Instrumental Pedal Tutorial

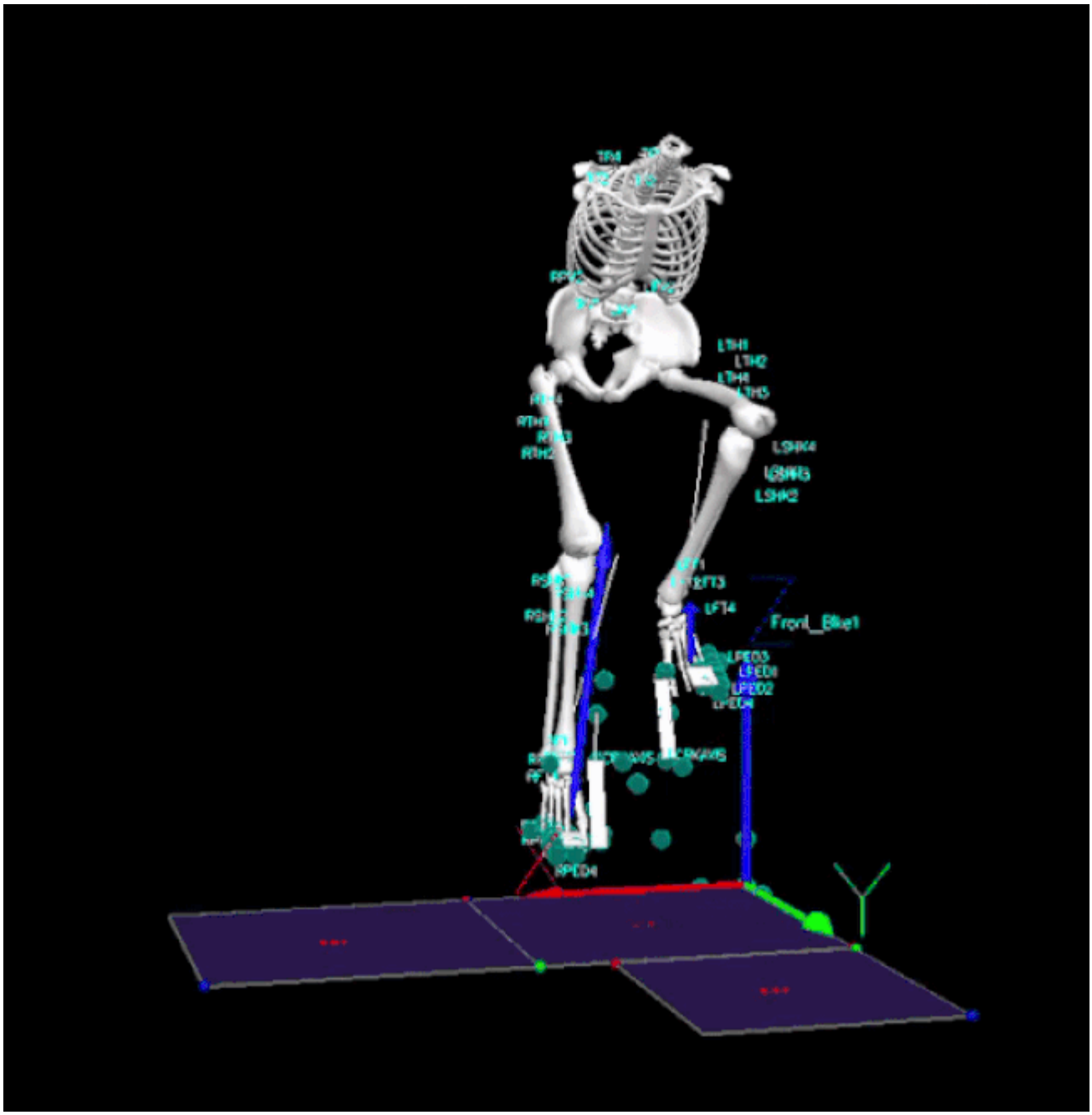
Overview

This tutorial outlines the process to build a model for a bike pedal and crank and how to assign force data from analog signals. This tutorial assumes your human model is already built. Follow this tutorial to create a model before continuing Building 6DOF Model. This tutorial will have two parts, the first part will show how to create the model for the bike pedal and crank, and the second will show the force data processing.

The following c3d files can be downloaded as a starting point:

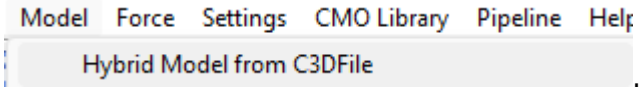
Bike Model c3d Starter

Full completed CMZ can be downloaded here: Bike Model CMZ Complete

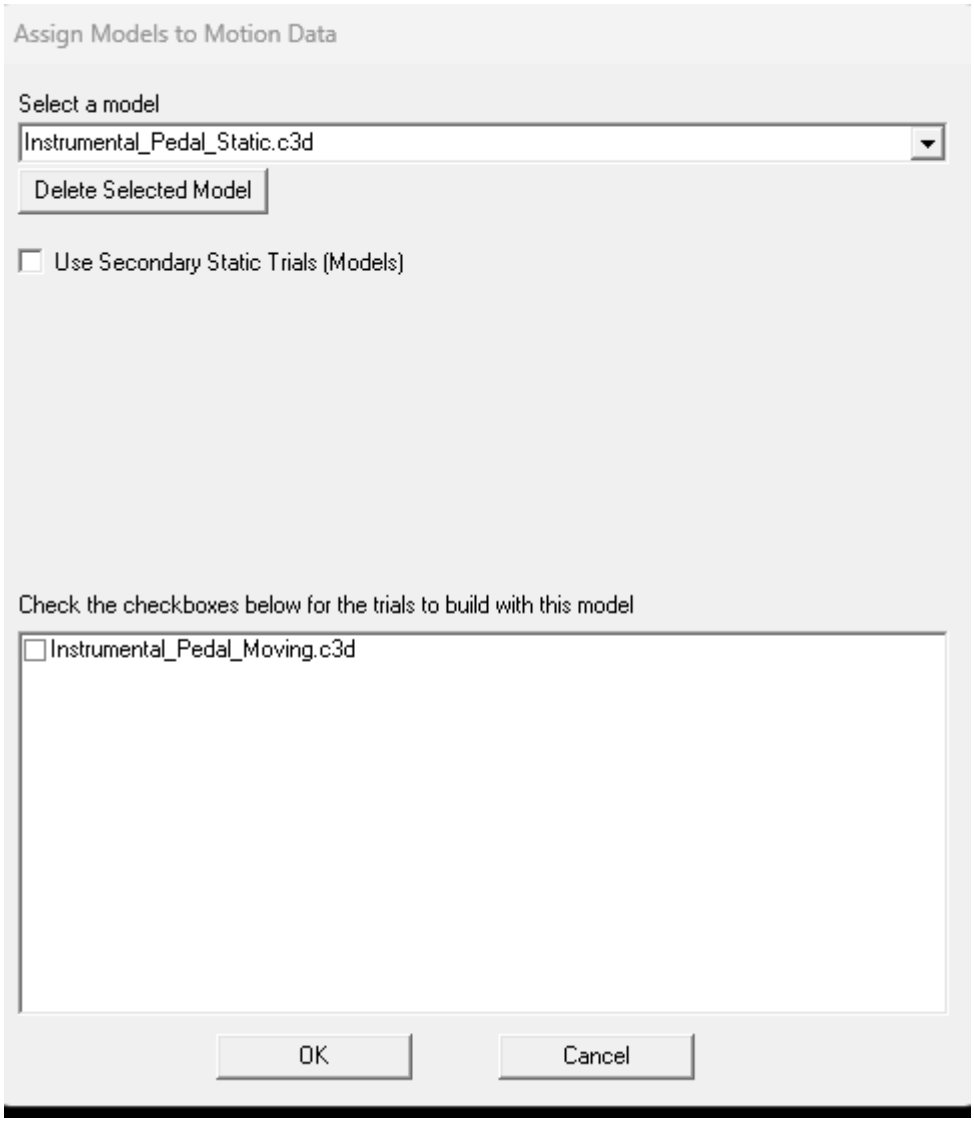


Full built model with properly assigned forces.

