Data File Contents for CMULTIS Data Collection

User Manual

2017

Table of Contents

1. Revision History

Revision	Date	Name	Comment
A	2-20-2017	E. Morrill/T. Bonner	Created

2. Purpose

This document was created for the CoBi Core MULTIS Data Collection system for *in vitro* testing. It explains the contents of configuration and data files for this specific project.

3. Data File Organization

Within the MULTIS Data test cell folder, folders exist corresponding to subject IDs with a convention of CMUTLISXXX-Y, where XXX is auto incremented unique for each subject and Y is a number starting at 1 and auto incremented if the operator chooses to retest the subject ~-2, -3, etc. Included in every subject folder are a Configuration and a Data folder. The Data folder includes a TDMS file for every experiment run collected with the following naming convention:

"Experiment Run Number"_"Subject ID"_"Limb Segment"_"Location"_"Test Type"-"Trial Number Index".tdms.

In the Configuration folder, sensor and state configuration files exist for every experiment run with the following respective naming conventions:

"Experiment Run Number"_"Subject ID"_"Limb Segment"_"Location"_"Test Type"-"Trial Number Index"_"Configuration File Type".cfg.

Also in the Configuration folder is a subject configuration file in XML format. The file name is CMULTISXXX-Y.xml.

Where:

- Experiment Run Number: 3 digit number that gets auto-incremented for each tdms file (order in which data is collected for each specimen)
- Subject ID
- Limb Segment: UA = Upper Arm, UL = Upper Leg, LA = Lower Arm, LL = Lower Leg
- Location: Two letters. First Letter - (A)nterior, (P)osterior, (M)edial, (L)ateral. Second Letter - (P)roximal, (D)istal, (C)entral.
- Test Type: I = Indentation, A = Anatomy (no indentation)
- Trial Number Index: auto-incremented for each trial. i.e. if the location is tested more than once the subsequent data files will be -2, -3, etc.
- Configuration File Type: Sensor or State
- Example Data File Name: 034_CMULTIS033-2_UA_AP_I-4.tdms
- Example Sensor Configuration File Name: 034_CMULTIS033-2_UA_AP_I-4_Sensor.cfg
  Example State Configuration File Name: 034_CMULTIS033-2_UA_AP_I-4_State.cfg

4. Sensor Configuration File Description

The sensor file is a .ini configuration file with three sensors included. Each sensor has properties that are used in the sensor readings. An explanation of important properties are described.

Digitizer

The digitizer is a 3D marker sensor for the NDI Optotrak system.

Properties

1. Optotrak Data Index
   This refers to the index in which the physical sensor is plugged into the strober.
2. Marker Name
   This is the name that the sensor is defined as in the Optotrak configuration
3. Units
   This will be in millimeters (10218 corresponds to millimeters)
4. Channel Names
   The channel names describe the position for each respective channel in the Optotrak global coordinate system.

Femur

The Femur is a 6D rigid body sensor for the NDI Optotrak system. This is the most recently measured position of the motion tracking sensor on the femur, in the native (WORLD1) reference frame.

Properties

1. Optotrak 6D Data Index
   This refers to the index in which the physical sensor is plugged into the strober.
2. Displacement Units
   This will be in millimeters (10218 corresponds to millimeters)
3. Rotation Units
   This will be in degrees (10146 corresponds to degrees)
4. Channel Names
   The channel names describe the position for each respective channel in the Optotrak global coordinate system, where (r)oll is a rotation about the x-axis, (p)itch is a rotation about the yaxis and ya(w) is a rotation about the z-axis.

Load Cell

The Load Cell is an analog sensor with 6 channels. The load cell signals are sent to LabVIEW as individual strain gage voltages. The properties described are necessary for converting the load cell's raw strain gage voltages into units of forces and torques.

