VICON

Advanced Gait Workflow Guide

Contents

Advanced Gait Workflow Guide, July 2017
For use with Vicon Nexus 2.6 and Advanced Gait Workflow 1.4.

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Introducing the Advanced Gait Workflow

Important

The Optimum Common Shape Technique (OCST)[1], Symmetrical Center of Rotation Estimation (SCoRE)[2] and Symmetrical Axis of Rotation Analysis (SARA)[3] methods are based on research publications that can be obtained from Vicon on request. As the research and validation of the values produced by these methods is a continuing effort, it is recommended that OCST, SCoRE and SARA are used for investigative and research purposes. It is the responsibility of the user to review the scientific references and understand the methods. Any use of the methods as part of a clinical assessment is strictly at the discretion of the user.

Nexus 2 introduced a new feature called **Biomechanics Workflow**. This area on the **Data Management** tab enables you to create a custom series of sequential steps that constitutes a collection protocol. These steps can automatically select aspects of Nexus for data collection and processing, including trial types, trial names, and processing pipelines.

The Advanced Gait Workflow (AGW) helps you to calculate a repeatable Hip Joint Center location using the SCoRE method, and an optimized Knee Joint Flexion Axis using the SARA method. The AGW also incorporates a mathematical approach (known as OCST) that finds the average or common shape for selected sets of markers. The OSCT method allows non-rigid arrangements of skin-based markers to be used in SCoRE and SARA calculations where rigidity is assumed. The AGW steps each have an associated step description in the **Biomechanics Workflow** area that guides you through the process from marker placement to capture and processing.

The Advanced Gait Workflow steps you through a series of trial captures and automated processes to:

- Calibrate the subject's labeling skeleton
- Calibrate the OCST pelvis, femur, and tibia segments
- Monitor the range of motion (ROM) of the hip and knee joints for SCoRE and SARA calibration
- Calibrate the SCoRE hip joint centers
- Calibrate the SARA knee flexion axes
- Capture a dynamic trial and use the calibrated OCST, SCoRE and SARA data to compute the hip joint centers and knee flexion axes for further analysis

The workflow enables you to accept the outcome of the current step and proceed to the next automatically or to reject it to repeat the step until the outcome is satisfactory. It illustrates how to use the Biomechanics Workflow and its corresponding features with the supplied AGW VSTs, but if required, you can modify it and the associated trial types, monitors and pipelines to suit your needs.

This guide describes each step in the workflow along with its outcome. It concludes by describing how to use the MATLAB Plug-in Gait scripts with the SCoRE and SARA data for further analysis.

Advanced Gait Workflow installed files

By default, the Advanced Gait Workflow files are located in the following installation folder:

C:\Program Files (x86)\Vicon\Nexus2.6\

You are given the option to change this location during the installation process.

AGW installed labeling skeleton template and marker files

The following labeling skeleton template and marker files are installed in:

<installation folder>\ModelTemplates

- PlugInGait FullBody Ai Functional.vst
- PlugInGait FullBody Ai Functional.mkr
- PlugInGait LowerBody Ai Functional.vst
- PlugInGait LowerBody Ai Functional.mkr

AGW installed pipelines

The following pipelines are installed in:

<installation folder>\Configurations\Pipelines

- AGW Static.Pipeline
- AGW LHip.Pipeline
- AGW LKnee.Pipeline
- AGW RHip.Pipeline
- AGW RKnee.Pipeline
- AGW Process.Pipeline

AGW installed trial types

The following trial types are installed in:

<installation folder>\Configurations\TrialTypes

- AGW Static.TrialTypes
- AGW LHip.TrialTypes
- AGW LKnee.TrialTypes

- AGW RHip.TrialTypes
- AGW RKnee.TrialTypes
- AGW Process.TrialTypes

AGW installed monitors

The following monitors are installed in:

<installation folder>**\Configurations\Monitors**

- AGW LHip.Monitors
- AGW LKnee.Monitors
- AGW RHip.Monitors
- AGW RKnee.Monitors

AGW installed capture workflow

The following capture workflow is installed in:

<installation folder>**\Configurations\CaptureWorkflows**

- AGW Lower Body.CaptureWorkflow

AGW installed MATLAB folder and files

The following MATLAB folder and files are installed in:

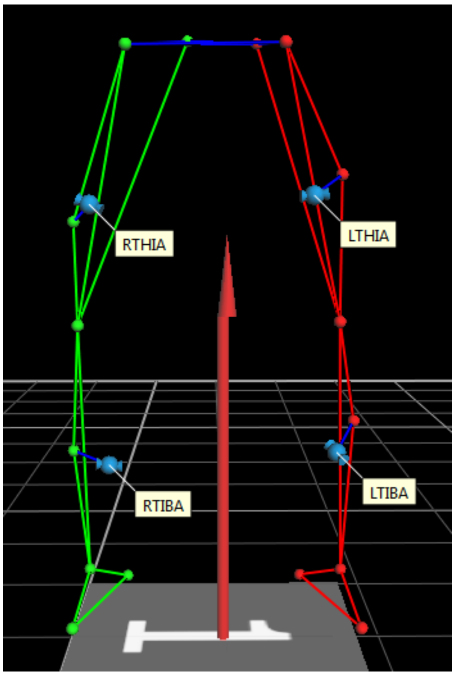
<installation folder>**\SDK\Matlab**

- + Vicon folder containing the Plug-in Gait MATLAB model
- DynamicPiG.m
- StaticPiG.m

About the PlugInGait FullBody Ai Functional VST

The **PlugInGait FullBody Ai.vst** uses the same marker set and marker locations as the legacy **PlugInGait FullBody (UPA and FRM).vst** but it has been rewritten into the new VST/VSK format to take advantage of the skeleton calibration and labeling algorithms of Nexus 2.

The **PlugInGait FullBody Ai Functional.vst** has four additional markers that are used to define independent thigh and tibia segments for SCoRE and SARA processing. (Note that this VST is just one example of the possible marker sets that can be used with SCoRE and SARA.) The additional markers include the L and R THIA, typically placed on the anterior aspect of the thigh, which combine with the THI and KNE markers to define the left and right femur OCST segments. Also the L and R TIBA markers, typically placed on the anterior aspect of the tibia, combine with the TIB and ANK markers to define the left and right tibia OCST segments. Although the exact placement of these additional markers does not necessarily correspond with anatomical landmarks, it's important that the markers form a solid geometrical relationship with the other markers on the segment to provide well-defined and stable OCST segments, as shown in the following illustration.



Preparing the subject for SCoRE and SARA and the Advanced Gait Workflow

1. Take the standard Plug-in Gait Full Body anthropometric measurements.
2. Attach the markers to the subject.
3. On the **Subjects** tab, click **Create a new subject from a Labeling Skeleton** and select **PlugInGait FullBody Ai Functional**.
4. Enter the subject's anthropometric measurements into the subject **Properties** fields.

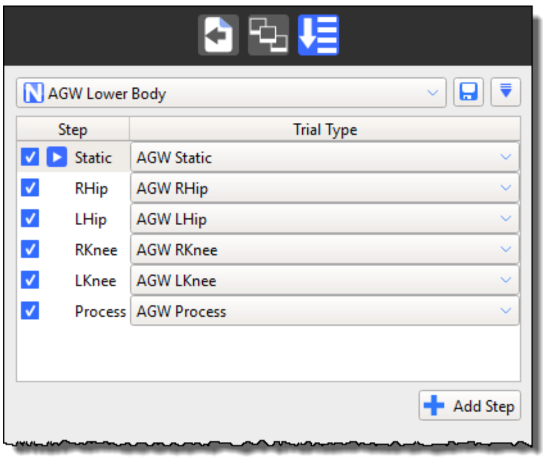
Note

These anthropometric measurements aren't used to calculate OCST/SCoRE/SARA values, however they are required for Plug-in Gait processing (standard and/or MATLAB).

Using the Advanced Gait Workflow

1. After attaching markers, have the subject enter the volume.
2. On the **Data Management** tab, click the **File Transfer/Batch Processing Interface** icon and then click the **Biomechanics Workflow** icon .
3. From the dropdown list, select **AGW Lower Body**.

   The steps are displayed in the **Biomechanics Workflow** area:



Complete the steps described in the following procedures.