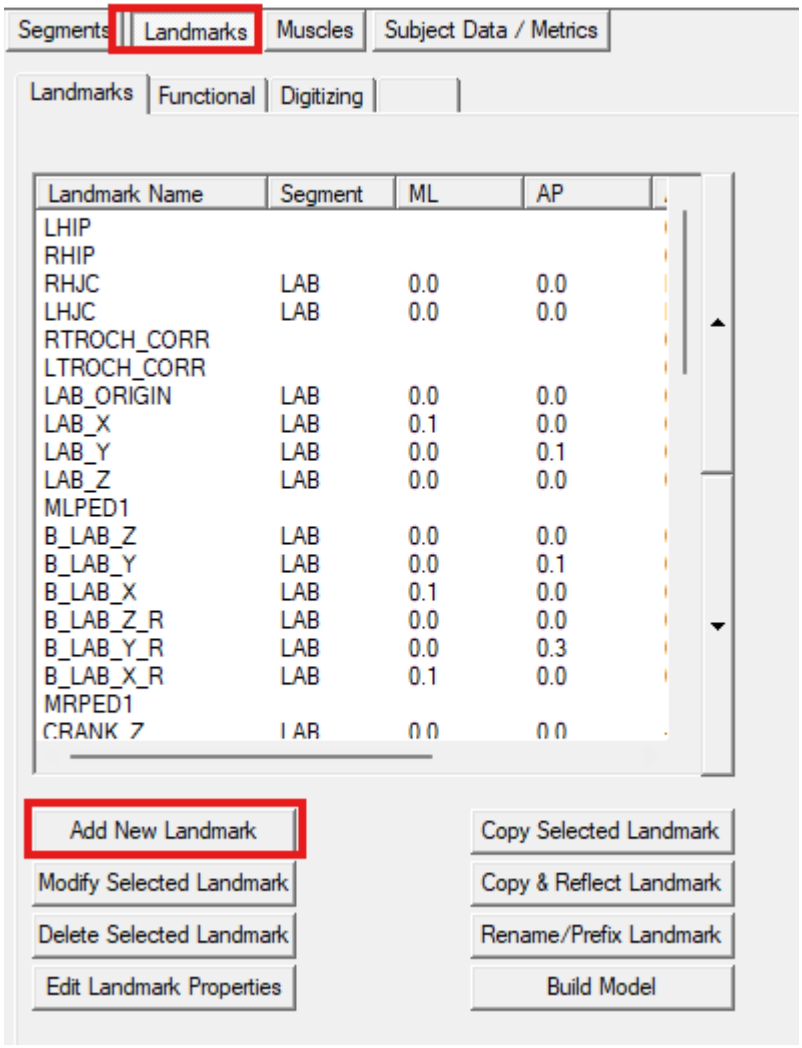
Model Building

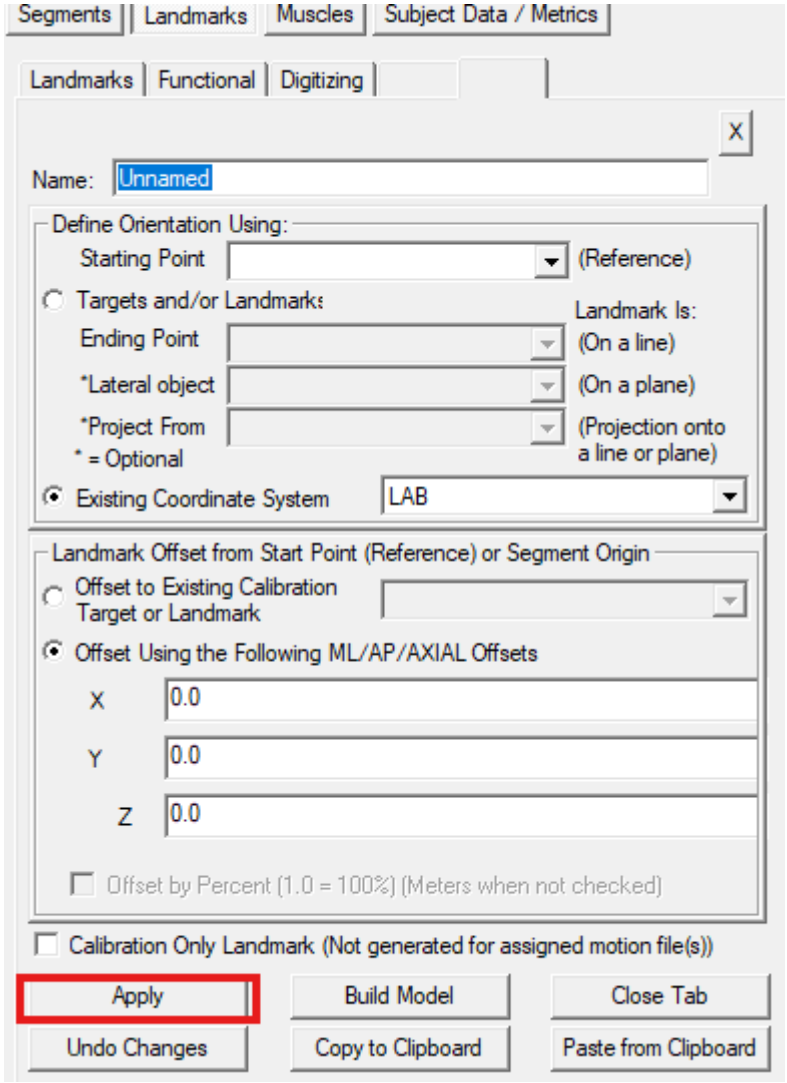
The create a model you first need to load the dynamic trial into the workspace. From here select the **Model** menu and select Hybrid model from c3d file 

. Open your static trial which should generate the dialog below, ensure you check the dynamic trial to be built with this model.

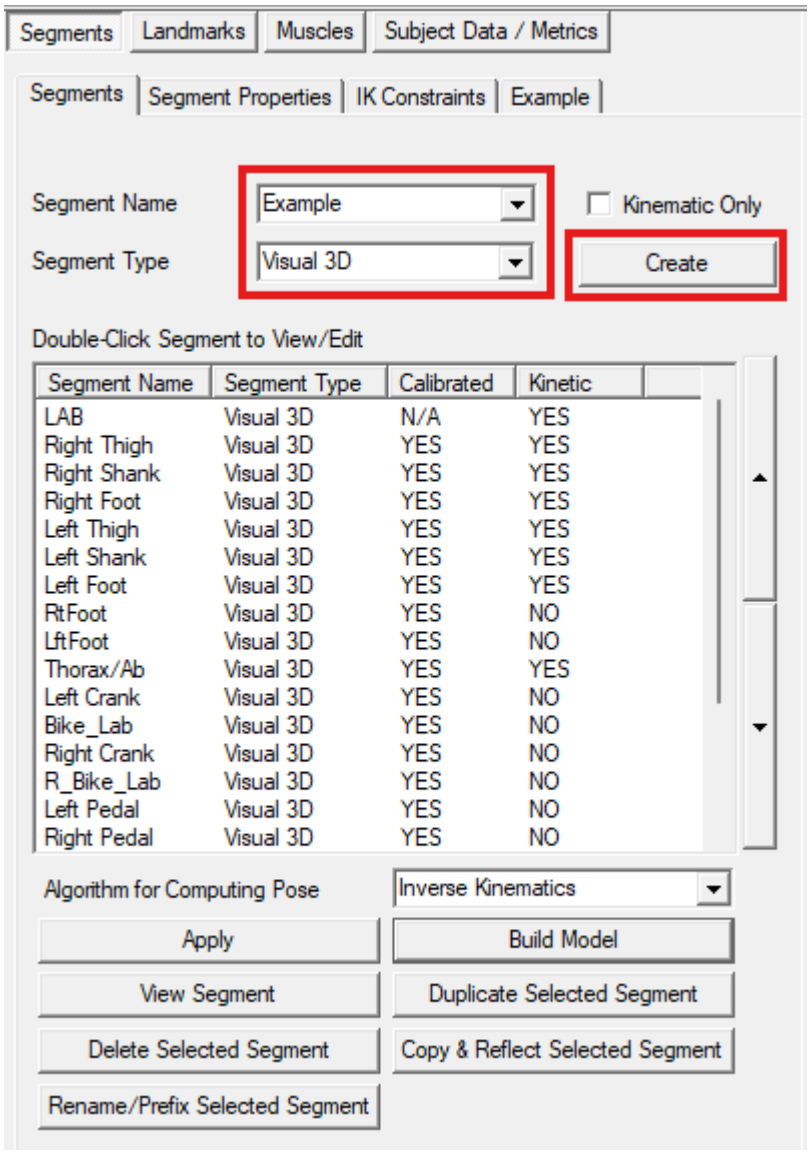


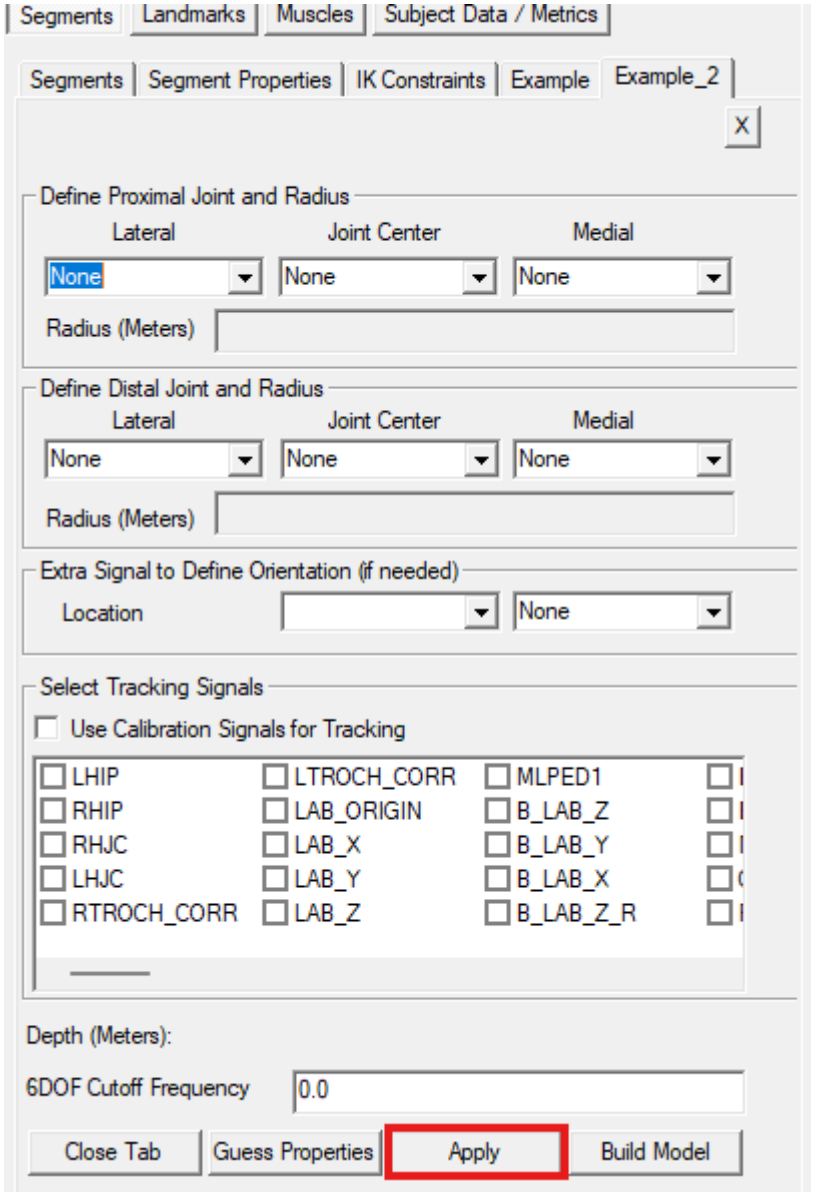
Building this model is very tedious as there are a lot landmarks and segments required. It is important to follow the order outlined below as certain landmarks and segments are build off previously defined items. To create a new landmark click on the **Landmarks** tab, select **Add New Landmark**, input the definitions below and press **Apply**. Not that when inputting the definitions below the pedal landmarks and their offsets are specific to this dataset and would need to adjusted for different data.


Segments
Landmarks
Muscles
Subject Data / Metrics
Landmarks
Functional
Digitizing
Landmark Name
Segment
ML
AP
LHIP
RHIP
RHJC LAB 0.0 0.0
LHJC LAB 0.0 0.0
RTROCH_CORR
LTROCH_CORR
LAB_ORIGIN LAB 0.0 0.0
LAB_X LAB 0.1 0.0
LAB_Y LAB 0.0 0.1
LAB_Z LAB 0.0 0.0
MLPED1
B_LAB_Z LAB 0.0 0.0
B_LAB_Y LAB 0.0 0.1
B_LAB_X LAB 0.1 0.0
B_LAB_Z_R LAB 0.0 0.0
B_LAB_Y_R LAB 0.0 0.3
B_LAB_X_R LAB 0.1 0.0
MRPED1
Add New Landmark
Modify Selected Landmark
Delete Selected Landmark
Edit Landmark Properties
Copy Selected Landmark
Copy & Reflect Landmark
Rename/Prefix Landmark
Build Model



To build a new segment select the **Segment** tab input your desired segment name, ensure the segment type is **Visual 3D**, select **Create**, input the definitions for the segments shown below, and select **Apply**.


Segments
Landmarks
Muscles
Subject Data / Metrics
Segments
Segment Properties
IK Constraints
Example
Segment Name
Example
Kinematic Only
Segment Type
Visual 3D
Create
Double-Click Segment to View/Edit
Segment Name
Segment Type
Calibrated
Kinetic
LAB Visual 3D N/A YES
Right Thigh Visual 3D YES YES
Right Shank Visual 3D YES YES
Right Foot Visual 3D YES YES
Left Thigh Visual 3D YES YES
Left Shank Visual 3D YES YES
Left Foot Visual 3D YES YES
RtFoot Visual 3D YES NO
LftFoot Visual 3D YES NO
Thorax/Ab Visual 3D YES YES
Left Crank Visual 3D YES NO
Bike_Lab Visual 3D YES NO
Right Crank Visual 3D YES NO
R_Bike_Lab Visual 3D YES NO
Left Pedal Visual 3D YES NO
Right Pedal Visual 3D YES NO
Algorithm for Computing Pose
Inverse Kinematics
Apply
Build Model
View Segment
Duplicate Selected Segment
Delete Selected Segment
Copy & Reflect Selected Segment
Rename/Prefix Selected Segment



The first set of **landmarks** define a virtual position for the cranks

Landmark	Starting Point	Existing Coordinate System	ML Offset	AP Offset	AXIAL Offset
VRCRKAXIS	RCRKAXIS	LAB	-0.0045	0	0
VLCRKAXIS	LCRKAXIS	LAB	0.0045	0	0

The following set of **landmarks** define virtual positions from the pedal markers in the LAB

Landmark	Starting Point	Existing Coordinate System	ML Offset	AP Offset	AXIAL Offset
VRPED1_X	RPED1	LAB	-0.3	0	0
VRPED1	RPED1	LAB	-0.6	0	0
VRPED2	RPED2	LAB	-0.3	0	0
VRPED3	RPED3	LAB	-0.5	0	0
VLPED1_X	LPED1	LAB	0.3	0	0
VLPED1	LPED1	LAB	0.6	0	0
VLPED2	LPED2	LAB	0.3	0	0
VLPED3	LPED3	LAB	0.5	0	0
VRPED3_0	RPED3	LAB	-0.2	0	0
VLPED3_0	LPED1	LAB	0.2	0	0

VRPED2_X1	RPED2	LAB	-0.07	0	0

Landmark	Starting Point	Ending Point	Project From
MRPED1	RPED1	VRPED1_X	VRCRKAXIS
MLPED1	LPED1	VLPED1_X	VLCRKAXIS

The following set of **landmarks** are for the Bike Lab Coordinate systems.

Landmark	Starting Point	Existing Coordinate System	ML Offset	AP Offset	AXIAL Offset
B_LAB_Z	LCRKAXIS	LAB	0	0	0.1
B_LAB_Y	LCRKAXIS	LAB	0	0.1	0
B_LAB_X	LCRKAXIS	LAB	0.1	0	0
B_LAB_Z_R	RCRKAXIS	LAB	0	0	0.1
B_LAB_Z_R	RCRKAXIS	LAB	0	0.3	0
B_LAB_Z_R	RCRKAXIS	LAB	0.1	0	0

We can now define our first **segments**.

Segment	Proximal Joint	Distal Joint	Extra Signal	Tracking Signals
Right Pedal 1	Lateral: VRPED3_0 Radius:0.07	lateral: RPED2 Radius:0.07	Medial: RPENDANT	MRPED1, RPED2, RPED3
Left Pedal 1	Lateral: VLPED3_0 Radius:0.07	lateral: LPED2 Radius:0.07	Medial: LPENDANT	MLPED1, LPED2, LPED3
Bike_Lab	Joint Center: B_LAB_Z Radius:0.07	Joint center: LCRKAXIS Radius:0.01	Anterior: B_LAB_Y	B_LAB_Z, B_LAB_Y, B_LAB_X, LCRKAXIS
R_Bike_Lab	Joint Center: B_LAB_Z_R Radius:0.07	Joint center: RCRKAXIS Radius:0.01	Anterior: B_LAB_Y_R	B_LAB_Z_R, B_LAB_Y_R, B_LAB_X_R, RCRKAXIS
AXIS	Joint Center: RCRKAXIS Radius:0.1	Joint center: CRANK_Z Radius:0.01	Medial: LCRKAXIS	Check **Use Calibration signals for Tracking**