Properties

1. DAQmx Physical Channel(s)
   This describes the actual channels in the NI USB-6289 DAQ system that will be read for this sensor
2. PreScaled Units
   This will be in volts (10348 corresponds to Volts)
3. Scaled Force Units
   This will be in Newtons (15875 corresponds to Newtons)
4. Scaled Torque Units
   This will be in Newton-Meters (15881 corresponds to Newton-meters)
5. Calibration Matrix
   This calibration matrix was provided by ATI and should be used with the appropriate load cell and signal processing box. The matrix is 6X6. When the matrix is multiplied by the raw strain gage voltages in the PreScaled units, the output will be force and torque data in the scaled units
6. Offset (Scaled Units)
   These offset values are subtracted from the scaled force torque data. These values are essentially the result of taring the load cell
7. Channel Names
   The channel names describe the loads for each respective channel in the reference frame of the load cell

Name: Orientation Sensor

The orientation sensor is a digitized 6 channel sensor, though only the last three channels have non-zero values. This is due to the sensor being treated as a 6 degree of freedom sensor even though it can only measure orientations (not positions). Euler angles are used to describe the orientation.

Properties

1. Displacement Units
   This will be in meters (10219 corresponds to m)
2. Rotation Units
   This will be in radians (10273 corresponds to radians)
3. Channel Names
   The channel names describe each respective channel in the reference frame of the orientation sensor where (r)oll is a rotation about the x-axis, (p)itch is a rotation about the yaxis and ya(w) is a rotation about the z-axis.

Name: Run Number Pulse Train

The Run Number Pulse Train is a single channel analog input that was directly converted from a digital output that was created from the same LabVIEW software that is reading the input.

Properties

1. Measurement Type
   Because this is a required property, something needs to be in place for this property. Even though force was chosen, force is *not* being measured by this sensor. We are simply measuring a voltage.
2. DAQmx Physical Channel(s)
   This describes the actual channels in the NI USB-6289 DAQ system that will be read for this sensor
3. Scale.PreScaled Units
   This will be in volts (10348 corresponds to Volts)
4. Scale.Scaled Force Units
   This will also be in volts (10348 corresponds to Volts)
5. Scale Range
   This includes the voltage range. Since the signal isn't being converted, the max and min volts and the max and min scale should be equal to each other. For this sensor, the range will be -5 to 5 Volts.

Tibia

The Tibia is a 6D rigid body sensor for the NDI Optotrak system. This is the most recently measured position of the motion tracking sensor on the tibia, in the native (WORLD1) reference frame.

Properties

1. Optotrak 6D Data Index
   This refers to the index in which the physical sensor is plugged into the strober.
2. Displacement Units

This will be in meters (10218 corresponds to mm)

3. Rotation Units

   This will be in radians (10146 corresponds to degrees)

4. Channel Names

   The channel names describe the position for each respective channel in the Optotrak global coordinate system, where (r)oll is a rotation about the x-axis, (p)itch is a rotation about the yaxis and ya(w) is a rotation about the z-axis.

US Probe

The US probe is a 6D rigid body sensor for the NDI Optotrak system. This is the most recently measured position of the motion tracking sensor of the ultrasound probe in the native (WORLD1) reference frame.

<u>Properties</u>

1. Optotrak 6D Data Index

   This refers to the index in which the physical sensor is plugged into the strober.

2. Displacement Units

   This will be in millimeters (10218 corresponds to millimeters)

3. Rotation Units

   This will be in degrees (10146 corresponds to degrees)

4. Channel Names

   The channel names describe the position for each respective channel in the Optotrak global coordinate system, where (r)oll is a rotation about the x-axis, (p)itch is a rotation about the yaxis and ya(w) is a rotation about the z-axis.

5. State Configuration File Description

The state file is a .ini configuration file with two states included. Each state has properties that are used in the sensor readings. An explanation of important properties are described.

6-DOF Load

The 6-DOF Load state is a 6 channel state that describes the reaction loads applied to the skin at the tip of the ultrasound probe after the weight of the probe has been compensated for.

1. Static Transformation Matrix- T_REF_LOAD

   This is a static transformation matrix describing the position and orientation of the load cell relative to the ultrasound tip. This matrix was calculates from probed points on the solidworks model of the instrumented probe. Depending on whether the 9L4 or the 14L5 is being used, this matrix will be different. The inverse of this matrix is used to transform the load cell sensor data to the ultrasound tip coordinate system.

2. Gravity Vector

This vector describes what direction is gravity relative to how the world is defined. In this case, the world is defined by the orientation sensor. The positive z-axis of the world is aligned with gravity, so the gravity vector is [0 0 1].