Step 1: Static

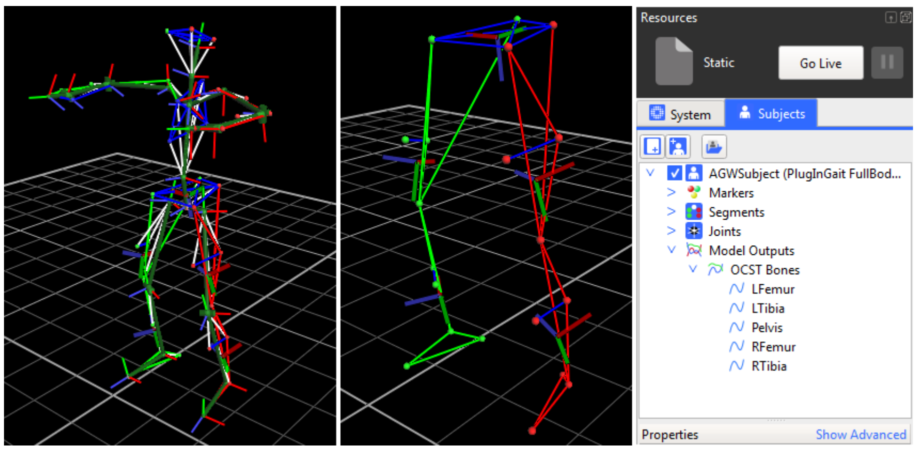
This step calibrates the subject's labeling skeleton and OCST segments from a static trial.

1. Have the subject stand in the motorbike pose and click on the first step, which is labeled **Static**. When selected, the play icon is positioned at that step, as shown in the previous illustration.
2. To initiate the capture, click **Start**.

   The **AGW Static** trial type is loaded automatically. It is set to capture a 1-second trial and run the **AGW Static** pipeline after the capture is complete. The outcome is a calibrated labeling skeleton and calibrated OCST Pelvis, RFemur, LFemur, RTibia, and LTibia segments.

3. Review the subject in the **3D Perspective** view to make sure the results are acceptable.

   The OCST local segment axes are displayed on the subject as well as written to the subject's **OCST Bones** node, in the **Model Outputs** node.



Tip

If the results look incorrect, check the **Log** tab for any error messages.

4. If the results are acceptable, click **Accept** to move on to the next step or to repeat the current step, click **Reject**.

   When you click **Accept**, the current offline trial is automatically saved, which updates the subject's **mp** file with the calibrated data.

Step 2: RHip

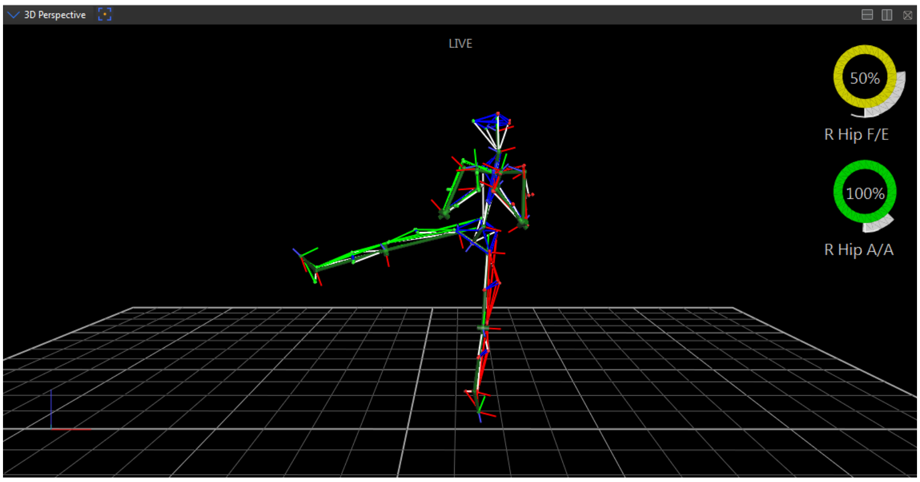
This step calibrates the right SCoRE hip joint center.

Important

To make the subject's skeleton joint data available to the range monitors, set the **Processing Output Level** property of **Local Vicon System** to **Kinematic Fit**.

1. Prepare the subject to perform a star-arc movement pattern for the right hip.
2. To initiate the capture, click **Start**.

   The **AGW RHip** trial type and the **AGW RHip** range monitor are loaded automatically. The trial type starts the capture automatically, but you must stop the capture after the hip joint has moved about all three axes through the acceptable ranges.