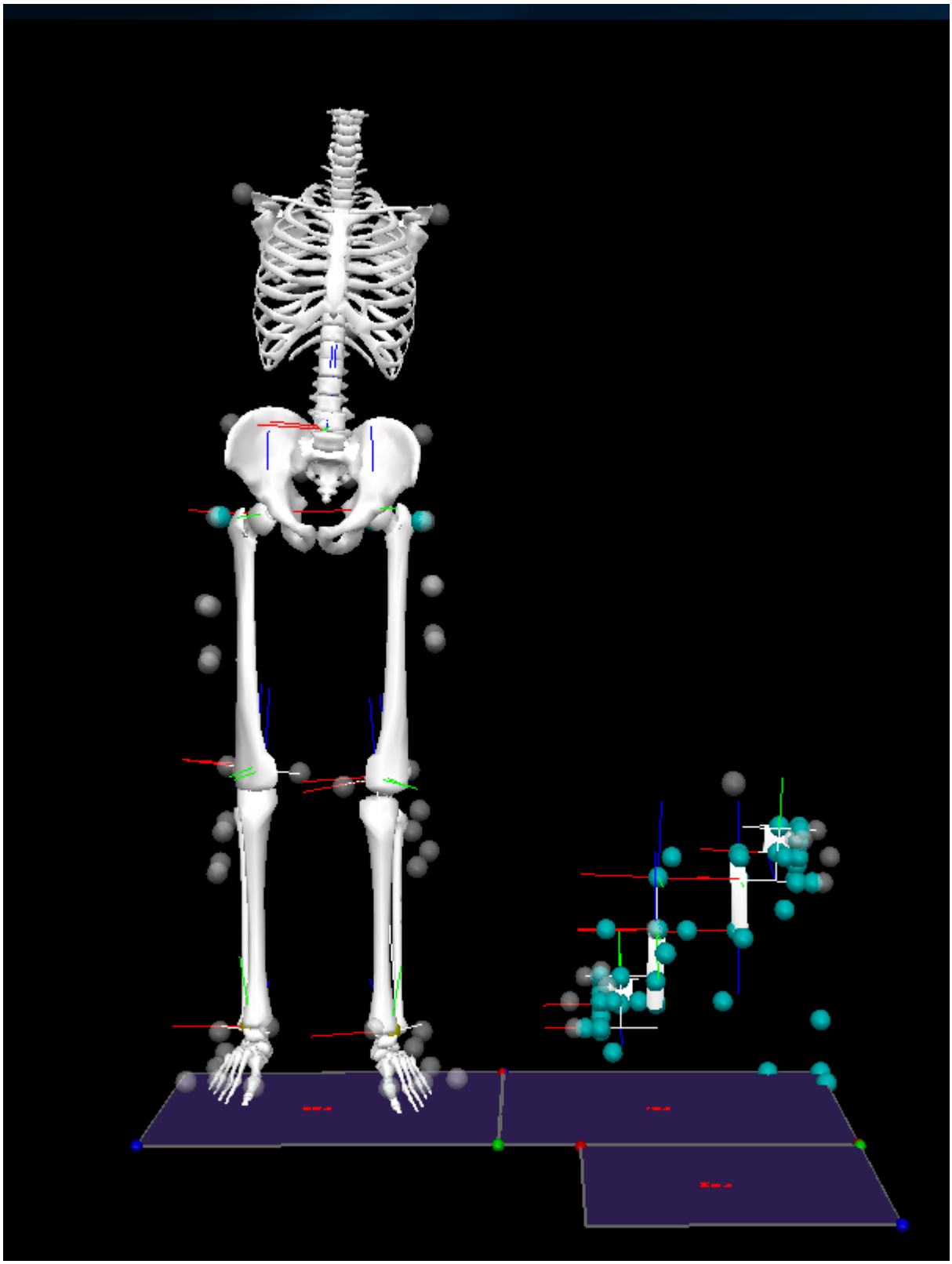
We can now define the next group of **Landmarks** built using the segments created above.

Landmark	Starting Point	Existing Coordinate System	ML Offset	AP Offset	AXIAL Offset
VRPED1_Z	VRPED1	Right Pedal 1	0	0.21	0
VRPED2_Z	VRPED2	Right Pedal 1	0	0.21	0
VRPED3_Z	VRPED3	Right Pedal 1	0	0.21	0
VLPED1_Z	VLPED1	Left Pedal 1	0	0.21	0
VLPED1_Z	VLPED2	Left Pedal 1	0	0.21	0
VLPED1_Z	VLPED3	Left Pedal 1	0	0.21	0
MRPED1_Z	MRPED1	Right Pedal 1	0	0.21	0
MLPED1_Z	MLPED1	Left Pedal 1	0	0.21	0
VRPED1_Z_X	VRPED1_Z	Right Pedal 1	-0.38	0	0
VRPED2_Z_X	VRPED2_Z	Right Pedal 1	-0.38	0	0
VLPED1_Z_X	VLPED1_Z	Left Pedal 1	-0.38	0	0
VLPED2_Z_X	VLPED2_Z	Left Pedal 1	-0.38	0	0

We now have all the required Landmarks to define the final 4 **segments**.

Segment	Proximal Joint	Distal Joint	Extra Signal	Tracking Signals	
Right Pedal	Joint Center: VRPED1_Z_X Radius:0.038	lateral: VRPED2_Z_X Radius:0.038	Lateral: VRPED1	MRPED1_Z, RPED2, RPED3	0.01
Left Pedal	Joint Center: VLPED1_Z_X Radius:0.038	lateral: VLPED2_Z_X Radius:0.038	Lateral: VLPED1	MLPED1_Z, LPED2, LPED3	0.01
Right Crank	Joint Center: RCRKAXIS Radius:0.01	lateral: MRPED1 Radius:0.01	Lateral: RPED1	MRPED1, RCRKAXIS, RPED1	0.01
Left Crank	Joint Center: LCRKAXIS Radius:0.01	lateral: MLPED1 Radius:0.01	Lateral: LPED1	MLPED1, LCRKAXIS, LPED1	0.01

You should now have all the landmarks and segments built for your model and you human and bike model should resemble the following.



Once your model is complete you should save the model template for future use. This is done by selecting **Save Model Template File**  and enter the desired name and file location. This model template can be applied to future dynamic trials with the same marker set-up. To apply a premade template follow the steps above to build a model from your static trial but once loaded select **Load Model Template**  and add your desired tempalte.

Force Processing

Force data from bikes is often imported using analog signals not force plates. Data requires processing to interpret. The following steps will show the command pipeline used for this process. The completed pipeline can also be downloaded here. Not there are values specific to this data such as variable names and lever arms based on pedal size that will need to be changed based on the specific data.