3. Gravity Compensation
   This is a boolean. A true value means that the mass of the ultrasound will be compensated for in force torque measurements
4. Center of Mass in Load Cell CS (mm)
   This defines the x, y and z coordinates of the center of mass of the ultrasound probe in the load cell reference frame.
5. Load Cell Mass (N)
   This is the calculated mass of the ultrasound probe to be compensated for
6. Load Cell Data Array
   This is a 6X60 array of load cell collections that map to the Load Cell Position wrt World array.
7. Load Cell Position wrt World
   This is a 6X60 array of load cell positions wrt world collections that map to the Load Cell Data array. These two arrays are used in an optimization that calculates the mass, center of mass and load cell offsets based off the of the collections.
8. Included Sensors
   This includes the names of the sensors by which measurements should be processed in the state calculation. In this case, only the Load Cell sensor is included.
9. Included States
   This includes the names of the states by which measurements should be processed in the state calculation. In this case, the Load Cell Position 2 RB state is included.
10. Channel Names
    These describe the meaning of the physical loads in the Ultrasound Probe reference frame. (i.e. Fx is a force along the x-axis, My is a moment about the y-axis)
11. Channel Units
    Units are Newtons for force and Newton-Meters for torques.

Femur-Sphere Positions

The Femur-Sphere Positions state was not created to collect data but to have a means of collecting points on fiducial spheres along with the 6D femur optotrak sensor. It should only be used to collect the point cloud and the Save data option on the State Manager should be unchecked. Ten points are collected for each sphere. There are 30 collection points defined for rigid body 1, which encompasses 3 proximal femur fiducial spheres (10 points for each sphere) and 30 collection points defined for rigid body 2, which encompasses 3 distal femur fiducial spheres (10 points for each sphere).

1. Included Sensors

   This includes the names of the sensors by which measurements should be processed in the state calculation. In this case, the Femur sensor is included for both rigid bodies.

1. Rigid Body(s)

   Two rigid bodies are defined (proximal (1) and distal (2) femur). Both rely on the Femur sensor for position tracking.
2. Channel Names

   The channel names describe the position for each respective channel in the Optotrak global coordinate system. Only the x, y, and z position are relevant for sphere registration.
3. Channel Units

   Units are mm for displacement and degrees for rotation.
4. Collected Points

   Digitized global position of point on outer surface of the respective sphere (x,y,z).
5. Collected Points Position Sensor

   Position from the Femur Optotrak sensor output in the global (WORLD 1) reference frame.

Load Cell Position 2 RB

The Load Cell Position 2 RB state is a 6 channel state that describes the location of the load cell with respect to the world. In this case, we can only really know orientation and not position due to limitations of the orientation sensor. There are a lot of properties of this class that are not necessary for calculating the state. These properties exist for more elaborate and complicated setups. Matrices that are not being used will be defined as identity and collected points will all be zeros. The important properties used for calculating the state are described.

1. T_Sensor2_RB2

   This is a static transformation matrix describing the position and orientation of the load cell relative to the orientation sensor. This matrix was calculated from probed points on the solidworks model of the instrumented probe. This matrix transforms the orientation sensor data to the load cell coordinate system so that the orientation of the load cell relative to a world can be calculated.
2. Included Sensors

   This includes the names of the sensors by which measurements should be processed in the state calculation. In this case, only the orientation sensor is included.

Probe-Femur Position

The Probe-Femur Position state defines the relative relationship between the Femur and Ultrasound Probe.

1. Included Sensors

This includes the names of the sensors by which measurements should be processed in the state calculation. In this case, the femur and ultrasound sensors are included.

2. Rigid Body(s)
   Two rigid bodies are defined (femur (1) and ultrasound probe (2)).
3. Channel Names
   The channel names describe the position for each respective channel in the Optotrak global coordinate system.
4. Channel Units
   Units are mm for displacement and degrees for rotation.
5. Collected Points
   Digitized points associated with each rigid body. For the femur, this includes 4 points around the femoral head, and the medial and lateral femoral epicondyles. For the ultrasound probe, this includes 14 divot points on the outer probe casing.
6. Collected Points Position Sensor
   Position from the associated Optotrak sensor output in the global (WORLD 1) reference frame.
7. T_Sensor1_RB1
   Transformation matrix from femur Optotrak sensor coordinate system to femur coordinate system.
8. T_Sensor2_RB2
   Transformation matrix from ultrasound Optotrak sensor coordinate system to ultrasound coordinate system.