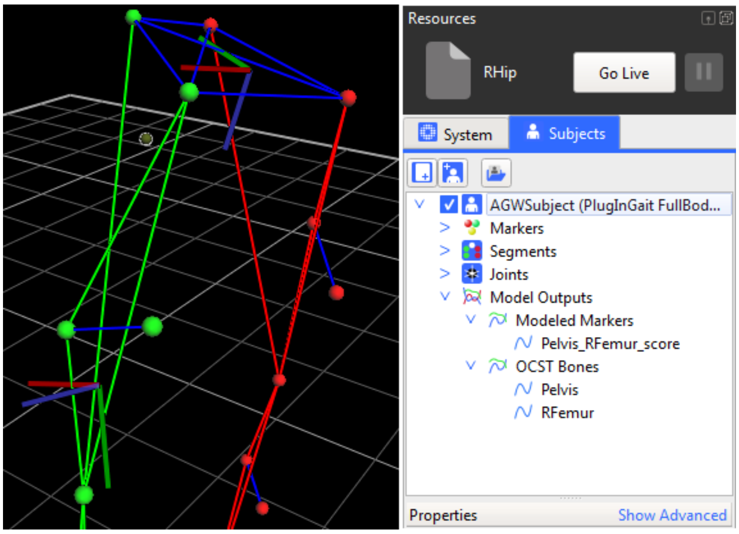


   Tip

   The axes correspond to the labeling skeleton's segment definitions, where **RHip X** is flexion/extension, **RHip Y** is internal/external rotation, and **RHip Z** is abduction/adduction. The range values defined within the monitors serve as examples, but can be modified to suit your application needs.

3. When the joint ranges have been satisfied, stop the capture manually.

The **AGW RHip** pipeline runs automatically and the outcome is a calibrated right SCoRE hip joint center. The hip joint center appears in the **3D Perspective** view as a virtual point and is added to the subject's **Modeled Markers** node in the **Model Outputs** node.



4. Review the virtual point location and the **Log** tab for errors.
5. If the results are acceptable, click **Accept** to move on to the next step or to repeat the current step, click **Reject**.

   When you click **Accept** the current offline trial is automatically saved, which updates the subject's mp file with the calibrated data.

Step 3: LHip

This step calibrates the left SCoRE hip joint center.

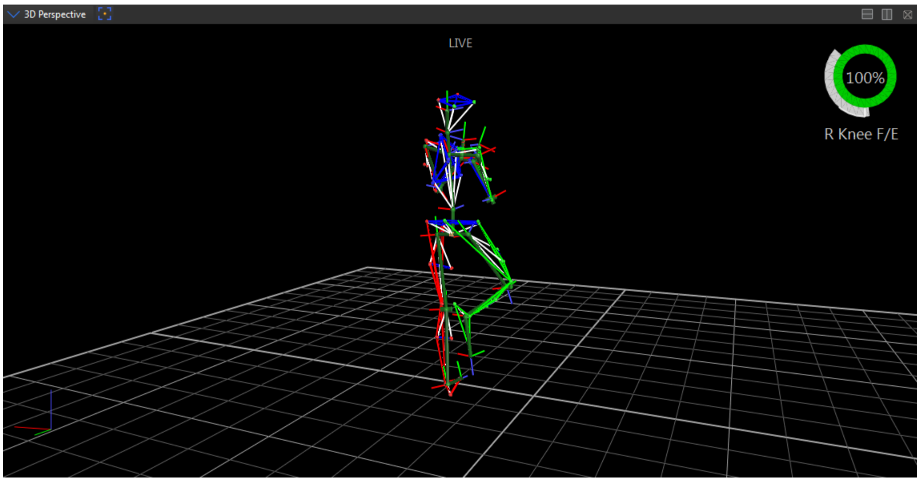
1. Prepare the subject to perform a star-arc movement pattern for the left hip.
2. Follow the same procedure as that of the right hip, but note that the **AGW LHip** trial type and the **AGW LHip** range monitor are automatically loaded.

Step 4: RKnee

This step calibrates the right knee SARA flexion axis.

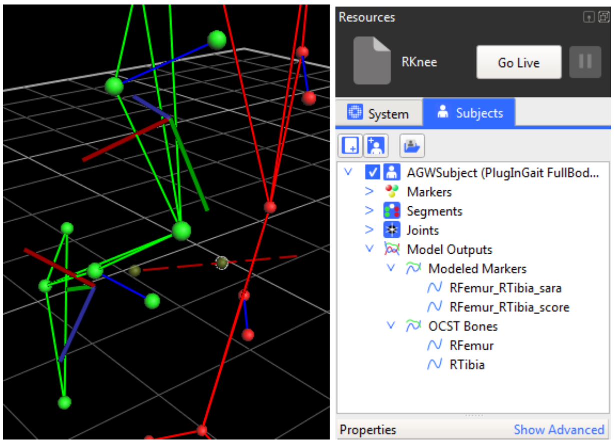
1. Prepare the subject to perform a knee flexion movement pattern for the right knee.
2. To begin capturing, click **Start**.

   The AGW RKnee trial type and the AGW RKnee range monitor are loaded automatically. The trial type starts the capture automatically, but you must stop the capture after the knee joint has moved about its flexion axis through the acceptable range.

3. When the joint range has been satisfied, stop the capture manually.

   The AGW RKnee pipeline runs automatically and the outcome is a calibrated right SARA knee flexion axis. The SCoRE knee joint center appears in the 3D Perspective view as a virtual point and is added to the subject's **Modeled Markers** node in the **Model Output** node. Because the knee joint range of motion is primarily about its flexion axis, the SCoRE joint center location is not as accurate as that of the hip. In this case, the knee joint center serves more appropriately as an endpoint of the knee flexion axis vector. The SARA knee flexion axis appears in the **3D Perspective** view as the opposite endpoint of a vector formed along with the SCoRE knee joint center. The joint axis line appears in the **3D Perspective** view. The anatomical knee joint center estimation is expected to be defined by more conventional means, such as Plug-in Gait.



4. Review the virtual point location and check the **Log** tab for any errors.
5. If the results are acceptable, click **Accept** to move on to the next step , or to repeat the current step, click **Reject**. When you click **Accept**, the current offline trial is automatically saved, which updates the subject's mp file with the calibrated data.

Step 5: LKnee

This step calibrates the left knee SARA flexion axis.

1. Prepare the subject to perform a knee flexion movement pattern for the left knee.
2. Follow the same procedure as that for the right hip, but note that the **AGW LKnee** trial type and the **AGW LKnee** range monitor are automatically loaded.

Step 6: Process

This step captures and processes a dynamic trial.

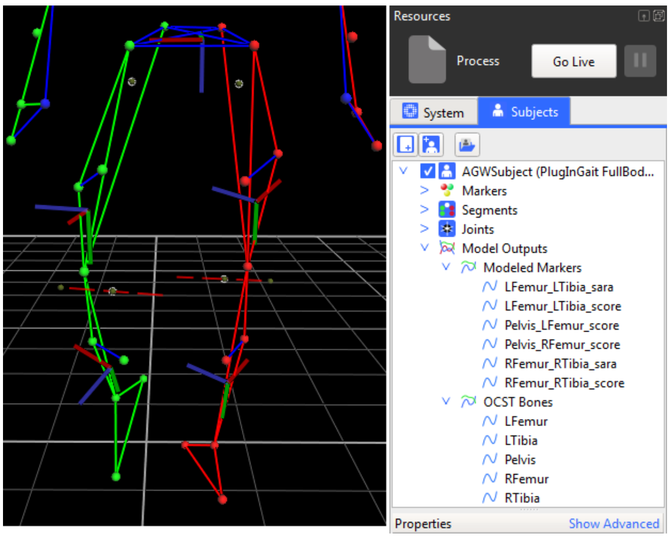
1. Prepare the subject to perform the dynamic activity.
2. Because the SCoRE and SARA calibrations are complete and there is not a range monitor associated with the dynamic capture step, at this stage, if desired, you can switch the **Processing Output Level** of **Local Vicon System** back to **Labels**.
3. To begin the capture, click **Start**.

   The AGW Process trial type is loaded and the capture starts automatically.

4. When the trial activity is complete, stop the capture.

   The **AGW Process** pipeline is run automatically and the outcome is a reconstructed and labeled trial that includes the processed SCoRE hip joint centers and the SARA knee flexion axes.

   As in the calibration steps, these calculations are represented in the **3D Perspective** view as well as in the subject's **Modeled Markers** node.



Troubleshooting reconstruction and labeling

If the captured data contains gaps or incorrect labels, you can adjust the settings of the **Combined Processing** operation, which is found in each of the installed pipelines (see Advanced Gait Workflow installed files on page 5) to improve the reconstruction and labeling of the data.

For more details on reconstruction and labeling, see the Vicon Nexus User Guide.