The original force data is very noisy so a low-pass filter is used to smooth the data. The command **Lowpass_Filter** can be under **Signal Filter** press » to add to your pipeline.

```
Lowpass_Filter
/SIGNAL_TYPES= ANALOG
! /SIGNAL_FOLDER=ORIGINAL
! /SIGNAL_NAMES=
! /RESULT_FOLDER=PROCESSED
! /RESULT_SUFFIX=
! /FILTER_CLASS=BUTTERWORTH
 /FREQUENCY_CUTOFF=6.0
 /NUM_REFLECTED=6
! /NUM_EXTRAPOLATED=0
/TOTAL_BUFFER_SIZE=20
! /NUM_BIDIRECTIONAL_PASSES=1
;
```

Once smoothed the **Evaluate_Expression** command can be used to determine the Force in each pedal before using the **Transform_Data_Coordinate_System** to convert force values to the Lab.

Force

/Right

```
Evaluate_Expression
/EXPRESSION=
VECTOR((-1.0*ANALOG::PROCESSED::Force.Fx_2),((1.0*ANALOG::PROCESSED::Force.F
y_3)+(1.0*ANALOG::PROCESSED::Force.Fy_4)),((1.0*ANALOG::PROCESSED::Force.Fz_
3)+(1.0*ANALOG::PROCESSED::Force.Fz_4)))
/SIGNAL_TYPES=ANALOG
! /SIGNAL_FOLDER=PROCESSED
/SIGNAL_NAMES=Force.Fx_2+Force.Fy_3+Force.Fy_4+Force.Fz_3+Force.Fz_4
! /SIGNAL_COMPONENTS=
! /RESULT_TYPES=DERIVED
/RESULT_FOLDERS=FORCE_RIGHT
/RESULT_NAME= FORCE
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=FALSE
;
```

```
Transform_Data_Coordinate_System
/SIGNAL_TYPES= DERIVED
/SIGNAL_FOLDER=FORCE_RIGHT
/SIGNAL_NAMES= FORCE
! /FROM_SEGMENT_CS= Right Pedal
/TO_SEGMENT_CS= LAB
/RESULT_TYPES= DERIVED
/RESULT_FOLDERS= FORCE_LAB_RIGHT
!/RESULT_NAME=
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=TRUE
/ORIENTATION_ONLY=TRUE
! /USE_DATA_RATE=FALSE
;

============
/Left
============

Evaluate_Expression
/EXPRESSION=
VECTOR((-1.0*ANALOG::PROCESSED::Force.Fx),((1.0*ANALOG::PROCESSED::Force.Fy)
+(1.0*ANALOG::PROCESSED::Force.Fy_2),((1.0*ANALOG::PROCESSED::Force.Fz)+(1.0
*ANALOG::PROCESSED::Force.Fz_2)))
/SIGNAL_TYPES=ANALOG
! /SIGNAL_FOLDER=PROCESSED
/SIGNAL_NAMES=Force.Fx+Force.Fy+Force.Fy_2+Force.Fz+Force.Fz_2
! /SIGNAL_COMPONENTS=
! /RESULT_TYPES=DERIVED
/RESULT_FOLDERS=FORCE_LEFT
/RESULT_NAME= FORCE
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=FALSE
;

Transform_Data_Coordinate_System
/SIGNAL_TYPES= DERIVED
/SIGNAL_FOLDER=FORCE_LEFT
/SIGNAL_NAMES= FORCE
! /FROM_SEGMENT_CS= Left Pedal
/TO_SEGMENT_CS= LAB
/RESULT_TYPES= DERIVED
/RESULT_FOLDERS= FORCE_LAB_LEFT
!/RESULT_NAME=
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=TRUE
/ORIENTATION_ONLY=TRUE
! /USE_DATA_RATE=FALSE
;
```

In order to change the force assignments the **Center Of Pressure** and **Freemoment** for each pedal are also required. First we must compute the moment, followed by the **COP** and finally the

Freemoment.

Moment

Note that the decimal coefficients are lever arm measurements that will change based on pedal size.

```
============
/Right
============

Evaluate_Expression
/EXPRESSION=VECTOR((0.02845*DERIVED::FORCE_RIGHT::FORCE::Y),((0.01945*ANALOG
::PROCESSED::Force.Fz_4-0.01945*ANALOG::PROCESSED::Force.Fz_3)-0.02845*ANALO
G::PROCESSED::Force.FX_2),((0.01945*ANALOG::PROCESSED::Force.Fy_4-0.01945*AN
ALOG::PROCESSED::Force.Fy_3)))
/RESULT_NAME=MOMENT
/RESULT_TYPE=DERIVED
/RESULT_FOLDER=FORCE_RIGHT
;

============
/Left
============

Evaluate_Expression
/EXPRESSION=VECTOR((0.02845*DERIVED::FORCE_LEFT::FORCE::Y),
((-0.01945*ANALOG::PROCESSED::Force.Fz +
0.01945*ANALOG::PROCESSED::Force.Fz_2) -
0.02845*ANALOG::PROCESSED::Force.FX), ((0.01945*ANALOG::PROCESSED::Force.Fy
- 0.01945*ANALOG::PROCESSED::Force.Fy_2)))
/RESULT_NAME=MOMENT
/RESULT_TYPE=DERIVED
/RESULT_FOLDER=FORCE_LEFT
;
```