Probe-Tibia Position

The Probe-Tibia Position state defines the relative relationship between the Tibia and Ultrasound Probe.

1. Included Sensors
   This includes the names of the sensors by which measurements should be processed in the state calculation. In this case, the tibia and ultrasound sensors are included.
2. Rigid Body(s)
   Two rigid bodies are defined (tibia (1) and ultrasound probe (2)).
3. Channel Names
   The channel names describe the position for each respective channel in the Optotrak global coordinate system.
4. Channel Units
   Units are mm for displacement and degrees for rotation.
5. Collected Points
   Digitized points associated with each rigid body. For the tibia, this includes 4 points at the distal end, and the medial and lateral tibial plateau. For the ultrasound probe, this includes 14 divot points on the outer probe casing.
6. Collected Points Position Sensor

Position from the associated Optotrak sensor output in the global (WORLD 1) reference frame.

7. T_Sensor1_RB1
   Transformation matrix from tibia Optotrak sensor coordinate system to tibia coordinate system.
8. T_Sensor2_RB2
   Transformation matrix from ultrasound Optotrak sensor coordinate system to ultrasound coordinate system.

Table

The Table state is the position state that defines the global position of the Table (base of the cadaver fixture). This is not intended to be used to calculate state data. It should only be used to collect the point cloud and then remove it from the state manager. Points are collected in terms of both the femur and tibia.

1. Included Sensors
   This includes the names of the sensors by which measurements should be processed in the state calculation. In this case, only the Tibia and Femur sensors are included.
2. Rigid Body(s)
   Two rigid bodies are defined (femur (1) and tibia (2)).
3. Channel Names
   The channel names describe the position for each respective channel in the Optotrak global coordinate system. Only the x, y, and z position are relevant for table plane registration.
4. Channel Units
   Units are mm for displacement and degrees for rotation.
5. Collected Points
   Digitized global position of point on top surface of fixture base (x,y,z).
6. Collected Points Position Sensor
   Position from the associated Optotrak sensor output in the global (WORLD 1) reference frame.

Tibia-Sphere Positions

The Tibia-Sphere Positions state was not created to collect data but to have a means of collecting points on fiducial spheres along with the 6D tibia optotrak sensor. It should only be used to collect the point cloud and the Save data option on the State Manager should be unchecked. Ten points are collected for each sphere. There are 30 collection points defined for rigid body 1, which encompasses 3 proximal tibia fiducial spheres (10 points for each sphere) and 30 collection points defined for rigid body 2, which encompasses 3 distal tibia fiducial spheres (10 points for each sphere).

1. Included Sensors
   This includes the names of the sensors by which measurements should be processed in the state calculation. In this case, only the Tibia sensor is included.

2. Rigid Body(s)
   Two rigid bodies are defined (proximal (1) and distal (2) tibia). Both rely on the Tibia sensor for position tracking.
3. Channel Names
   The channel names describe the position for each respective channel in the Optotrak global coordinate system. Only the x, y, and z position are relevant for sphere registration.
4. Channel Units
   Units are mm for displacement and degrees for rotation.
5. Collected Points
   Digitized global position of point on outer surface of the respective sphere (x,y,z).
6. Collected Points Position Sensor
   Position from the Tibia Optotrak sensor output in the global (WORLD 1) reference frame.

6. Subject XML File Description

In the GXML Root, the Subject Data has 9 components:

Name: Subject ID

Type: String

Description: Includes the subject identifier in the format of CMULTISXXX-Y where XXX is autoincremented for each subject, starting with 001 for the first subject. Y is the repetition number, where 1 corresponds to the first test for a particular subject and ~2, ~3… corresponds to any retesting

Name: Test Date

Type: Time

Description: Includes the timestamp for when the subject was first created in the format of HH:MM:SS M/D/YEAR.

Name: Notes

Type: String

Description: This is a place holder allowing the operator to include any pertinent notes on the subject or the testing for the records.