Processing a kinematic model using SCoRE and SARA

The SCoRE and SARA operations are solely joint calibrations and are not a full kinematic model. If you want to produce kinematic outputs (for example, Joint Angles), the Hip Joint locations and Knee flexion axes must be input into a secondary full kinematic model such as Plug-in Gait.

When the AGW is installed, a version of Plug-in Gait written in MATLAB is also installed. The remainder of this guide describes how to use this model to calculate Plug-in Gait variables that use SCoRE hip joint centers and SARA optimized knee axes as their foundation.

Using Plug-in Gait Matlab with SCoRE and SARA

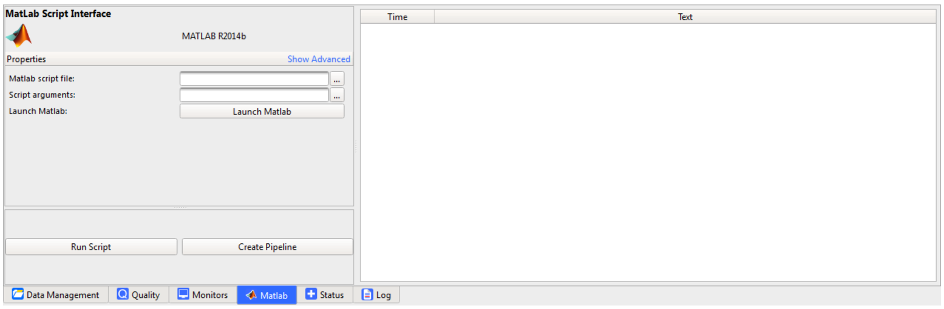
Plug-in Gait Matlab has been created for research purposes and to allow the incorporation of SCoRE and SARA within the modeling process.

Important

To run PlugInGait Matlab, you need a valid MATLAB license.

Processing static Plug-in Gait

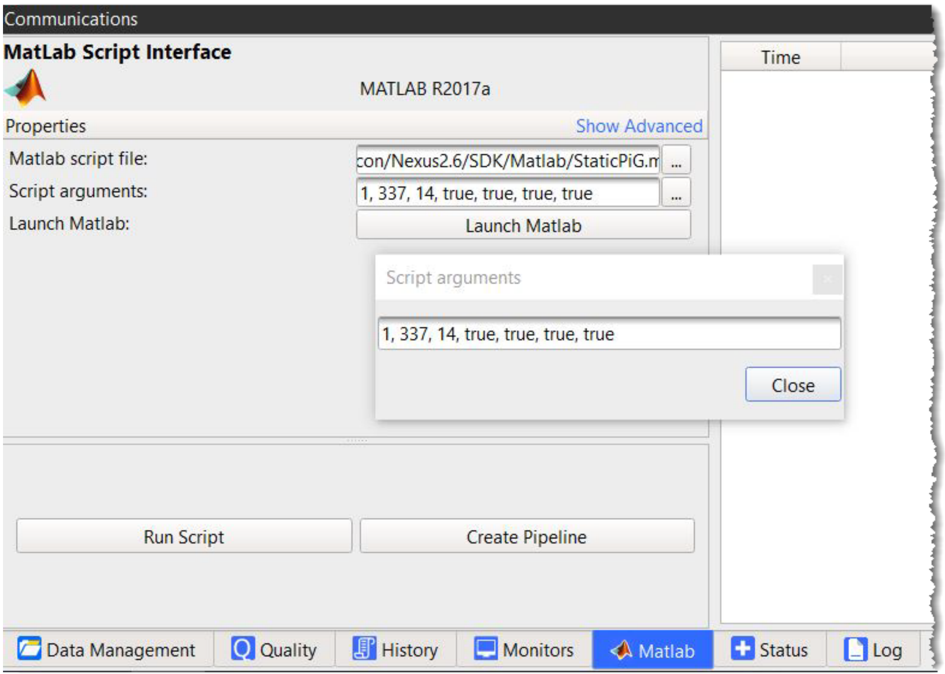
1. Load your static trial (created during Step 1: Static on page 10).
2. Run the **AGW Process** pipeline to calculate the SCoRE hip joint centers and SARA knee flexion axes outputs for the static trial.
3. Click on the **Matlab** tab.



