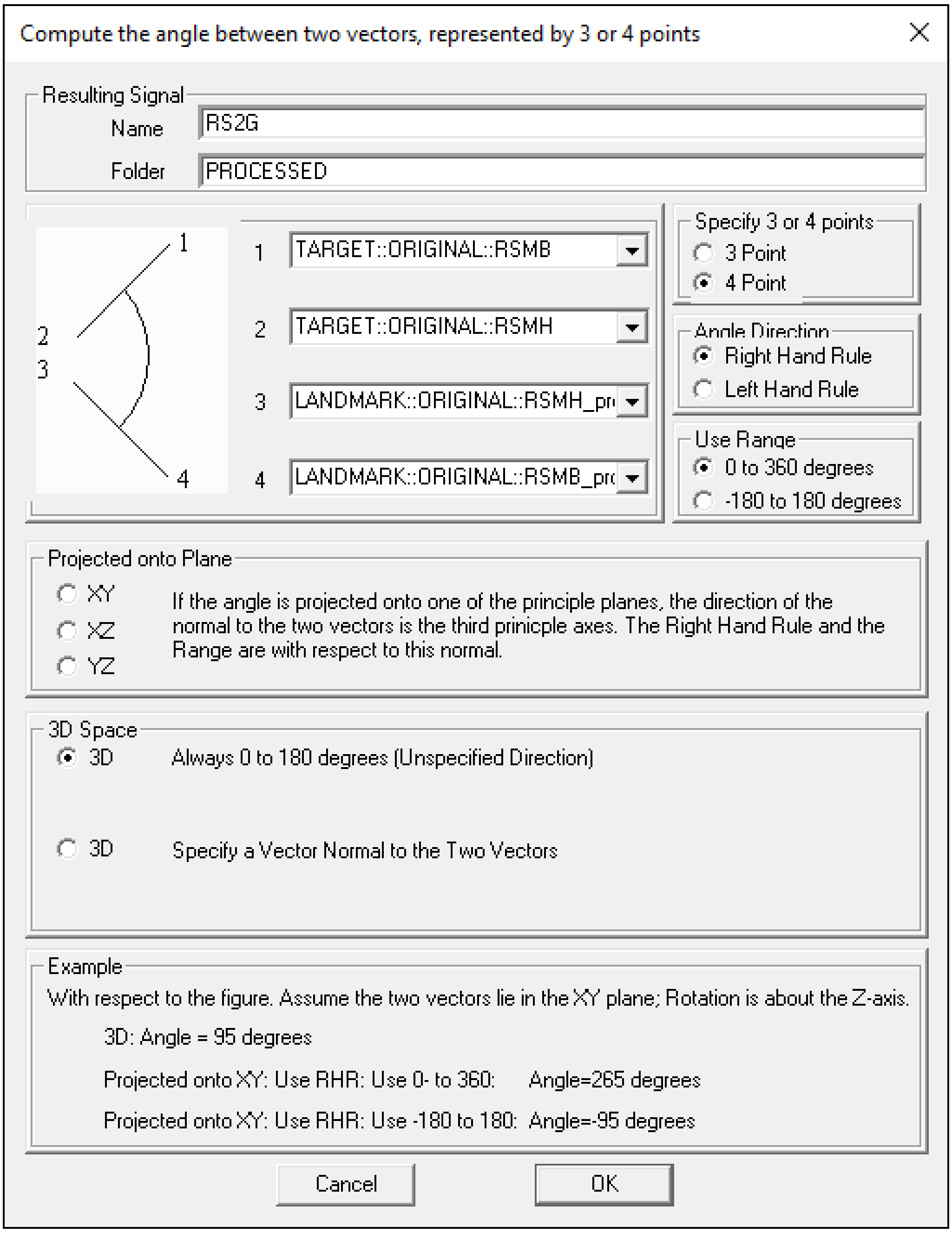
S2G Angle – 3D angle of the second metatarsus relative to the ground



\\

1. Create RS2G planar angle:

1. Define **Resulting Signal** Name: RS2G
2. Calculate a **4 point angle** between the following targets:
    1. TARGET::ORIGINAL::RSMB
    2. TARGET::ORIGINAL::RSMH
    3. TARGET::ORIGINAL::RSMH_proj
    4. TARGET::ORIGINAL::RSMB_proj
        - **Angle Direction:** Right Hand Rule
        - **3D Space:** Always 0 to 180 degrees