Name: Test Type

Type: Enum (New(0) or Retest(1))

Description: This is automatically filled in as a new test for the particular subject or a retest

Name: Donor ID

Type: String (“ “)

Description: The issued donor ID. To be used to link specimens coming from the same donor.

Name: Demographics

Type: Cluster Includes:

1. Name: Age

Type: Double

Description: Subject's age in years

2. Name: Gender

Type: Enum (Male(0) or Female(1))

Description: Subject's gender

3. Name: Ethnicity

Type: Enum (Hispanic or Latino(0) or Not Hispanic or Latino(1)) Description:
Subject's ethnicity

4. Name: Race

Type: Enum (White(0), Black or African American(1), American Indian or Alaska Native(2), Asian(3), or Native Hawaiian or Other Pacific Islander(4)) Description:
Subject's Ethnicity

Name: Segment

Type: Enum (Arm(0) or Leg(1))

Description: Currently testing arm or leg?

Name: Height and Mass

Type: Cluster Includes:

1. Name: Height

Type: Cluster

Includes:

1. *Name: Magnitude*

   Type: Double

   Description: The height of the subject in the unit specified

2. *Name: Units*

   Type: Enum (cm(31))

   Description: Units are hardcoded to be centimeters for height

2. Name: Mass

Type: Cluster

Includes:

1. *Name: Magnitude*
   Type: Double
   Description: The mass of the subject in the unit specified
2. *Name: Units*
   Type: Enum (kgf(20))
   Description: Units are hardcoded to be kilograms in for mass

Name: Ultrasound File Path array

Type: 1D Cluster Array
Description: Each element includes information for each of the Ultrasound Locations included in the UltrasoundLoactions.ini file Cluster Includes:

1. Name: Ultrasound Location

Type: String
Description: The name of the location in the following format <<Number>>. <<Upper or Lower>> - <<Arm or Leg>> - <<Lateral, Medial, Anterior or Posterior>> - <<Proximal, Central or Distal>> - <<Indentation or "nothing">>
Example: "6. Lower - Arm - Anterior - Central" or "51. Upper - Leg - Posterior - Central - Indentation"

2. Name: Location File Abbreviation

Type: String
Description: Abbreviation of the ultrasound location that is included in the TDMS file name where the first letter of each letter is used
Example: Ultrasound location "6. Lower - Arm - Anterior - Central" would have an abbreviation of "LA_AC_A" and ultrasound location "51. Upper - Leg - Posterior - Central - Indentation" would have an abbreviation of "UL_PC_I"

3. Name: TDMS File Path Array

Type: 1D Cluster Array
Description: Because each ultrasound location could have more than one data collection, certain details are provided for each instance of collected data. More than one collection might occur if there is a hardware, collection or operator error.
Cluster Includes:

1. *Name: Data File Path*
   Type: Path
   Description: The path location of the data file
2. *Name: Accepted*
   Type: Boolean
   Description: At the end of a data collection, the operator can choose to accept or reject the collection.

3. *Name: Time Stamp*
   Type: Time
   Description: The time of the start of the data collection in HH:MM:SS M/D/YYYY
4. *Name: Run Number*
   Type: String
   Description: This number is auto incremented so that no two data collections for the same subject has the same run number value
5. *Name: Sensor Configuration File Path*
   Type: Path
   Description: The path location of the unique sensor configuration file that goes with the specified data collection
6. *Name: State Configuration File Path*
   Type: Path
   Description: The path location of the unique state configuration file that goes with the specified data collection
7. *Name: Ultrasound Probe*
   Type: String
   Description: Designates which of the two ultrasound probes were used, 9L4 or 14L5

4. Name: Collected

Type: Boolean

Description: This value indicates whether or not any of the data collections for the specified ultrasound location was accepted

Name: Anatomical Measurements

Type: Cluster Includes:

1. Name: Units

Type: Enum (cm(31))

Includes: all measurements are in centimeters

2. Name: Upper Arm

Type: Cluster

Includes: Seven clusters of the same type. It should be noted that a 1D cluster array would be more appropriate, however, in order to use the TAB key to quickly move through the inputs, an array would not have worked Cluster includes:

1. *Name: Description*
   Type: String
   Description: Each cluster has its own predefined description (1. Length, 2. Distal Circumference, 3. Central Circumference, 4. Proximal Circumference, 5. Shoulder

landmark to Distal Circumference, 6. Shoulder landmark to Central Circumference, 7. Shoulder landmark to Proximal Circumference)

2. *Name: Measurement*
   Type: Double
   Description: Includes the described measurement in centimeters

3. Name: Lower Arm

Type: Cluster
Includes: Seven clusters of the same type. It should be noted that a 1D cluster array would be more appropriate, however, in order to use the TAB key to quickly move through the inputs, an array would not have worked Cluster includes:

1. *Name: Description*
   Type: String
   Description: Each cluster has its own predefined description (1. Length, 2. Distal Circumference, 3. Central Circumference, 4. Proximal Circumference, 5. Elbow landmark to Distal Circumference, 6. Elbow landmark to Central Circumference, 7. Elbow landmark to Proximal Circumference)
2. *Name: Measurement*
   Type: Double
   Description: Includes the described measurement in centimeters

4. Name: Upper Leg

Type: Cluster
Includes: Seven clusters of the same type. It should be noted that a 1D cluster array would be more appropriate, however, in order to use the TAB key to quickly move through the inputs, an array would not have worked Cluster includes:

1. *Name: Description*
   Type: String
   Description: Each cluster has its own predefined description (1. Length, 2. Distal Circumference, 3. Central Circumference, 4. Proximal Circumference, 5. Hip landmark to Distal Circumference, 6. Hip landmark to Central Circumference, 7. Hip landmark to Proximal Circumference)
2. *Name: Measurement*
   Type: Double
   Description: Includes the described measurement in centimeters

5. Name: Lower Leg

Type: Cluster

Includes: Seven clusters of the same type. It should be noted that a 1D cluster array would be more appropriate, however, in order to use the TAB key to quickly move through the inputs, an array would not have worked Cluster includes:

1. *Name: Description*
   Type: String
   Description: Each cluster has its own predefined description (1. Length, 2. Distal Circumference, 3. Central Circumference, 4. Proximal Circumference, 5. Knee landmark to Distal Circumference, 6. Knee landmark to Central Circumference, 7. Knee landmark to Proximal Circumference)
2. *Name: Measurement*
   Type: Double
   Description: Includes the described measurement in centimeters

7. TDMS Data File Description

For the amount and type of data being created in the TDMS format is limited in its ability to create and organize data in a hierarchical format. It only has two levels, group and channel. Each group is described.

Root

The root includes a list of all the groups and the channels within the groups. Within the TDMS file each channel has properties (attributes) that allow the user to know how to properly interpret the temporal and magnitude information. Custom attributes can be assigned to waveform data, but the following list contains the standard set of attributes that should be in each channel. These attributes are specified in the Root of the TDMS file. For more details see http://zone.ni.com/reference/en-XX/help/371361J-01/glang/tdms_set_properties/

Property Name	**Data Type**	**Description**
name	String	Specifies the object name, such as the root name, group name, or channel name, in a .tdms file.
NI_ChannelLength	64-bitunsigned integer numeric	Represents the number of values in a channel of a.tdms file.
NI_DataType	16-bit unsigned integer numeric	Represents the data type of a channel. The value is an integer that corresponds to a LabVIEW type code.
unit_string	String	Specifies the unit of the channel data in a .tdmsfile.
wf_increment	Double	Represents the increment between two consecutive samples on the *x*-axis.

wf_samples	32-bit signed integer numeric	Represents the number of samples in the first data chunk of the waveform you write to a .tdmsfile. The value must be greater than zero.
wf_start_offset	Double	Frequency-domain data and histogram results use this value as the first value on the *x*-axis.
wf_start_time	Timestamp	Represents the time at which the waveform was acquired or generated. This property can be zero if the time information is relative or the waveform is not in time domain.
NI_ChannelName	String	Specifies the name of the waveform that was written to the channel in a .tdms file.
NI_UnitDescription	String	Specifies the units of the waveform that was written to the channel in

Experiment Run Details

Includes 7 channels.

Includes information about the experiment run that might be useful in processing.