4. In the Matlab script file field, browse to **C:\Program Files (x86)\Vicon\Nexus2.6\SDK\Matlab** and select **StaticPiG.m**
5. In the **Script arguments** field enter the following values as a comma-separated string:
   - FirstFrame (a number)
   - LastFrame (a number)
   - MarkerSize (marker size in mm)
   - bAntTiltPos (true or false)
   - bLFootFlat (true or false)
   - bRFootFlat (true or false)
   - bHeadLevel (true or false)

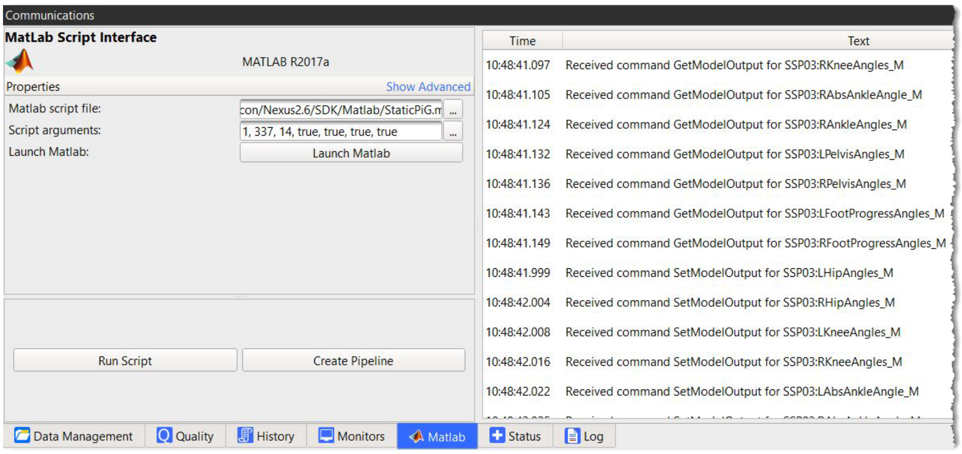
Static example:

`1, 337, 14, true, true, true, true`

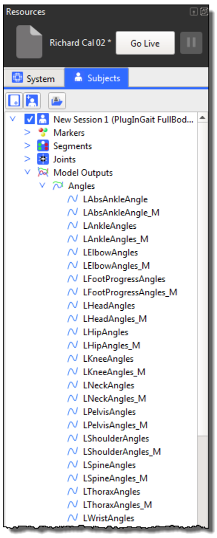


6. After you have entered all the required information, click **Run Script**.

   The log file displays the relevant feedback.



An extra set of Model Outputs are created - <AngleName>_M:



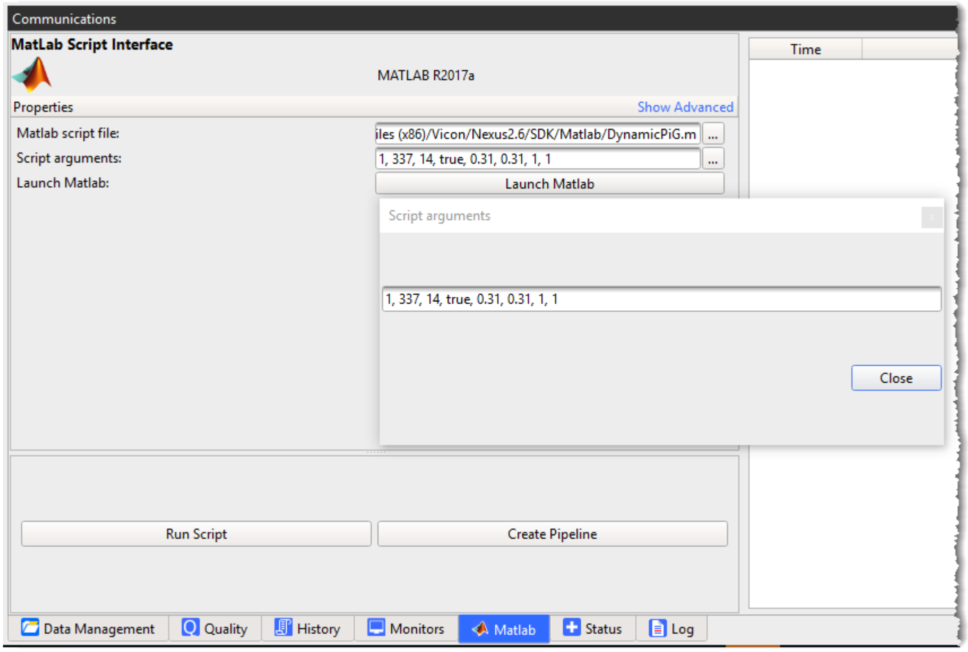
7. Save the trial.

Processing dynamic Plug-in Gait

1. Load your dynamic trial (created in Step 6: Process on page 15).
2. Click on the **Matlab** tab.
3. In the **Matlab script** file field, browse to **C:\Program Files (x86)\Vicon\Nexus2.6\SDK\Matlab** and select **DynamicPiG.m**
4. In the **Script arguments** field, enter the following values as a comma-separated string:
   - FirstFrame (a number)
   - LastFrame (a number)
   - MarkerSize (marker size in mm)
   - bAntTiltPos (true or false)
   - PelvisROG (0.31)
   - ThoraxROG (0.31)
   - ReactionFrame (a number: 0=proximal segment, 1=distal segment, 2=global frame)
   - PowerOutput (a number: 1=single value power, 3=3-component power)
   - bAllowCrossPlateStrikes (true or false, optional, default false). When this variable is set to true, Plug-in Gait combines the dynamics of foot strikes that straddle two adjacent plates.

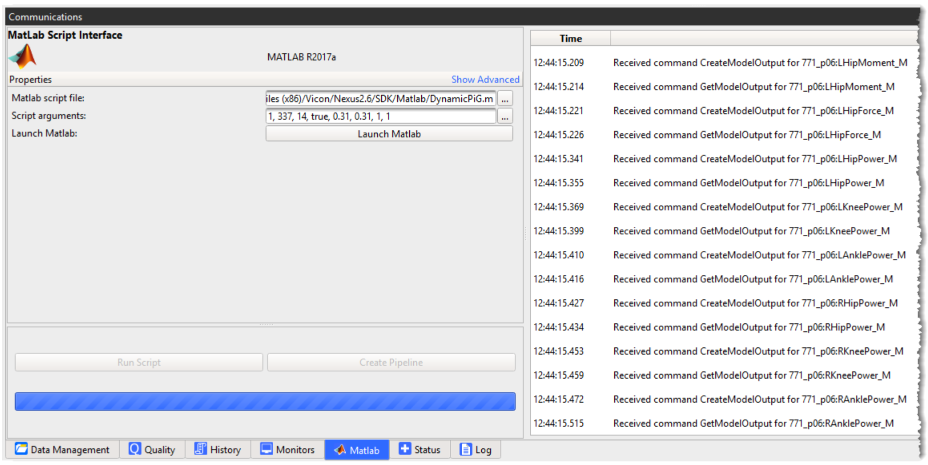
Dynamic example:

`1, 337, 14, true, 0.31, 0.31, 1, 1`

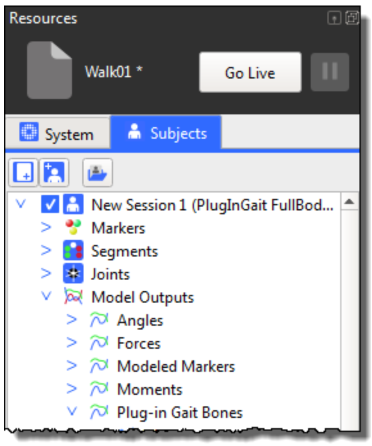


5. After you have entered all the required information, click **Run Script**.

   The **Log** file displays all the relevant feedback.



An extra set of **Model Outputs** is created: <AnglesName>_M, <ForcesName>_M, <ModeledMarkers>_M, <MomentsName>_M, <Plug-InGaitBonesName>_M, <PowerName>_M



6. Save the trial.

Research references

1. Repeatability and reproducibility of OSSCA, a functional approach for assessing the kinematics of the lower limb. W.R. Taylor, E.I. Kornaropoulos, G.N. Duda, S. Kratzenstein, R.M. Ehrig, A. Arampatzis, M.O. Heller. publ. Gait & Posture 32 (2010) 231–236
2. A survey of formal methods for determining functional joint axes. Rainald M. Ehrig, William R. Taylor, Georg N. Duda, Markus O. Heller. Journal of Biomechanics 40 (2007) 2150–2157
3. A survey of formal methods for determining the centre of rotation of ball joints. Rainald M. Ehrig, William R. Taylor, Georg N. Duda, Markus O. Heller. Journal of Biomechanics 39 (2006) 2798–2809

Contact Vicon

In addition to the documentation and the information on the Vicon Support web pages, the following resources are also available:

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