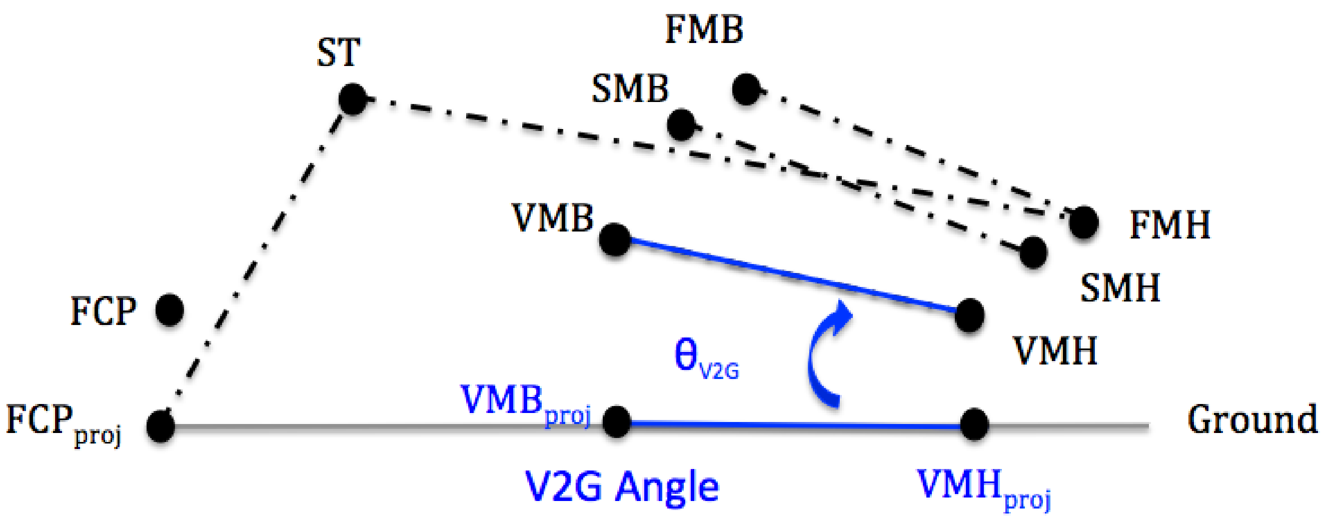


2. Create LS2G planar angle:

1. When defining the left signal, use the same definitions as for the right angle.

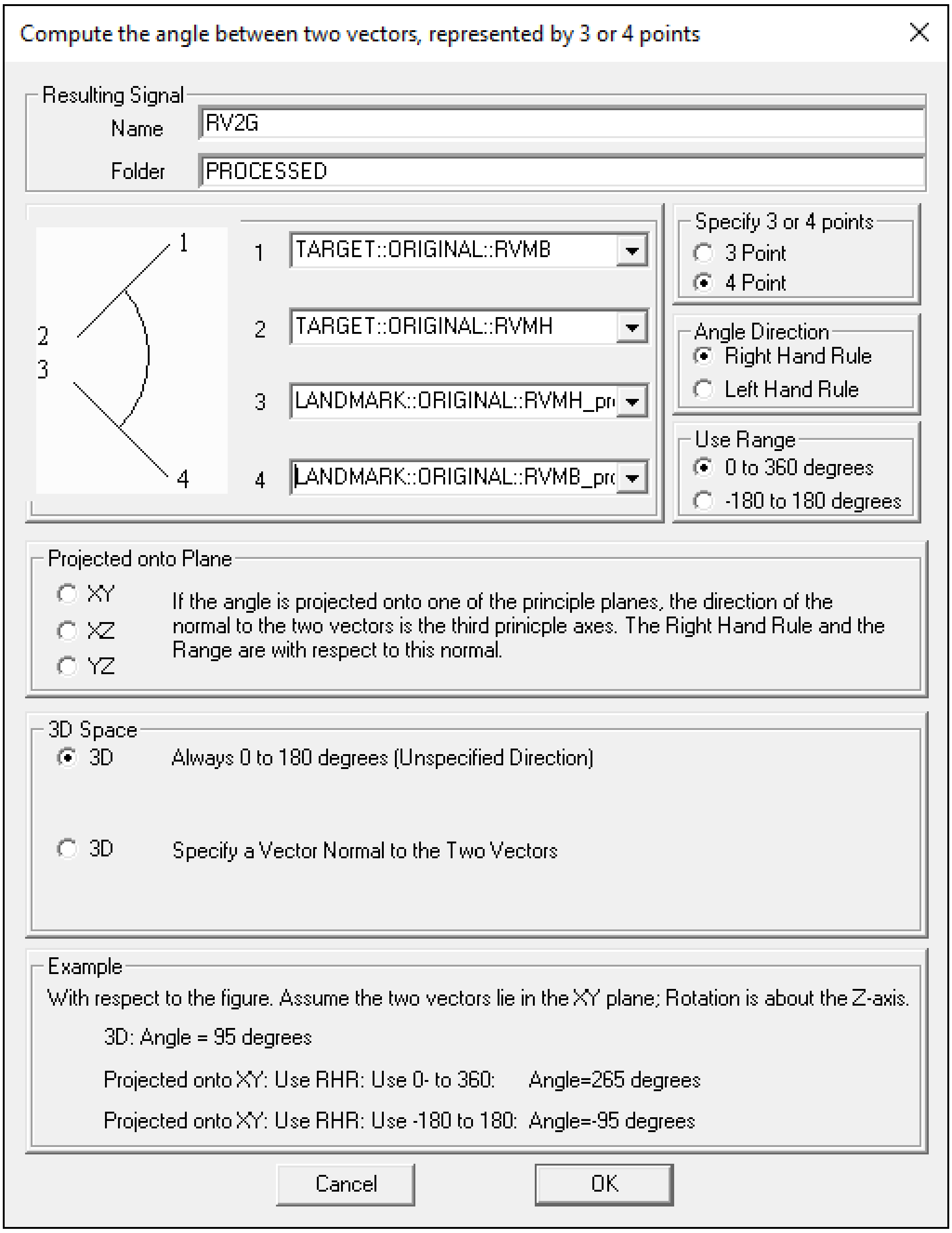
V2G Angle

V2G Angle – 3D angle of the fifth metatarsus relative to the ground



1. Create RV2G planar angle:

1. Define **Resulting Signal** Name: RV2G
2. Calculate a **4 point angle** between the following targets:
    1. TARGET::ORIGINAL::RVMB
    2. TARGET::ORIGINAL::RVMH
    3. TARGET::ORIGINAL::RVMH_proj
    4. TARGET::ORIGINAL::RVMB_proj
        - **Angle Direction:** Right Hand Rule
        - **3D Space:** Always 0 to 180 degrees

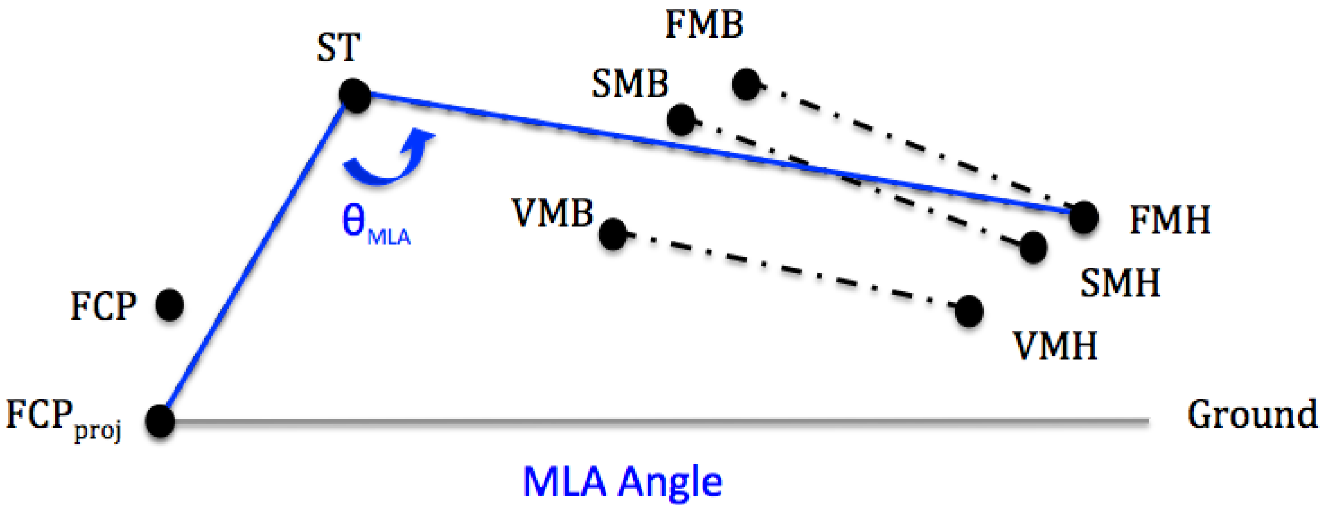


2. Create LV2G planar angle:

1. When defining the left signal, use the same definitions as for the right angle.

MLA Angle

MLA Angle – MLA Angle – Medial Longitudinal Arch/Navicular drop



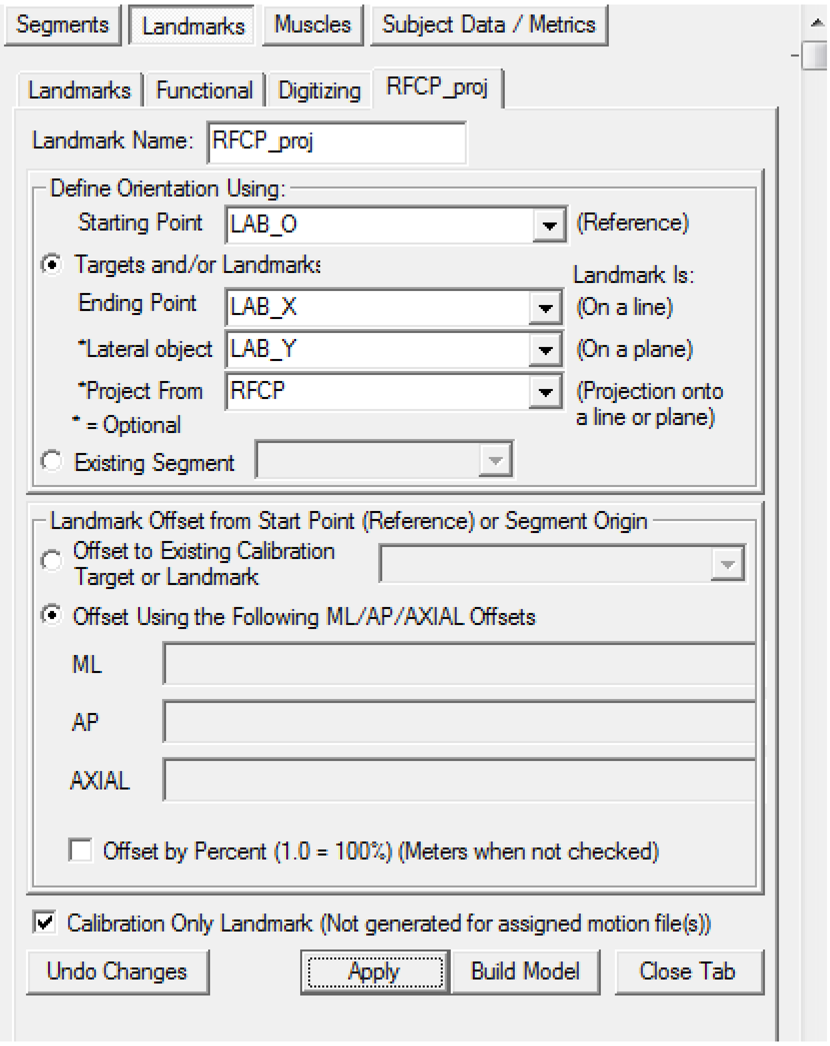
MLA Angle Landmarks:

The MLA angle is calculated using the proximal heel target projected onto the ground, tracked using the calcaneus segment.
To accomplish this, two landmarks must be created:
1. The projection of the proximal heel target onto the ground
2. Track the proximal heel target projection using the calcaneus segment
To create these landmarks, the **LAB_O, LAB_X and LAB_Y** landmarks must be created and the calcaneus segment must be defined.

NOTE: The image for the MLA Angle shows the PROCESSED target folder being used for the signal definition. If you have used the ORIGINAL target data for the other planar angles, you should continue to use the ORIGINAL folder.

1. Create RFCP_proj:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RFCP_proj
    2. **Define Orientation Using:**
        - **Starting Point:** LAB_O
        - **Ending Point:** LAB_X
        - **Lateral Object:** LAB_Y
        - **Project From:** RFCP
    3. **Do Not Check:** Offset by Percent (1.0 = 100%)
    4. **Check:** Calibration Only Landmark



2. Create LFCP_proj:

1. When defining the left signal, use the same definitions as for the right landmark.

3. Create RFCP_proj_track:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RFCP_proj_track
    2. **Define Orientation Using:**
        - **Starting Point:** RFCP_proj
        - Click **Existing Segment:** RCal
    3. **Do Not Check:** Offset by Percent (1.0 = 100%)
    4. **Do Not Check:** Calibration Only Landmark

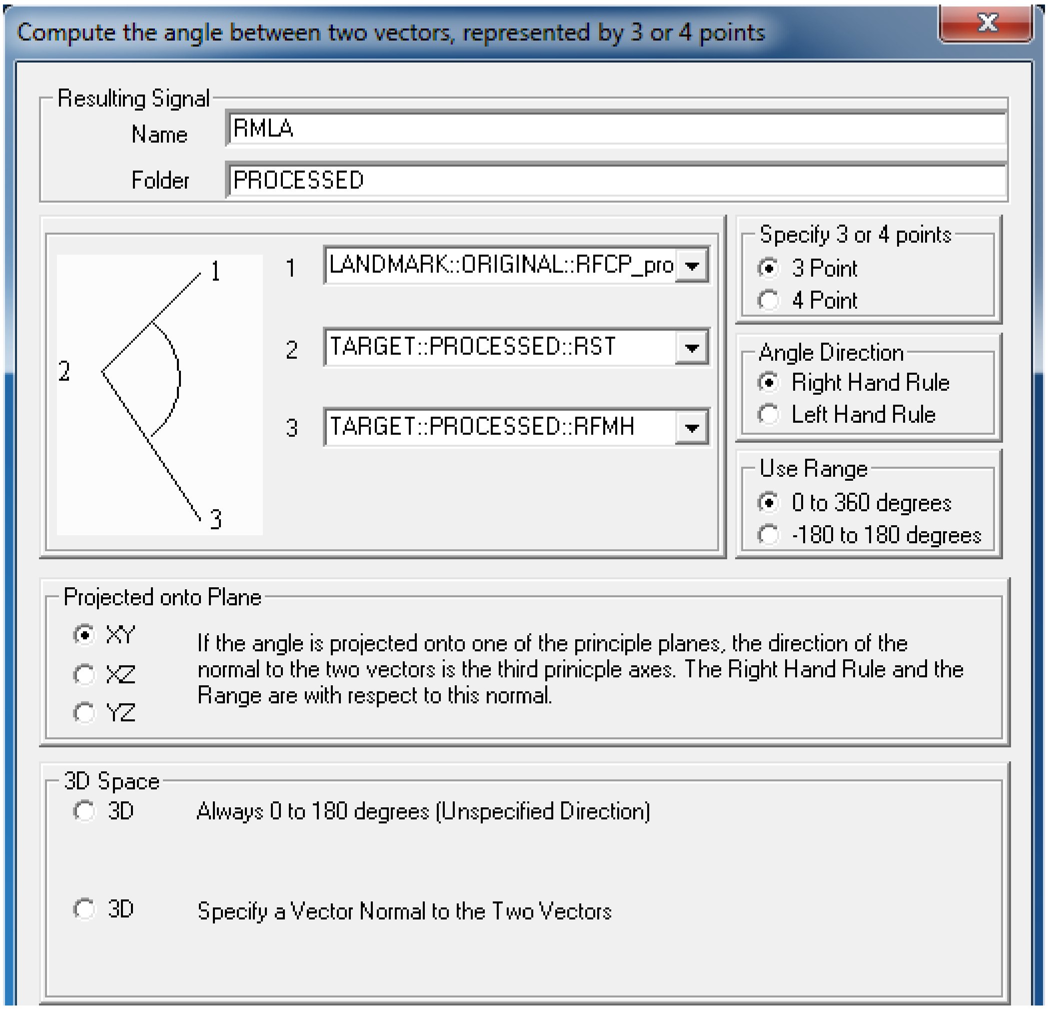
4. Create LFCP_proj_track

1. When defining the left signal, use the same definitions as for the right landmark.

MLA Definition:

1. Create RMLA planar angle:

1. Define **Resulting Signal** Name: RMLA
2. Calculate a **3 point angle** between the following targets:
    1. LANDMARK::ORIGINAL::RFCP_track
    2. TARGET::ORIGINAL::RST
    3. 3 - TARGET::ORIGINAL::RFMH
    - **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 RMF within the text option.
    - Command text should have the internal name (e.g. RMF) and not the display name “Right Virtual Foot”. Segment Default Names



2. Create LMLA planar angle:

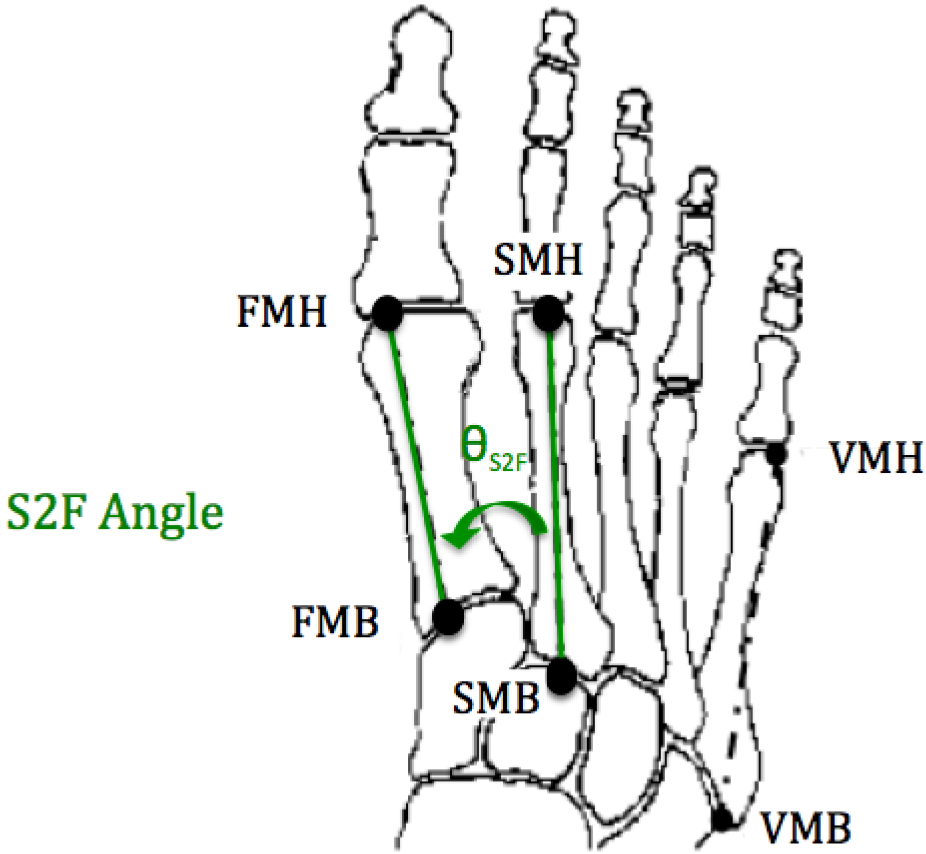
1. When defining the left signal, use the same definitions as for the right angle.

- **Note: The reference segment will need to be changed to Left Virtual Foot within the text option.**

Transverse Planar Angles

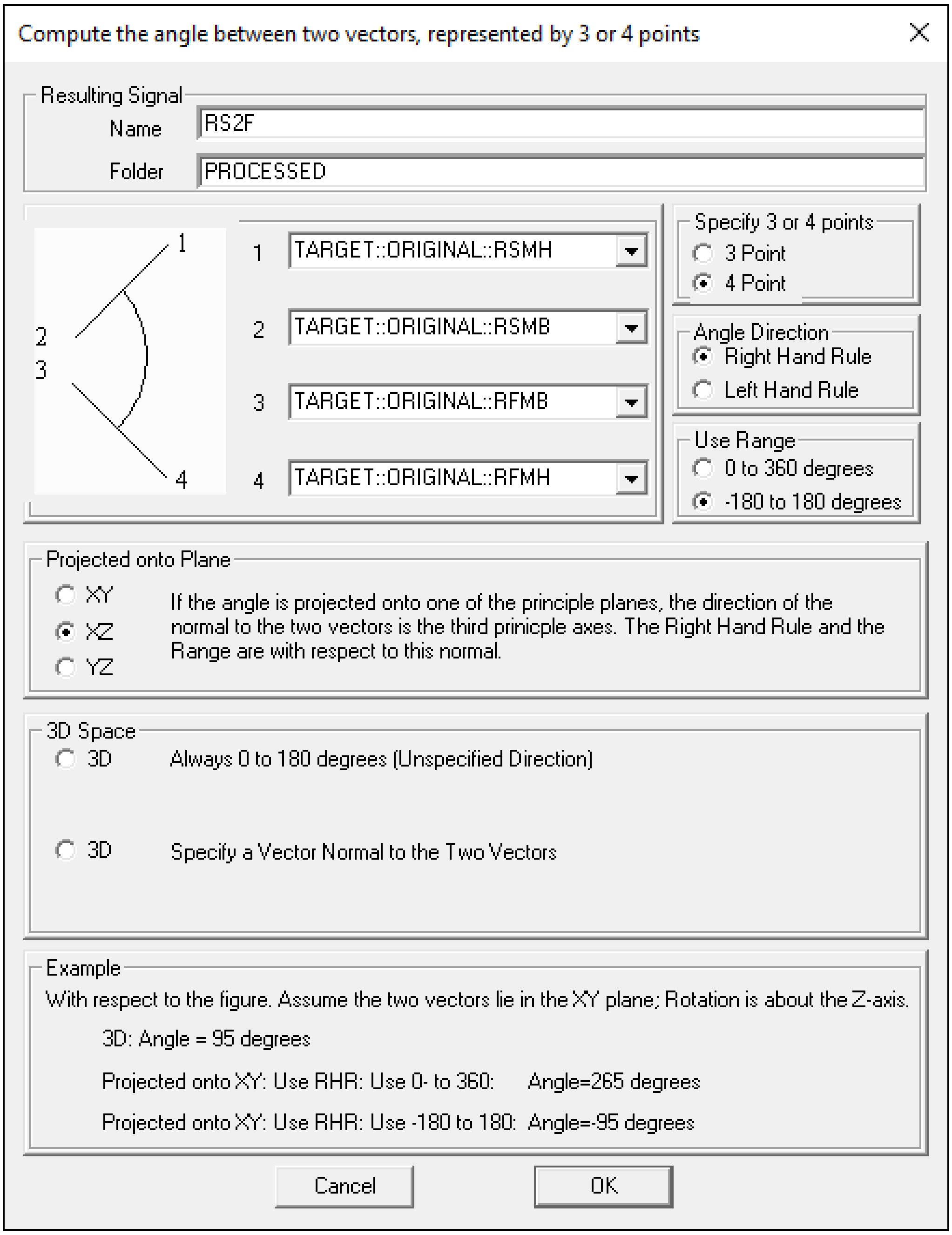
S2F Angle

S2F Angle – Angle between the first and second metatarsus projected on to the transverse plane of the Met segment



S2F Definition: 1. Create RS2F planar angle:

1. Define **Resulting Signal** Name: RS2F
2. Calculate a **4 point angle** between the following targets:
    1. TARGET::ORIGINAL::RSMH
    2. TARGET::ORIGINAL::RSMB
    3. TARGET::ORIGINAL::RFMB
    4. TARGET::ORIGINAL::RFMH
        - **Angle Direction:** Right Hand Rule
        - **3D Space:** -180 to 180 degrees
        - **Projected onto Plane:** XZ
        - **Note:** The reference segment will need to be changed to RMet within the text option.



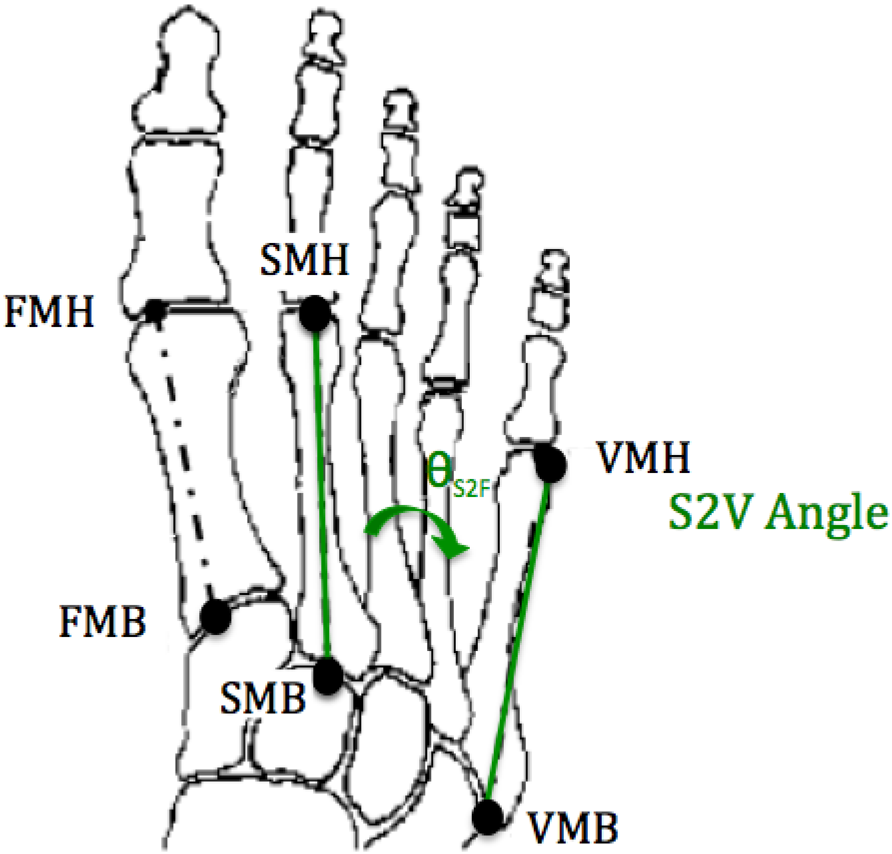
2. Create LS2F planar angle:

1. When defining the left signal, use the same definitions as for the right angle.

- **Angle Direction:** Left Hand Rule
- **Note:** The reference segment will need to be changed to LMet within the text option.

S2V Angle

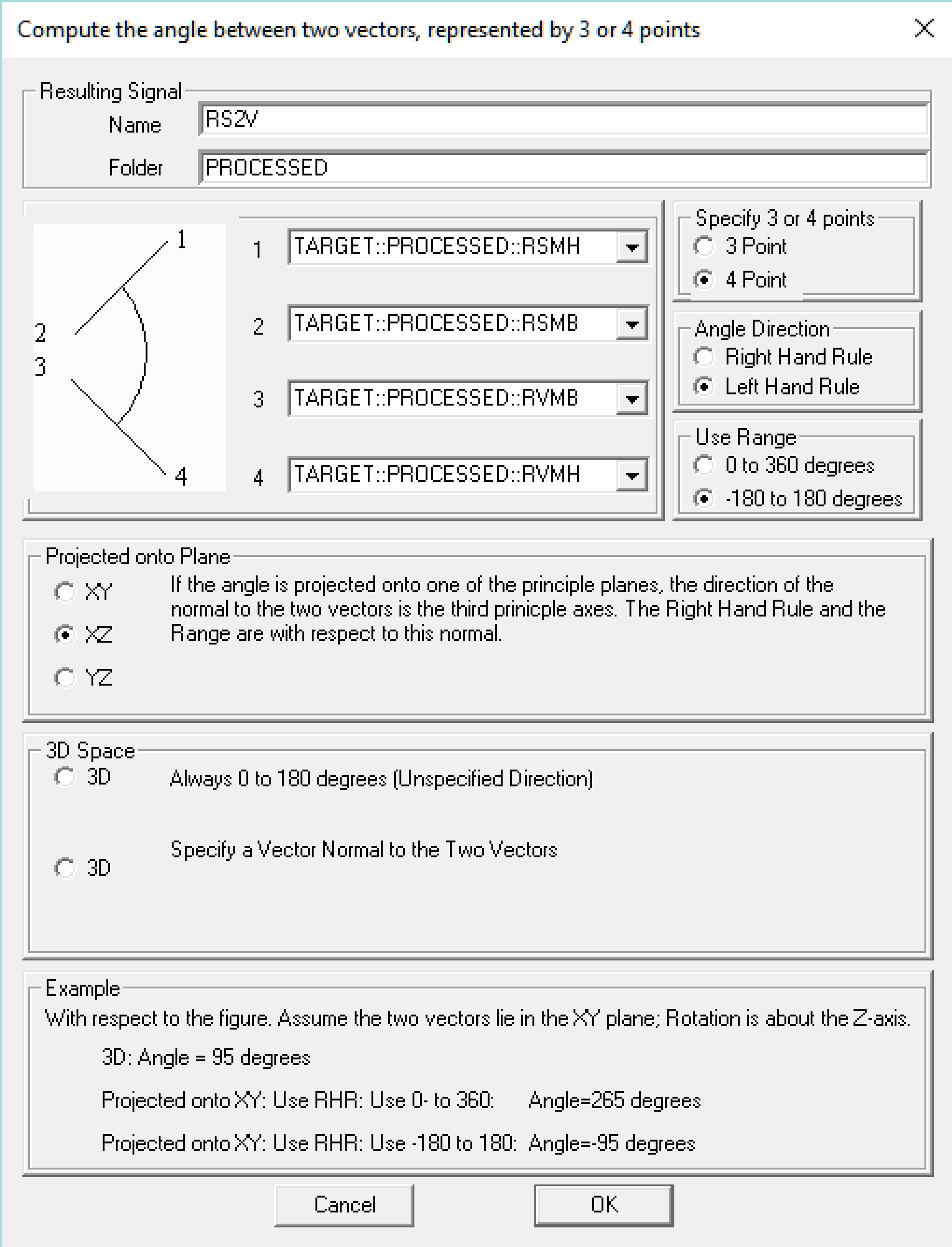
S2V Angle – Angle between the fifth and second metatarsus projected on to the transverse plane of



the Met segment\\

S2V Definition: 1. Create RS2V planar angle:

1. Define **Resulting Signal** Name: RS2V
2. Calculate a **4 point angle** between the following targets:
    1. TARGET::ORIGINAL::RSMH
    2. TARGET::ORIGINAL::RSMB
    3. TARGET::ORIGINAL::RVMB
    4. TARGET::ORIGINAL::RVMH
        - **Angle Direction:** Left Hand Rule
        - **3D Space:** -180 to 180 degrees
        - **Projected onto Plane:** XZ
        - **Note:** The reference segment will need to be changed to RMet within the text option.



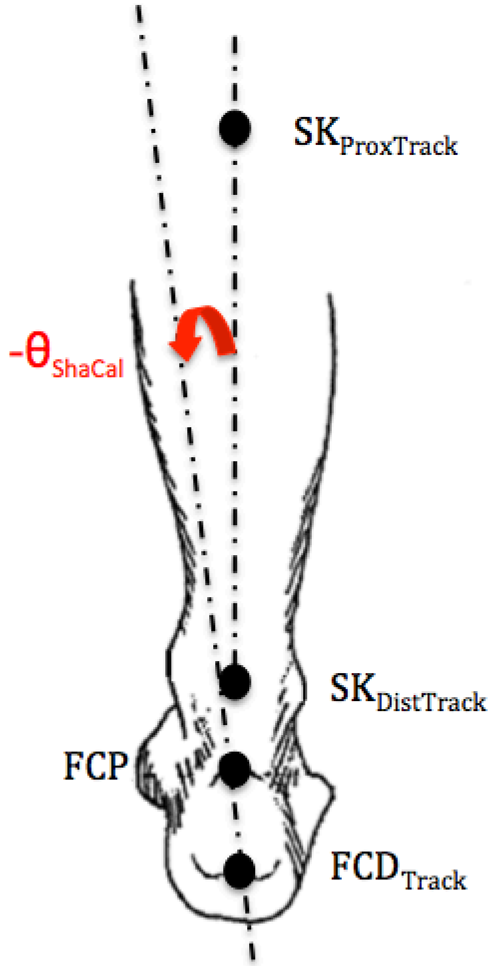
2. Create LS2F planar angle:

1. When defining the left signal, use the same definitions as for the right angle.

- **Angle Direction:** Right Hand Rule
- **Note:** The reference segment will need to be changed to LMet within the text option.

Calcaneus Inv/Eve

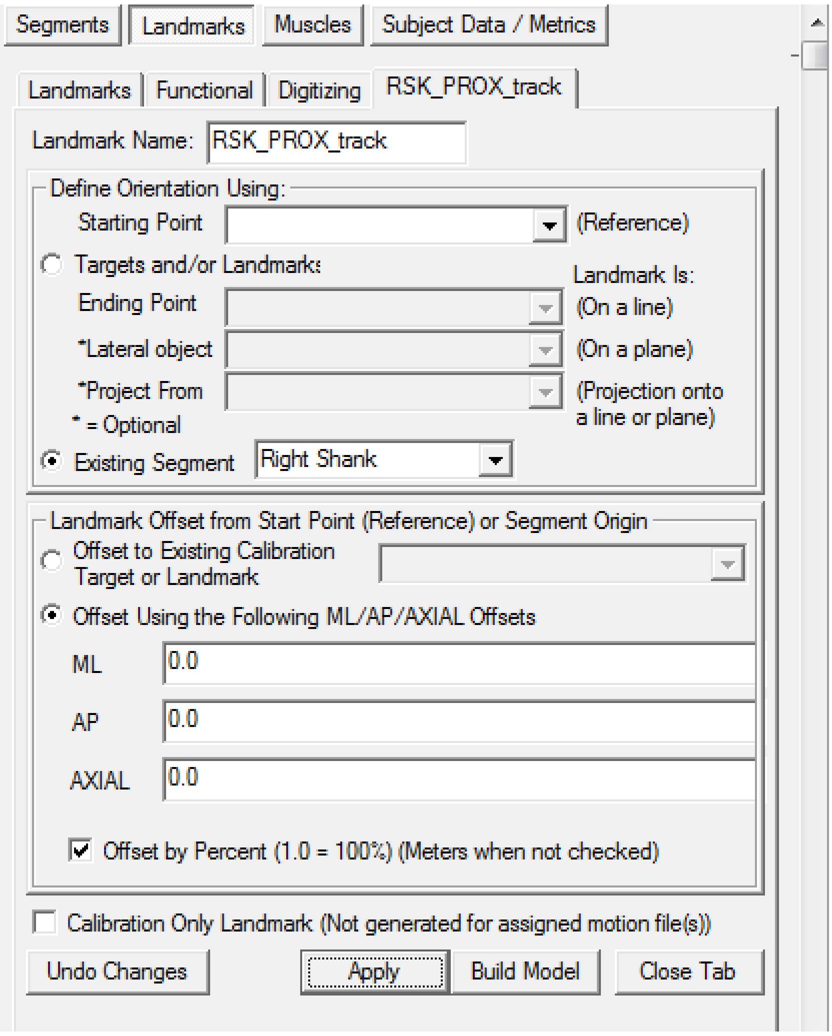
Sha_Cal_Frontal Angle – Angle of the calcaneus segment relative to the shank segment
This planar angle will be used to replace the inversion/eversion angle of the Sha_Cal joint angle
0 degrees indicates the calcaneus is aligned with the shank.



Sha_Cal_Frontal Landmarks

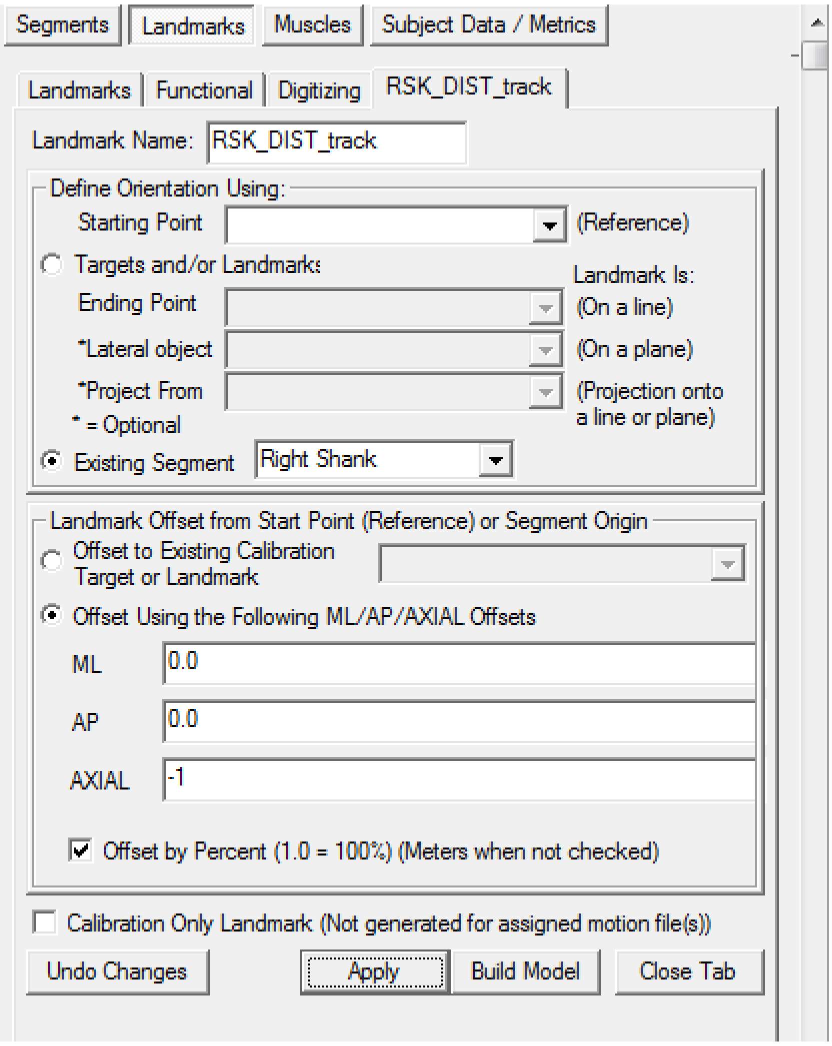
1. Create RSK_PROX_TRACK:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RSK_PROX_track
    2. **Define Orientation Using:**
        - **Existing Segment:** RSK
    3. Offset Using the Following **ML/AP/AXIAL** Offsets:
        - **X:** 0.0 **Y:** 0.0 **Z:** 0.0
    4. **Check:** Offset by Percent (1.0 = 100%)
    5. **Do Not Check:** Calibration Only Landmark



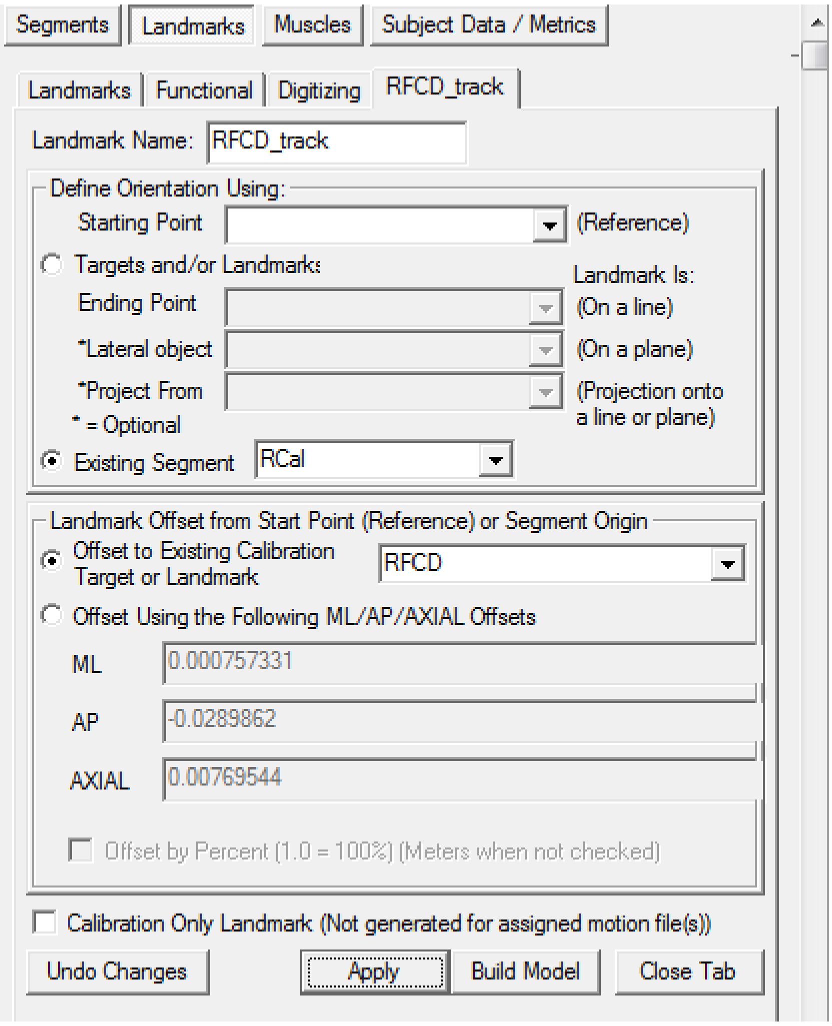
2. Create RSK_DIST_TRACK:

1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RSK_DIST_track
    2. **Define Orientation Using:**
        - **Existing Segment:** RSK
    3. Offset Using the Following **ML/AP/AXIAL** Offsets:
        - **X:** 0.0 **Y:** 0.0 **Z:** -1.0
    4. **Check:** Offset by Percent (1.0 = 100%)
    5. **Do Not Check:** Calibration Only Landmark



3. Create RFCS_track Joint Center:

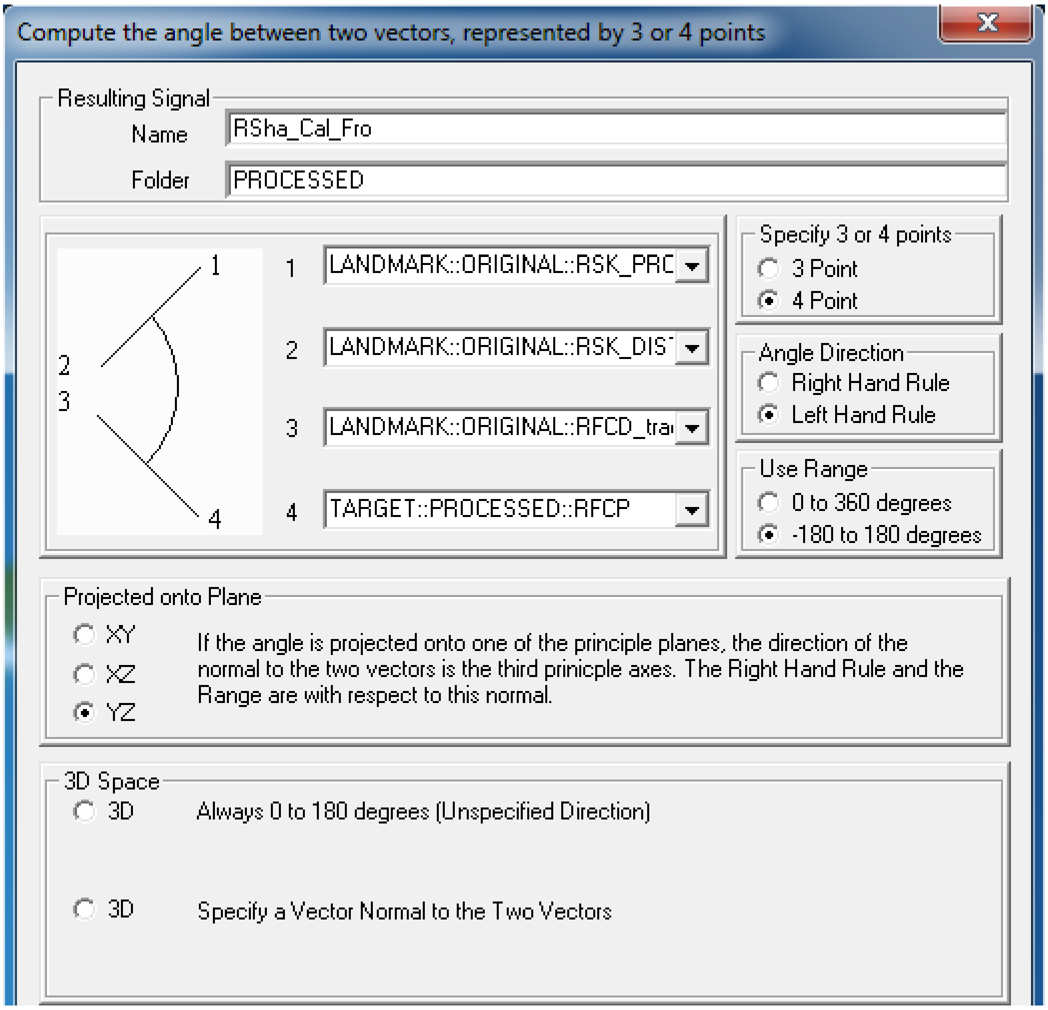
1. Click **Landmarks**
2. Click **Add New Landmark** button
3. Create Landmark:
    1. **Landmark Name:** RFCD_track
    2. **Define Orientation Using:**
        - **Existing Segment:** RCal
    3. Offset to Existing Calibration Target or Landmark: RFCD
    4. **Do Not Check:** Offset by Percent (1.0 = 100%)
    5. **Do Not Check:** Calibration Only Landmark



Sha_Cal_Frontal Definition

1. Create RSha_Cal_Fro planar angle:

1. Define **Resulting Signal** Name: RSha_Cal_Fro
2. Calculate a **4 point angle** between the following targets:
    1. LANDMARK::ORIGINAL::RSK_PROX_TRACK
    2. LANDMARK::ORIGINAL::RSK_DIST_TRACK
    3. LANDMARK::ORIGINAL::RFCD_TRACK
    4. TARGET::ORIGINAL::RFCP
        - **Angle Direction:** Left Hand Rule
        - **3D Space:** -180 to 180 degrees
        - **Projected onto Plane:** YZ
        - **Note:** The reference segment will need to be changed to RSK within the text option.



2. Create LSha_Cal_Fro planar angle:

1. When defining the left signal, use same definitions **except** set:

- **Angle Direction:** Right Hand Rule
- **Note:** The reference segment will need to be changed to LSK within the text option.

Joint Angles

Joint Angle definitions for the:

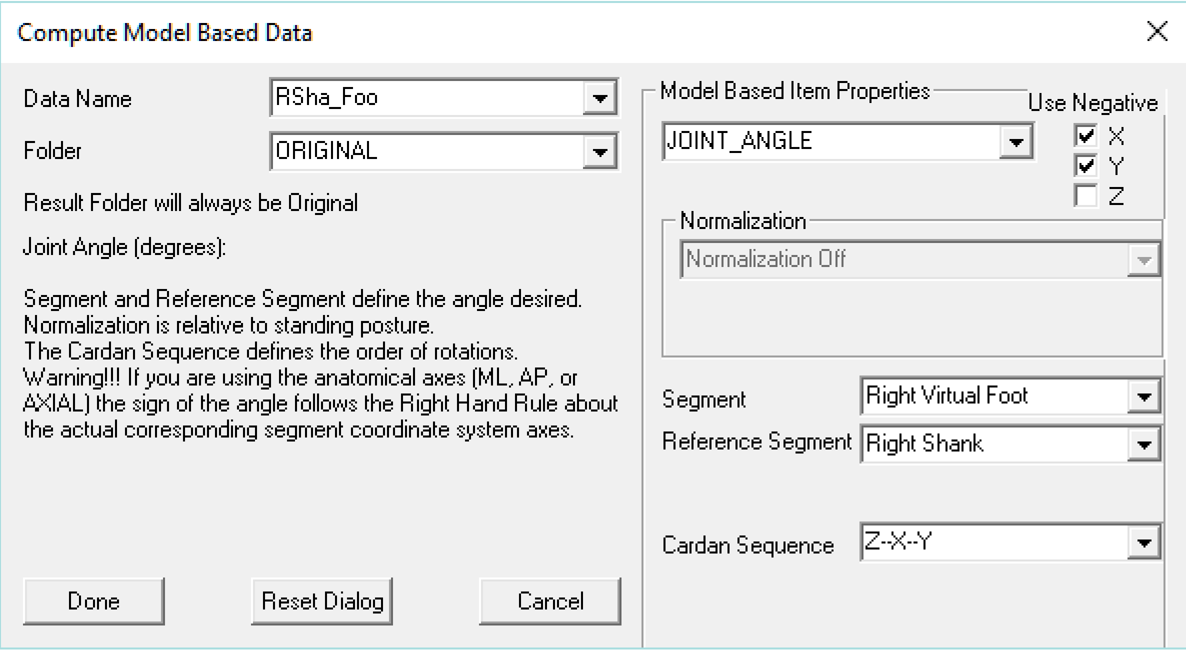
- Sha_Foo_Angle
- Sha_Cal_Angle
- Cal_Mid_Angle
- Mid_Met_Angle
- Cal_Met_Angle
- Met_Hal_Angle

The Met_Hal_Angle calculations are used to replace the F2Ps & F2Pt planar angles from the 2007 paper[1].

Joint Angle Definitions

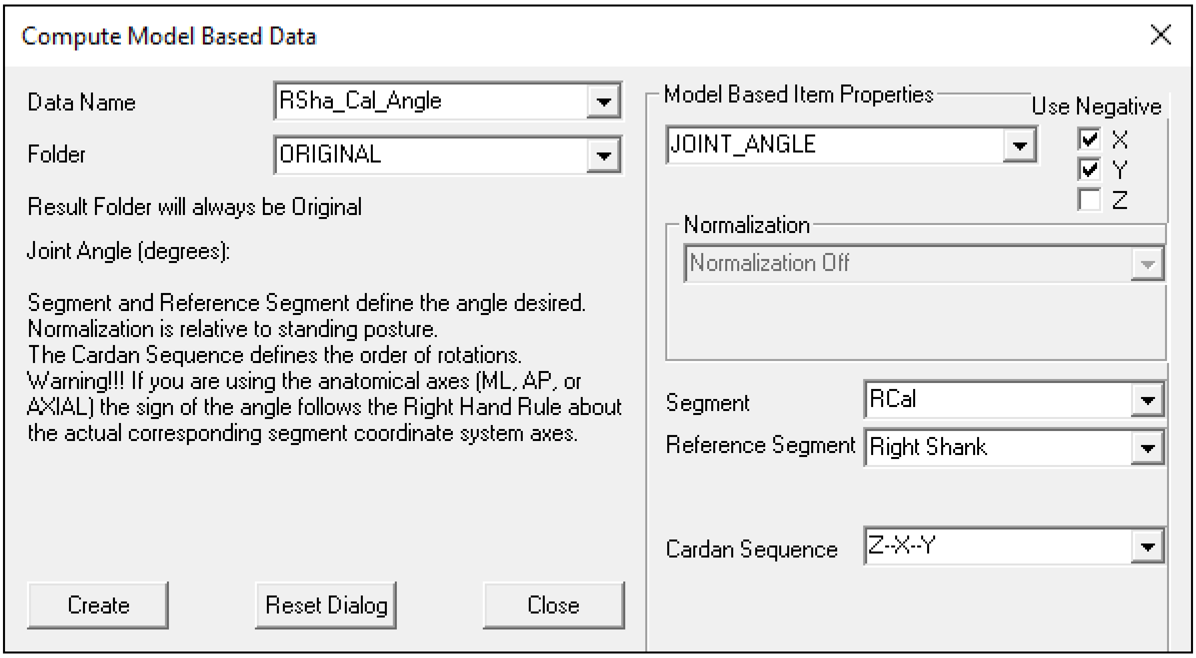
1. Define the RSha_Foo_Angle:

1. Open the **Compute Model Based** dialog
2. Select **JOINT_ANGLE** from the drop down list
   - **Data Name:** RSha_Foo_Angle
   - **Segment:** Right Virtual Foot
   - **Reference Segment:** Right Shank
   - **Cardan Sequence:** Z-X-Y
3. **Use Negative: X:** TRUE **Y:** TRUE **Z:** FALSE



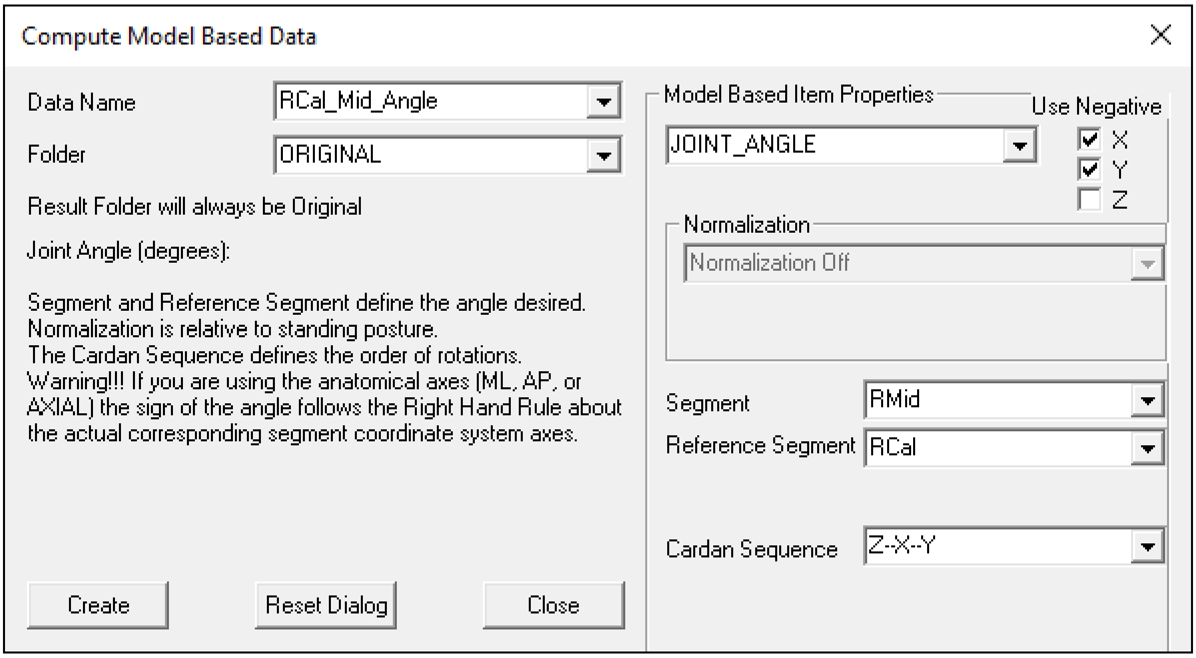
2. Define RSha_Cal_Angle:

1. Open the **Compute Model Based** dialog
2. Select **JOINT_ANGLE** from the drop down list
   - **Data Name:** RSha_Cal_Angle
   - **Segment:** RCal
   - **Reference Segment:** Right Shank
   - **Cardan Sequence:** Z-X-Y
3. **Use Negative: X:** TRUE **Y:** TRUE **Z:** FALSE



3. Define the Cal_Mid_Angle:

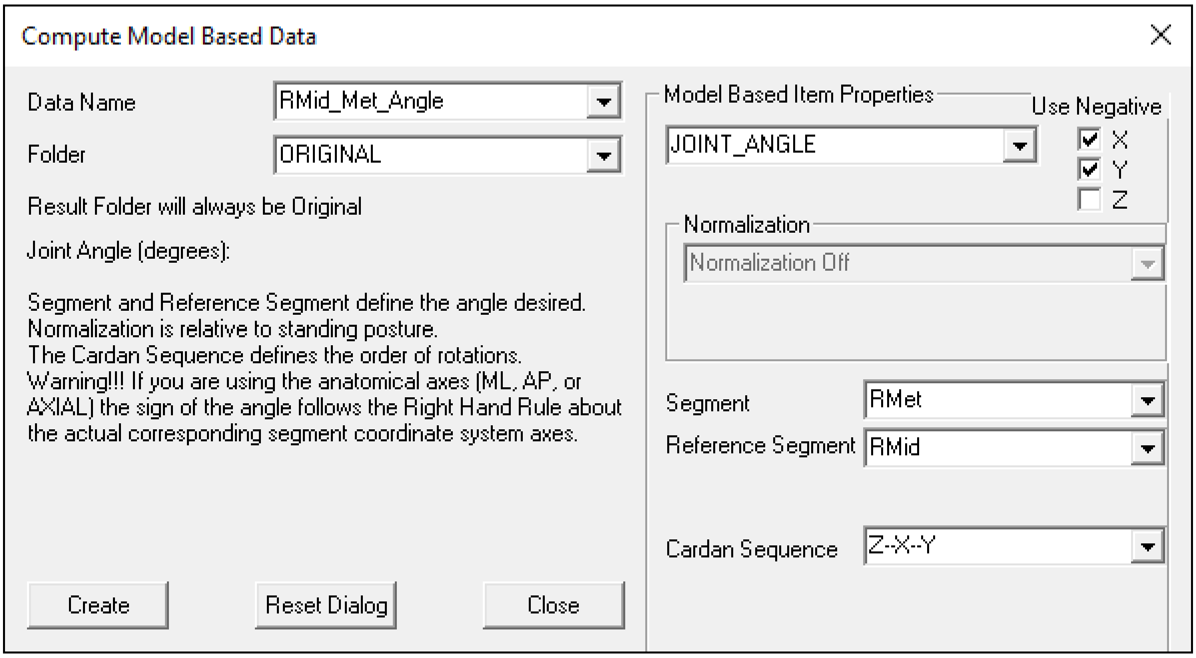
1. Open the **Compute Model Based** dialog
2. Select **JOINT_ANGLE** from the drop down list
    - **Data Name:** RCal_Mid_Angle
    - **Segment:** RMid
    - **Reference Segment:** RCal
    - **Cardan Sequence:** Z-X-Y
3. **Use Negative: X:** TRUE **Y:** TRUE **Z:** FALSE



4. Define the RMid_Met_Angle:

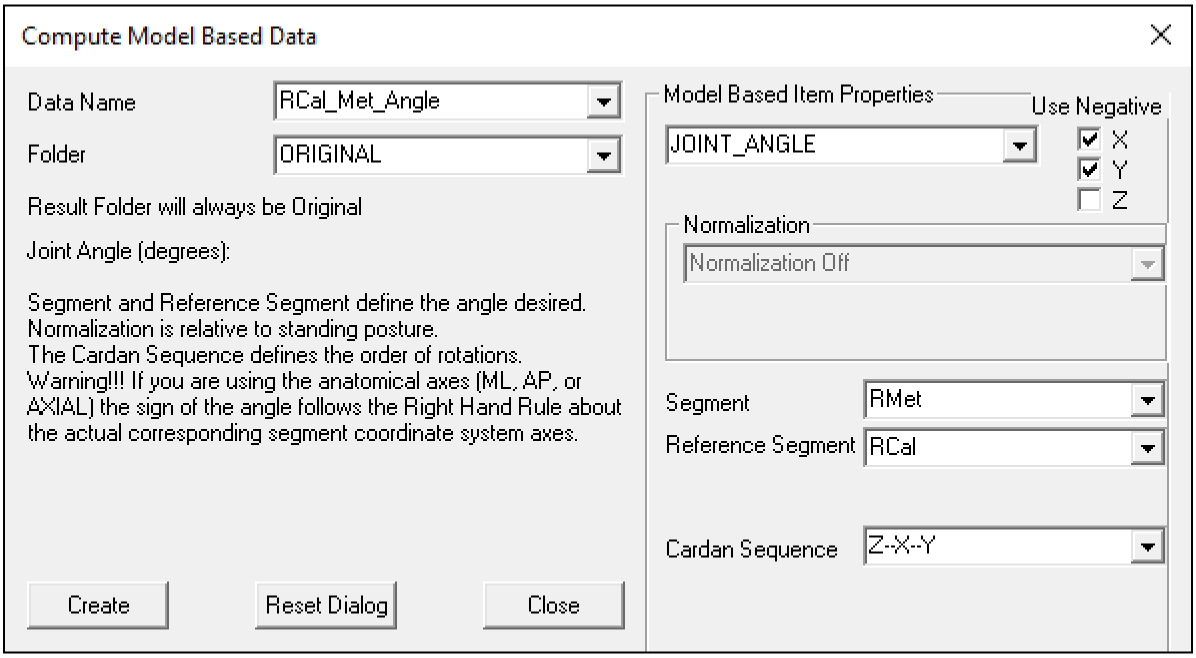
1. Open the **Compute Model Based** dialog
2. Select **JOINT_ANGLE** from the drop down list
    - **Data Name:** RMid_Met_Angle
    - **Segment:** RMet

  - **Reference Segment:** RMid
  - **Cardan Sequence:** Z-X-Y
3. **Use Negative: X:** TRUE **Y:** TRUE **Z:** FALSE



5. Define the RCal_Met_Angle:

1. Open the **Compute Model Based** dialog
2. Select **JOINT_ANGLE** from the drop down list
  - **Data Name:** RCal_Met_Angle
  - **Segment:** RMet
  - **Reference Segment:** RCal
  - **Cardan Sequence:** Z-X-Y
3. **Use Negative: X:** TRUE **Y:** TRUE **Z:** FALSE



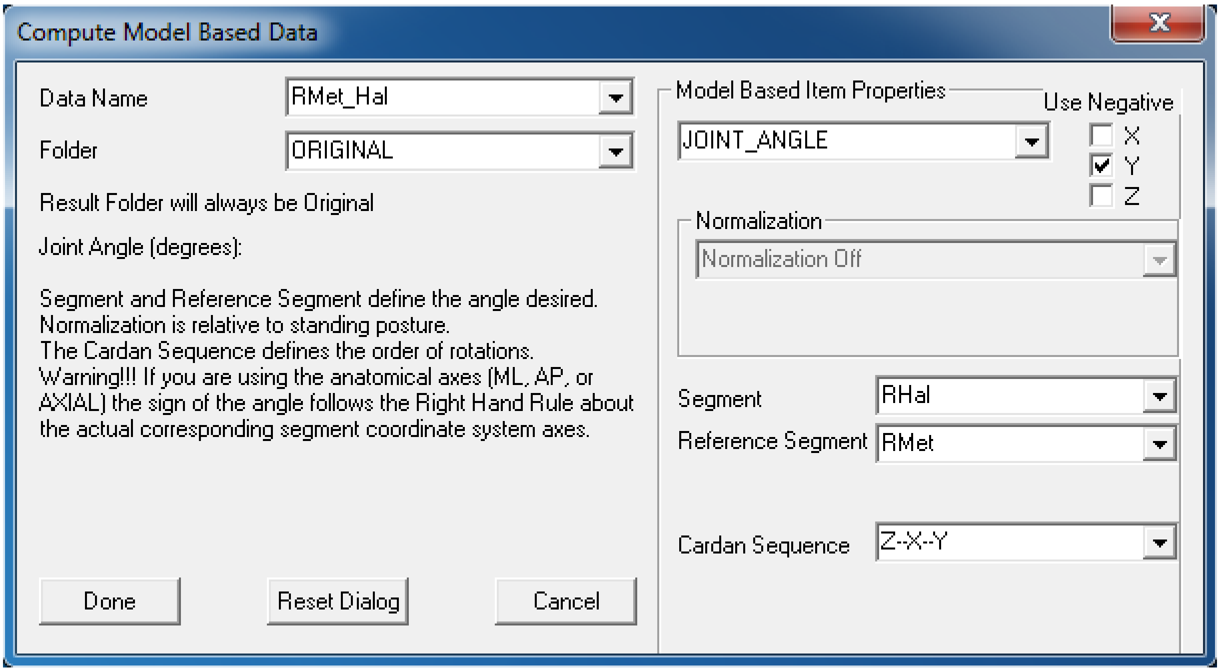
Met_Hal_Angle:

The Met_Hal angle is the angle of the hallux relative to the metarsus segment.

This sagittal and transverse angles of the Met_Hal_Angle angles create the F2Ps & F2Pt planar angles from the 2007 paper[1]. Since the targets used to track this segment are nearly colinear, useful information cannot be calculated from rotations in the coronal plane.
F2Ps - the angle between the lines FMH-PM and FMB-FMH projected onto the sagittal plane of the metatarsus
Represents: dorsiflexion of the first metatarso-phalangeal joint
F2Pt - the angle between the lines FMH-PM and FMB-FMH projected onto the transverse plane of the metatarsus
Represents: valgus of the first metatarsophalangeal joint

6. Define the RMet_Hal_Angle:

1. Open the **Compute Model Based** dialog
2. Select **JOINT_ANGLE** from the drop down list
   - **Data Name:** RMet_Hal_Angle
   - **Segment:** RHal
   - **Reference Segment:** RMet
   - **Cardan Sequence:** Z-X-Y
3. **Use Negative: X:** FALSE **Y:** TRUE **Z:** FALSE



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 1.12 1.13 1.14 1.15 1.16 1.17 1.18 1.19 1.20 1.21 1.22 1.23 1.24 1.25 1.26 1.27 1.28 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. ↑ 2.00 2.01 2.02 2.03 2.04 2.05 2.06 2.07 2.08 2.09 2.10 2.11 2.12 2.13 Portinaro, N., A. Leardini, A. Panou, V. Monzani, and P. Caravaggi. “Modifying the Rizzoli foot model to improve the diagnosis of pes-planus: application to kinematics of feet in teenagers.” Journal of Foot and Ankle Research (2014)
3. ↑ 3.00 3.01 3.02 3.03 3.04 3.05 3.06 3.07 3.08 3.09 3.10 3.11 3.12 3.13 3.14 3.15 Serge van Sint Jan “Color Atlas of Skeletal

Landmark Definitions: Guidelines for Reproducible Manual and Virtual Palpations” 2007 - Churchill Livingstone