1. Sensor file path Type: String
   Includes the path to the sensor configuration file including properties that were used to transform raw voltage data streamed into the sensor data included in the file
2. State file path
   Type: String
   Includes the path to the state configuration file including properties that were used to transform sensor and/or state data into state data
3. Ultrasound Probe
   Type: String
   Name of the ultrasound probe used (either 9L4 or 14L5)
4. Load Cell Calibration
   Type: String
   Name of the Load Cell calibration serial number. This number (either FT17991 or FT17992) determines which of two calibration matrices for the load cell is used.
5. Ultrasound Weight (N)
   Type: Double
   Ultrasound weight in Newtons based on the results of establishing orientation in the MULTIS collection software
6. Ultrasound Center of Mass (mm)
   Type: 1X3 Double
   Ultrasound center of mass in mm based on the results of establishing orientation in the MULTIS collection software

7. Load Cell Offsets (N, Nm)
   Type: 1X6 Double
   Load cell offsets in Newtons and Newton-meters based on the results of establishing orientation in the MULTIS collection software

Sensor.Femur

Type: 6XN Double

Femur Optotrak sensor position sensor in millimeters and degrees.

Channels are Femur_smart_02.x (mm), Femur_smart_02.y (mm), Femur_smart_02.z (mm), Femur_smart_02.p (deg), Femur_smart_02.r (deg), Femur_smart_02.w (deg). They represent position and orientation of the femur sensor.

Sensor.Load Cell

Type: 6XN Double

Load cell data in Newtons and Newton-meters. Raw voltage from the individual load cell strain gages are multiplied by the calibration matrix (found in the sensor configuration file) to calculate the forces and torques. Load cell offsets are subtracted from the scaled forces and torques to calculates the tared load cell values displayed.

Channels are Load Cell_Fx (N), Load Cell_Fy (N), Load Cell_Fz(N), Load Cell_Mx(Nm), Load Cell_My(Nm), and Load Cell_Mz(Nm). They represent forces and torques along or about the load cell axes.

Sensor.Orientation Sensor

Type: 6XN Double

Orientation sensor data in millimeters and degrees. The sensor cannot measure position, however, in order to consider the sensor as a 6 degree of freedom position sensor, place holder columns for positions were included. These first three columns will always be zeros. The orientation sensor data is being read in quarternions and transformed into euler angles.

Channels are Orientation Sensor_x (mm), Orientation Sensor_y (mm), Orientation Sensor_z (mm), Orientation Sensor_r (degrees), Orientation Sensor_p (degrees), Orientation Sensor_w (degrees). They represent translations (not measured) and rotations with respect to a world coordinate system. The world is defined with the z-axis aligned with the gravitational vector. The x and y axes are aligned with cardinal directions. The orientation sensor utilizes internal accelerometers and a compass to measure its orientation with respect to the world.

Sensor.Run Number Pulse Train

Type: 1XN Double

Run number pulse train is an analog input. The MULTIS data collection software generates an analog output pulse train that is base off of the experiment run number and the subject number. The digital output is converted to and input and read in the same manner as the load cell. This ensures that the load cell data and pulse train are lined up in time. No conversions or transformation occur to generate this data. It is read directly as voltage

Sensor.Tibia

Type: 6XN Double

Tibia Optotrak sensor position sensor in millimeters and degrees. Channels are Tibia_smart_02.x (mm), Tibia_smart_02.y (mm), Tibia_smart_02.z (mm), Tibia_smart_02.p (deg), Tibia_smart_02.r (deg), Tibia_smart_02.w (deg). They represent position and orientation of the femur sensor.

Sensor.US Probe

Type: 6XN Double

Ultrasound Optotrak sensor position sensor in millimeters and degrees.

Channels are US Probe_smart_02.x (mm), US Probe_smart_02.y (mm), US Probe_smart_02.z (mm), US Probe_smart_02.p (deg), US Probe_smart_02.r (deg), US Probe_smart_02.w (deg). They represent position and orientation of the femur sensor.

State.6-DOF Load

Type: 6XN Double

6-DOF Load describes the reaction loads applied to the skin at the tip of the ultrasound probe after the weight of the probe has been compensated for.

The gravitational forces and torques are calculated at the world reference frame based on the Load Cell Position 2 World orientations, the mass and the center of mass. The load cell data is also transformed to the world reference frame so that the gravitational forces and torques could be subtracted. The compensated loads are transformed back to the load cell reference frame. A static matrix describing the position and orientation of the tip of the ultrasound probe in the load cell reference frames is used to transform the compensated load cell loads to the tip of the ultrasound probe. This static matrix was calculated based on probed points on the solidworks model. A different matrix exists for each of the ultrasound probes (9L4 or 14L5). This is why the proper ultrasound probe should be loaded in the MULTIS data collection software. The static matrix can be found in the 6-DOF Load section of the state configuration file under the property name “Static Transformation Matrix- T_REF_LOAD”

Channels are 6-DOF Load Fx (N), 6-DOF Load Fy (N), 6-DOF Load Fy (N), 6-DOF Load Mx (Nm), 6DOF Load My (Nm), 6-DOF Load My (Nm).They represent external forces and torques applied to the tip of the ultrasound probe in the defined ultrasound probe coordinate system.

State.Load Cell Position 2 RB Type: 6XN Double

Load Cell Position to RB describes where the load cell is relative to the world. Only the rotational data is used. The position data is not accurate as the orientation sensor is not able to measure orientation. A static transformation matrix was calculated to describe the position and orientation of the load cell with respect to the orientation sensor. This matrix was calculated based on probed points on the solidworks model of the instrumented ultrasound and the matrix can be found in the Load Cell Position 2 RB section of the state configuration file under the property name "T_Sensor2_RB2." The orientation sensor data is transformed to the load cell coordinate system by multiplying the data by the static transformation. This orientation data collected is important because we can know the orientation of the load cell relative to gravity. This will allow for the compensation of the mass of the ultrasound.

Channels are Load Cell Position 2 RB x (mm), Load Cell Position 2 RB y (mm), Load Cell Position 2 RB z (mm), Load Cell Position 2 RB roll (degrees), Load Cell Position 2 RB pitch (degrees), Load Cell Position 2 RB yaw (degrees). They represent translations (fictitious) and rotations of the load cell with respect to a world coordinate system. The world is defined with the z-axis aligned with the gravitational vector. The x and y axes are aligned with cardinal directions. The orientation sensor utilizes internal accelerometers and a compass to measure its orientation with respect to the world.

State.Probe-Femur Position Type: 6XN Double

Probe-Femur Position describes where the ultrasound probe tip is relative to the femur coordinate system. Two static transformations were calculated to describe the position of the femur coordinate system with respect to the femur Optotrak sensor "T_Sensor1_RB1" and the position of the ultrasound probe tip coordinate system with respect to the ultrasound probe Optotrak sensor "T_Sensor2_RB2" (both transformations can be found in the state configuration file under Probe-Femur Position). The position and orientation of the ultrasound probe tip relative to the femur bone coordinate system is calculated from the static transformation matrices and the Optotrak sensor data.

Channels are Probe-Femur Position x (mm), Probe-Femur Position y (mm), Probe-Femur Position z (mm), Probe-Femur Position roll (degrees), Probe-Femur Position pitch (degrees), Probe-Femur Position yaw (degrees). They represent translations and rotations of the ultrasound probe tip with respect to the femur bone coordinate system.

State.Probe-Tibia Position Type: 6XN Double

Probe-Tibia Position describes where the ultrasound probe tip is relative to the tibia coordinate system. Two static transformations were calculated to describe the position of the tibia coordinate system with respect to the tibia Optotrak sensor "T_Sensor1_RB1" and the position of the ultrasound probe tip coordinate system with respect to the ultrasound probe Optotrak sensor “T_Sensor2_RB2” (both transformations can be found in the state configuration file under Probe-Tibia Position). The position and orientation of the ultrasound probe tip relative to the tibia bone coordinate system is calculated from the static transformation matrices and the Optotrak sensor data.

Channels are Probe-Tibia Position x (mm), Probe-Tibia Position y (mm), Probe- Tibia Position z (mm), Probe- Tibia Position roll (degrees), Probe- Tibia Position pitch (degrees), Probe-Tibia Position yaw (degrees). They represent translations and rotations of the ultrasound with respect to the tibia bone coordinate system.