Center Of Pressure

```

============
/Right
============

Evaluate_Expression
/EXPRESSION=VECTOR((-1 * DERIVED::FORCE_RIGHT::MOMENT::Y /
DERIVED::FORCE_RIGHT::FORCE::Z), (DERIVED::FORCE_RIGHT::MOMENT::X /
DERIVED::FORCE_RIGHT::FORCE::Z), (0.0*analog::processed::Force.Fx_2))
/RESULT_NAME=COP
 /RESULT_TYPE=DERIVED
 /RESULT_FOLDER=FORCE_RIGHT
```

```
;

Transform_Data_Coordinate_System
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=COP
/SIGNAL_FOLDER=FORCE_RIGHT
/FROM_SEGMENT_CS=Right Pedal
/TO_SEGMENT_CS=Lab
/RESULT_TYPE=Derived
/RESULT_FOLDER=FORCE_LAB_RIGHT
/RESULT_SUFFIX=
/ORIENTATION_ONLY=FALSE
! /USE_DATA_RATE=FALSE
;

============
/Left
============

Evaluate_Expression
/EXPRESSION=VECTOR((-1*DERIVED::FORCE_LEFT::MOMENT::Y /
DERIVED::FORCE_LEFT::FORCE::Z), (DERIVED::FORCE_LEFT::MOMENT::X /
DERIVED::FORCE_LEFT::FORCE::Z), (0.0*analog::processed::Force.Fx))
/RESULT_NAME=COP
 /RESULT_TYPE=DERIVED
 /RESULT_FOLDER=FORCE_LEFT
;

Transform_Data_Coordinate_System
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=COP
/SIGNAL_FOLDER=FORCE_LEFT
/FROM_SEGMENT_CS=Left Pedal
/TO_SEGMENT_CS=Lab
/RESULT_TYPE=Derived
/RESULT_FOLDER=FORCE_LAB_LEFT
/RESULT_SUFFIX=
/ORIENTATION_ONLY=FALSE
! /USE_DATA_RATE=FALSE
;
```

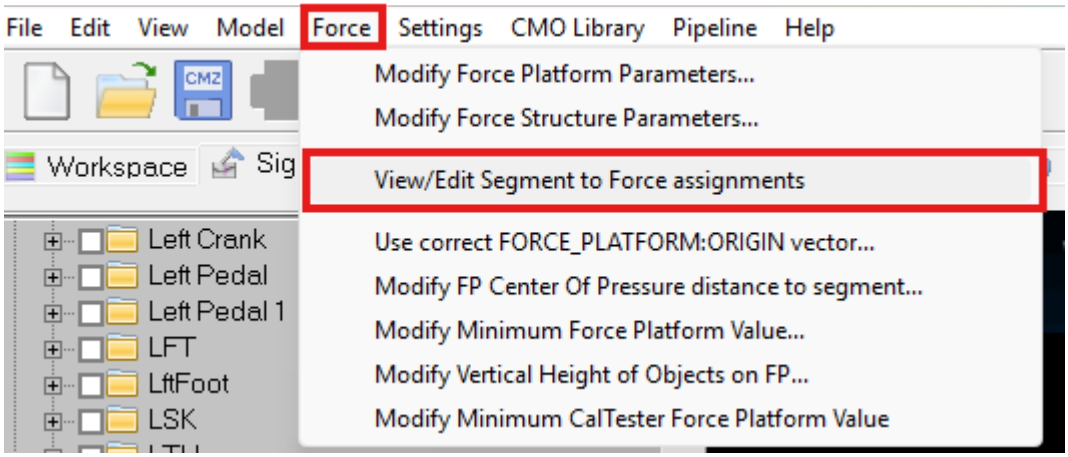
Freemoment

```
============
/Right
============

Evaluate_Expression
```

```
/EXPRESSION=VECTOR((0.0*analog::processed::Force.Fx_2),(0.0*analog::processe
d::Force.Fy_3),(Derived::FORCE_RIGHT::MOMENT::Z -
Derived::FORCE_RIGHT::FORCE::Y * Derived::FORCE_RIGHT::COP::X +
Derived::FORCE_RIGHT::FORCE::X * Derived::FORCE_RIGHT::COP::Y))
/RESULT_NAME=FREEMOMENT
 /RESULT_TYPE=DERIVED
 /RESULT_FOLDER=FORCE_RIGHT
;

Transform_Data_Coordinate_System
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=FREEMOMENT
/SIGNAL_FOLDER=FORCE_RIGHT
/FROM_SEGMENT_CS=Right Pedal
/TO_SEGMENT_CS=Lab
/RESULT_TYPE=Derived
/RESULT_FOLDER=FORCE_LAB_RIGHT
/RESULT_SUFFIX=
/ORIENTATION_ONLY=TRUE
! /USE_DATA_RATE=FALSE
;

============
/Left
============
Evaluate_Expression
/EXPRESSION=VECTOR((0.0*analog::processed::Force.Fx),(0.0*analog::processed:
:Force.Fy),(Derived::FORCE_LEFT::MOMENT::Z - Derived::FORCE_LEFT::FORCE::Y *
Derived::FORCE_LEFT::COP::X + Derived::FORCE_LEFT::FORCE::X *
Derived::FORCE_LEFT::COP::Y))
/RESULT_NAME=FREEMOMENT
 /RESULT_TYPE=DERIVED
 /RESULT_FOLDER=FORCE_LEFT
;

Transform_Data_Coordinate_System
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=FREEMOMENT
/SIGNAL_FOLDER=FORCE_LEFT
/FROM_SEGMENT_CS=Left Pedal
/TO_SEGMENT_CS=Lab
/RESULT_TYPE=Derived
/RESULT_FOLDER=FORCE_LAB_LEFT
/RESULT_SUFFIX=
/ORIENTATION_ONLY=TRUE
! /USE_DATA_RATE=FALSE
;
```

Modifying Force Assignments

With all values calculated the force assignments for the Right and Left feet can be set. Select **Add/Modify Segment Assignment To Force** under the **Force** tab in the upper toolbar.



Select **Add Segment Assignment** and enter the following values. Change the end frame to the last frame in your specific trial.