GPEM Plug-Ins for Nexus

Hand Model

Plug-in for Vicon Nexus

A GPEM implementation of the Hand Model in Vicon Nexus

USER'S GUIDE

(Version 1.1)

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Description

The aim of this guide is to show how to correctly install and use the GPEM Hand Model (HM) plugin for Vicon Nexus.
An audiovisual version is also available, check the GPEM YouTube channel for the video tutorial.
Please note that the angles computed by the HM plugin are currently not validated for clinical trials.

What is the HM?

The Hand Model is a tool written in Vicon BodyLanguage to calculate joint angles for the hand fingers. It uses a custom set of markers for the hand modeling in order to enable a full 3D description of the fingers kinematics.
The Hand Model is compatible with Vicon Nexus (version 1 and version 2).
The marker set defined is independent from the marker set defined in the Plug-in Gait upper limb section, so you can use them in conjunction and process, store, and visualize the captured and modeled HM data in Vicon Nexus alongside the Plugin Gait model. You can also generate reports in Vicon Polygon as you would for any biomechanical model.

Which options does it offer?

HM - Left:	This model provides markers configuration for the left hand only.
HM - Right:	This model provides markers configuration for the right hand only.
HM - Both:	Model for analyzing both hands.

You can use the Hand Model (left, or right, or both) on its own to obtain just the finger angles.
If you want to view these along with the standard Plug-in Gait output angles, you need to run them in conjunction.

Which are the requirements of the HM plugin?

For a correct use of this plugin you will need a valid license for Vicon Nexus.

Installing the HM plugin

The plugin works under Vicon Nexus. Before starting the installation procedure, please check your Nexus license. You can download Nexus updates at https://www.vicon.com/downloads.

Plugin installation

Launch *GPEM_HM_plugin.exe*. After completing the installation, open the Vicon Nexus software.
If you are in Live Mode, click the 'Go Offline' button, and select the Pipeline menu.
To check if the installation has completed successfully, in your 'Current Pipeline' list four new pipelines should be available:

HM_GPEM – RIGHT Hand Model Static
HM_GPEM – LEFT Hand Model Static
HM_GPEM – LEFT Hand Dynamic
HM_ GPEM – RIGHT Hand Dynamic

These pipelines will be described in the next paragraphs.

HM Subject Preparation

This section shows you the marker placement. The figures below provide right and left hand reference.

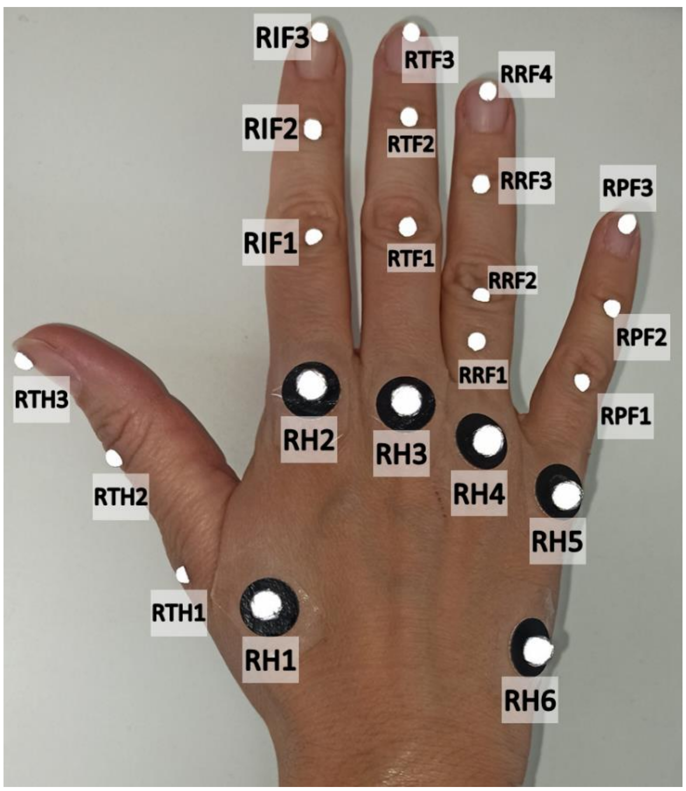


Figure 1 Right hand markers positioning

Marker Label	Definition
RH1	Base of second metacarpus - Right Hand
RTH1	Head of first metacarpus (base of thumb) - Right Hand
RTH2	Head of proximal thumb finger bone - Right Hand
RTH3	Tip of thumb finger - Right Hand
RH2	Head of second metacarpus (base of index finger) - Right Hand
RIF1	Head of proximal index finger bone - Right Hand
RIF2	Head of middle index finger bone - Right Hand
RIF3	Tip of index finger - Right Hand
RH3	Head of third metacarpus (base of third finger) - Right Hand
RTF1	Head of proximal third finger bone - Right Hand
RTF2	Head of middle third finger bone - Right Hand
RTF3	Tip of third finger - Right Hand
RH4	Head of fourth metacarpus (base of ring finger) - Right Hand
RRF1	Middle of proximal ring finger bone (position of ring) - Right Hand
RRF2	Head of proximal ring finger bone - Right Hand
RRF3	Head of middle ring finger bone - Right Hand
RRF4	Tip of ring finger - