

Plug-In Gait Lower Limb Modified

While every effort has been made to ensure the correct implementation of the Plug-In Gait model in Visual3D, some differences may still persist, most likely caused by the different pose estimations used within Nexus and Visual3D.

Introduction

The conventional gait model (CGM) has many variations and can go by many names: Helen Hayes, Vicon Clinical Manager, Newington, and Cleveland Clinic to name a few. We highly recommend reading the [Tutorial: Building a Conventional Gait Model](#) prior to going through this tutorial.

Workstation or *Nexus* users will be familiar with the Plug-In Gait variation as Vicon's implementation of the CGM.

In this tutorial, we describe this implementation of [Vicon's](#) Plug-In Gait using Visual3D, with the necessary modifications made for marker placement error specific to this dataset.

In some trials, clear errors in marker placement can be identified when viewing the model. Here we make the necessary adaptations to the model to compensate.

Marker Placement Error

Modifications Explained

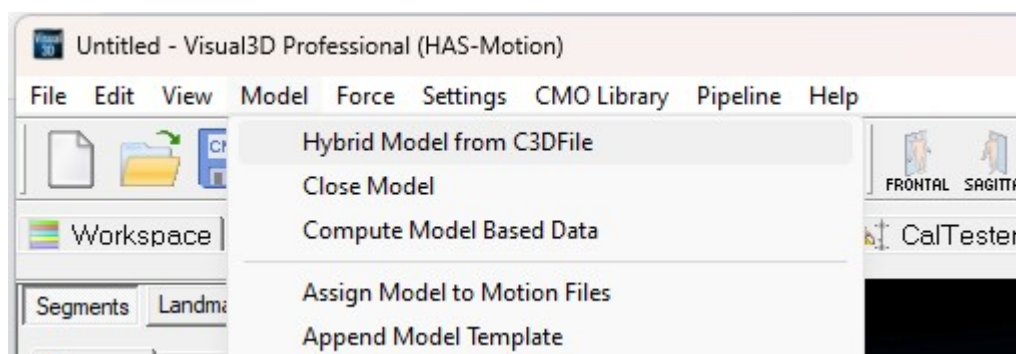
Shank Definition: In this tutorial the RKNE marker was added as the lateral boundary for the right shank definition. This was added to improve alignment of the shank and correct excessive incorrect internal rotation of the tibia that was previously present.

Toe Landmark: The R_Toe_Z landmark was introduced to align the anterior axis of the foot with that of the shank and thigh segments (assuming the subject is standing in alignment). It serves as the distal joint center and the posterior foot alignment.

Load Static Trial

You can download the sample files [here](#). These sample files were generously provided by Vicon (OMG plc, UK).

Load the static trial:



1. From the **Model** menu, select **Hybrid Model from C3DFile**
2. In the **Select the calibration file for the new model** dialog, select *WalkingStaticLowerBody.c3d*
 1. If using a knee alignment device, select *Sub01_Static_KAD_01.c3d*
3. Click **Open**.

Define Necessary Model Metrics

Create Model Metrics

1. Create Subject Metrics:

1. Click **Subject Data/Metrics** button
2. Select the *Mass* and click the **Modify Selected Item** button
 - Name:** *Mass*
 - Value or Expression:** *75*
 - NOTE:** This value MUST be changed for each subject
3. Select the *Height* and click the **Modify Selected Item** button
 - Name:** *Height*
 - Value or Expression:** *1.76*
 - NOTE:** This value MUST be changed for each subject
4. Click **Add New Item** button
 1. **Name:** *MarkerRadius*
 - Value or Expression:** *0.005*
 - NOTE:** This value MUST reflect the size of the markers used in YOUR lab
 2. **Name:** *Left_Knee_Width //*
 - Value or Expression:** *//0.105*
 - Create the *Right_Knee_Width*
 - NOTE:** This value MUST be changed for each subject
 3. **Name:** *Knee_Width*
 - Value or Expression:** *(Left_Knee_Width + Right_Knee_Width)/2*
 4. **Name:** *Left_Ankle_Width*
 - Value or Expression:** *0.070*

Create the *Right_Ankle_Width*

NOTE: This value **MUST** be changed for each subject

5. **Name:** *Ankle_Width*

Value or Expression: $(Left_Ankle_Width + Right_Ankle_Width)/2$

Pelvis Segment

Pelvis with 4 Targets

For an alternative pelvis definition with 3 targets see the original tutorial.

Pelvis with 4 Targets - Landmarks

Segments | Landmarks | Muscles | Subject Data / Metrics

Landmarks | Functional | Digitizing | SCRM

Landmark Name: SCRM

Define Orientation Using:

Starting Point: RPSI (Reference)

Targets and/or Landmark:

Ending Point: LPSI (On a line)

*Lateral object: (On a plane)

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

* = Optional

Existing Segment: LAB

Landmark Offset from Start Point (Reference) or Segment Origin

Offset to Existing Calibration Target or Landmark: ()

Offset Using the Following ML/AP/AXIAL Offsets

ML: ()

AP: ()

AXIAL: 0.5

☒ 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

Copy to Clipboard | Paste from Clipboard

1. Create SCRM:

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

Landmark Name: SCRM

Define Orientation Using:

Starting Point: *RPSI*

Ending Point: *LPSI*

Offset Using the Following **ML/AP/AXIAL** Offsets:

AXIAL: 0.5

Check: *Offset by Percent (1.0 = 100%)*

Check: *Calibration Only Landmark*

Pelvis with 4 Targets - Definition

The screenshot shows the 'Pelvis' tab in a software interface. The 'Define Segment Type' section has 'CODA' selected in the 'Segment Type' dropdown. The 'Define Calibration Targets' section has four dropdowns: 'R.ASIS' (RASI), 'L.ASIS' (LASI), 'R.PSIS' (SCRM), and 'L.PSIS' (SCRM). The 'Define ASIS Target Radius for Hip Joint Center Offset' section has '0.0000' in the 'ASIS Target Radius' input field. The 'Select Tracking Targets (Ctrl-Left Mouse Click to Multiselect)' section has a checkbox 'Use Calibration Targets for Tracking' which is unchecked. Below this, there is a grid of checkboxes for various landmarks: SCRM, RIGHT_HIP, LEFT_HIP, LANK, LASI, LHEE, LKNE, LTHI, LTIB, LTOE, RANK, RHEE, RKNE, RPSI, RTHI, RTIB, and RTOE. The checkboxes for LASI, LPSI, RASI, and RPSI are checked. At the bottom, there are four buttons: 'Close Tab', 'Guess Properties', 'Apply', and 'Build Model'.

Select Tracking Targets (Ctrl-Left Mouse Click to Multiselect)			
☐ SCRM	☐ LHEE	☐ LTOE	☒ RPSI
☐ RIGHT_HIP	☐ LKNE	☐ RANK	☐ RTHI
☐ LEFT_HIP	☒ LPSI	☒ RASI	☐ RTIB
☐ LANK	☐ LTHI	☐ RHEE	☐ RTOE
☒ LASI	☐ LTIB	☐ RKNE	

2. Create Pelvis Segment:

1. In the **Segments** tab, select *Pelvis* in the Segment Name box.
2. Select **CODA** in the Segment Type box.
3. Click on the **Create Segment** button.

4. In the **Pelvis** tab, enter these values:

Define Calibration Targets

R.ASIS: *RASI* **L.ASIS:** *LASI*

R.PSIS: *SCRM* **L.PSIS:** *SCRM*

Define ASIS Target Radius for Hip Joint Center Offset

ASIS Target Radius: *MarkerRadius*

Select Tracking Targets:

LASI, LPSI, RASI, RPSI

5. Click on **Build Model**.

6. Click on **Close Tab** before proceeding.

Hip Joint Center

The CODA pelvis automatically creates hip joint centers using the Bell and Brand regression equations. The PiG model uses the [Davis regression equations](#).

The directions below walk you through the necessary steps to create the RHJC and LHJC using the Davis regression equations. Please note, some metrics can be manually entered OR target data can be used to estimate these values.

Create Model Metrics for Hip Joint Center

1. Create Subject Metrics:

1. Click **Subject Data/Metrics** button

2. Click **Add New Item** button

1. **Name:** *Left_Leg_Length*

(A) **Value or Expression:** *0.940*

OR:

(B) **Value or Expression:** *DISTANCE(LASI,LANK)*

Create the *Right_Leg_Length*

NOTE: If you specify an explicit value (ex. 0.940), this value **MUST** be changed for each subject

2. **Name:** *Leg_Length*

Value or Expression: *(Left_Leg_Length + Right_Leg_Length)/2*

3. **Name:** *C*

Value or Expression: *0.115*Leg_Length - 0.0153*

4. **Name:** *theta*

Value or Expression: *28.4*PI/180.0*

5. **Name:** *beta*

Value or Expression: *18.0*PI/180.0*

6. **Name:** *Xdis*
(A) **Value or Expression:** *0.750*
OR:
(B) **Value or Expression:** $0.1288 * \text{Leg_Length} - 0.04856$
NOTE: If you specify an explicit value (ex. 0.750), this value **MUST** be changed for each subject
 7. **Name:** *HJC_ML*
Value or Expression: $(C * \sin(\theta) - 0.5 * \text{ASIS_distance})$
 8. **Name:** *HJC_AP*
Value or Expression: $(-Xdis - \text{MarkerRadius}) * \cos(\beta) + C * \cos(\theta) * \sin(\beta)$
 9. **Name:** *HJC_AX*
Value or Expression: $(-Xdis - \text{MarkerRadius}) * \sin(\beta) - C * \cos(\theta) * \cos(\beta)$
-

Helen Hayes Hip Landmarks

1. Create RHIP:



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

Landmark Name: *RHIP*

Define Orientation Using:

Click **Existing Segment:** *Pelvis*

Offset Using the Following **ML/AP/AXIAL** Offsets:

X: *-HJC_ML* **Y:** *HJC_AP* **Z:** *HJC_AX*

Do NOT Check: *Offset by Percent (1.0 = 100%)*

Do NOT Check: *Calibration Only Landmark*



2. Create LHIP:

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

Landmark Name: *LHIP*

Define Orientation Using:

Click **Existing Segment:** *Pelvis*

Offset Using the Following **ML/AP/AXIAL** Offsets:

X: *HJC_ML* **Y:** *HJC_AP* **Z:** *HJC_AX*

Do NOT Check: Offset by Percent (1.0 = 100%)

Do NOT Check: Calibration Only Landmark

Thigh Segment

Segments | Landmarks | Muscles | Subject Data / Metrics

Segments | Segment Properties | IK Constraints | **Right Thigh**

Define Proximal Joint and Radius

Lateral: None | Joint Center: **RHJC** | Medial: None

Radius (Meters): $0.5 \times \text{DISTANCE}(\text{RHJC}, \text{LHJC})$

Define Distal Joint and Radius

Lateral: **RKNE** | Joint Center: None | Medial: None

Radius (Meters): $0.5 \times \text{Knee_Width} + \text{MarkerRadius}$

Extra Target to Define Orientation (if needed)

Location: Lateral | **RTHI**

Select Tracking Targets (Ctrl-Left Mouse Click to Multiselect)

☒ Use Calibration Targets for Tracking

Depth (Meters):

Close Tab | Guess Properties | Apply | Build Model

1. Create Right Thigh Segment:

1. In the **Segments** tab, select *Right Thigh* in the Segment Name box.
2. Click on the **Create Segment** button.
3. In the **Right Thigh** tab, enter these values:

Define Proximal Joint and Radius

Lateral: *None* **Joint:** *RHJC* **Medial:** *None*

Radius: $0.5 * \text{DISTANCE}(\text{RHJC}, \text{LHJC})$

Define Distal Joint and Radius

Lateral: *RKNE* **Joint:** *None* **Medial:** *None*

Radius: $0.5 * \text{Knee_Width} + \text{MarkerRadius}$

Extra Target to Define Orientation

Location: *Lateral* *RTHI*

Select Tracking Targets:

Check: *Use Calibration Targets for Tracking*

4. Click on **Build Model**.
 5. Click on **Close Tab** before proceeding.
-

Shank Segment

Segments | Landmarks | Muscles | Subject Data / Metrics

Landmarks | Functional | Digitizing | RKJC

Landmark Name: RKJC

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: Right Thigh

Landmark Offset from Start Point (Reference) or Segment Origin

Offset to Existing Calibration Target or Landmark

Offset Using the Following ML/AP/AXIAL Offsets

ML: 0.0

AP: 0.0

AXIAL: -1

☒ 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

Copy to Clipboard | Paste from Clipboard

Shank Landmarks

1. Create RKJC:

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

Landmark Name: *RKJC*

Define Orientation Using:

Click **Existing Segment:** *Right Thigh*

Offset Using the Following **ML/AP/AXIAL** Offsets:

ML: *0.0* **AP:** *0.0* **AXIAL:** *-1.0*

Check: *Offset by Percent (1.0 = 100%)*

Do NOT Check: Calibration Only Landmark

Segments Landmarks Muscles Subject Data / Metrics

Segments Segment Properties IK Constraints Right Foot Right Shank

Define Proximal Joint and Radius

Lateral Joint Center Medial

RKNE RKJC None

Radius (Meters) 0.0575

Define Distal Joint and Radius

Lateral Joint Center Medial

RANK None None

Radius (Meters) $0.5 \cdot \text{Ankle_Width} + \text{MarkerRadius}$

Extra Signal to Define Orientation (if needed)

Location None

Select Tracking Signals

☒ Use Calibration Signals for Tracking

Depth (Meters):

6DOF Cutoff Frequency 0.0

Close Tab Guess Properties Apply Build Model

Shank Definition

1. Create Right Shank Segment:

1. In the **Segments** tab, select *Right Shank* in the Segment Name box.
2. Click on the **Create Segment** button.
3. In the **Right Shank** tab, enter these values:

Define Proximal Joint and Radius

Lateral: RKNE **Joint:** RKJC **Medial:** None

Define Distal Joint and Radius

Lateral: RANK **Joint:** None **Medial:** None

Radius: $0.5 * \text{Ankle_Width} + \text{MarkerRadius}$

Select Tracking Targets:

Check: *Use Calibration Targets for Tracking*

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

Foot Segment

Foot Landmarks

The image displays two screenshots of a software interface for defining foot landmarks. The left screenshot shows the 'RAJC' landmark configuration, and the right screenshot shows the 'R_Toe_Z' landmark configuration.

Left Screenshot (RAJC Landmark):

- Landmark Name:** RAJC
- Define Orientation Using:**
 - Starting Point: (Reference)
 - Ending Point: (On a line)
 - *Lateral object: (On a plane)
 - *Project From: (Projection onto a line or plane)
 - * = Optional
- Existing Segment:** Right Shank
- Landmark Offset from Start Point (Reference) or Segment Origin:**
 - Offset to Existing Calibration Target or Landmark: (On a line)
 - Offset Using the Following ML/AP/AXIAL Offsets:
 - ML: 0.0
 - AP: 0.0
 - AXIAL: -1
 - Offset by Percent (1.0 = 100%) (Meters when not checked): ☒
- Calibration Only Landmark (Not generated for assigned motion file(s)):** ☐
- Buttons:** Undo Changes, Apply, Build Model, Close Tab, Copy to Clipboard, Paste from Clipboard

Right Screenshot (R_Toe_Z Landmark):

- Name:** R_Toe_Z
- Define Orientation Using:**
 - Starting Point: RTOE (Reference)
 - Ending Point: (On a line)
 - *Lateral object: (On a plane)
 - *Project From: (Projection onto a line or plane)
 - * = Optional
- Existing Coordinate System:** LAB
- Landmark Offset from Start Point (Reference) or Segment Origin:**
 - Offset to Existing Calibration Target or Landmark: (On a line)
 - Offset Using the Following ML/AP/AXIAL Offsets:
 - X: 0.0
 - Y: 0.0
 - Z: -0.1
 - Offset by Percent (1.0 = 100%) (Meters when not checked): ☐
- Calibration Only Landmark (Not generated for assigned motion file(s)):** ☒
- Buttons:** Apply, Build Model, Close Tab, Undo Changes, Copy to Clipboard, Paste from Clipboard

1. Create RAJC:

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

Landmark Name: RAJC

Define Orientation Using:

Click **Existing Segment:** *Right Shank*

Offset Using the Following **ML/AP/AXIAL** Offsets:

ML: 0.0 **AP:** 0.0 **AXIAL:** -1.0

Check: *Offset by Percent (1.0 = 100%)*

Do NOT Check: *Calibration Only Landmark*

2. Create R_TOE_Z:

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

Landmark Name: *R_TOE_Z*

Define Orientation Using:

Click **Starting Point and Existing Segment:** *RTOE and LAB*

Offset Using the Following **ML/AP/AXIAL** Offsets:

ML: 0.0 **AP:** 0.0 **AXIAL:** -0.1

Check: *Offset by Percent (1.0 = 100%)*

Do NOT Check: *Calibration Only Landmark*

Foot Definition

1. Create Right Foot Segment:

1. In the **Segments** tab, select *Right Foot* in the Segment Name box.
2. Click on the **Create Segment** button.
3. In the **Right Foot** tab, enter these values:

Define Proximal Joint and Radius

Lateral: *None* **Joint:** *RAJC* **Medial:** *None*

Radius: *RSK_DISTAL_RADIUS*

Define Distal Joint and Radius

Lateral: *None* **Joint:** *RTOE* **Medial:** *None*

Radius: *RSK_DISTAL_RADIUS*

Extra Target to Define Orientation

Location: *Posterior* *R_Toe_Z*

Select Tracking Targets:

Select: *RHEE, RMT5, and RTOE*

4. Click on **Build Model**.

5. Click on **Close Tab** before proceeding.

Virtual Foot Segment

The screenshot shows the 'RVirtualFoot' configuration window. At the top, there are tabs: 'Segments', 'Landmarks', 'Muscles', and 'Subject Data / Metrics'. Below these, there are sub-tabs: 'Segments', 'Segment Properties', 'IK Constraints', and 'RVirtualFoot'. The 'RVirtualFoot' sub-tab is active. The window is divided into several sections:

- Define Proximal Joint and Radius:** This section has three dropdown menus: 'Lateral' (set to 'None'), 'Joint Center' (set to 'RHEE'), and 'Medial' (set to 'None'). Below these is a text input field for 'Radius (Meters)' with the value '0.1'.
- Define Distal Joint and Radius:** This section has three dropdown menus: 'Lateral' (set to 'None'), 'Joint Center' (set to 'RTOE'), and 'Medial' (set to 'None'). Below these is a text input field for 'Radius (Meters)' with the value '0.1'.
- Extra Target to Define Orientation (if needed):** This section has a 'Location' dropdown set to 'Anterior' and a dropdown set to 'RAJC'.
- Select Tracking Targets (Ctrl-Left Mouse Click to Multiselect):** This section has a checkbox labeled 'Use Calibration Targets for Tracking' which is checked. Below the checkbox is a large empty rectangular box for selecting targets.
- Depth (Meters):** A text input field at the bottom of the configuration area.

At the bottom of the window, there are four buttons: 'Close Tab', 'Guess Properties', 'Apply', and 'Build Model'.

1. Create RVirtualFoot Segment:

1. In the **Segments** tab, type *RVirtualFoot* in the Segment Name box.
2. Check **Kinematic Only**.
3. Click on the **Create Segment** button.

4. In the **RVirtualFoot** tab, enter these values:

Define Proximal Joint and Radius

Lateral: *None* **Joint:** *RHEE* **Medial:** *None*

Radius: *0.1*

Define Distal Joint and Radius

Lateral: *None* **Joint:** *RTOE* **Medial:** *None*

Radius: *0.1*

Extra Target to Define Orientation

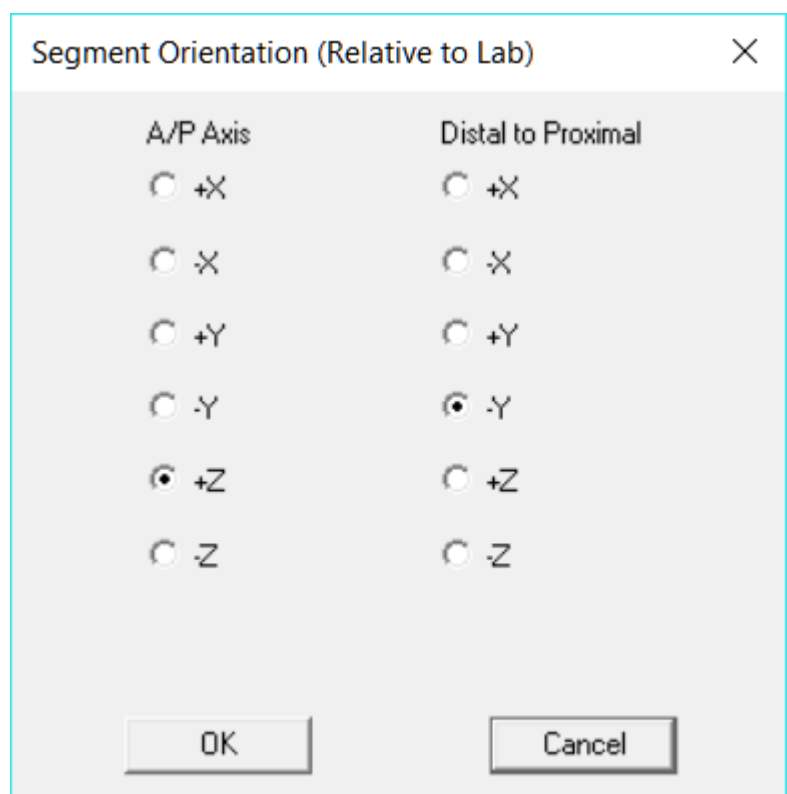
Location: *Anterior* *RAJC*

Select Tracking Targets:

Check: *Use Calibration Targets for Tracking*

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: *-Y*

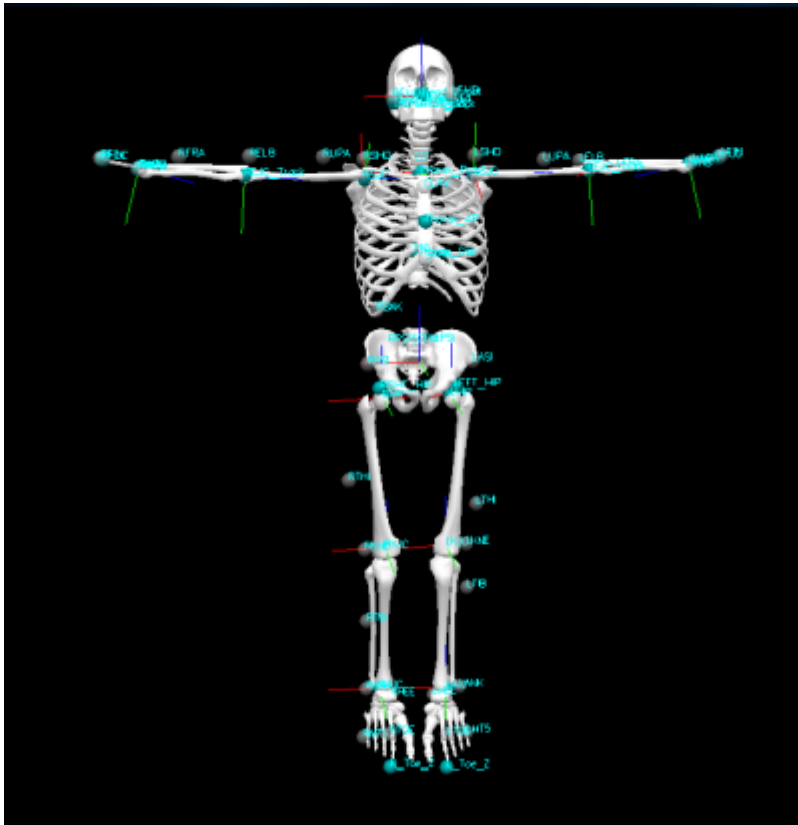
Left Side Model

To build the left side of the model start by copying and reflecting the appropriate landmarks that were created for the right side. Do the same for the thigh, shank and foot segments.

Impact of Modifications

The images below show the original model, before modifications, compared to the modified model. Significant errors in tibial rotation and foot orientation can be seen in the original that are corrected for in the updated model.

Original:



Modified:

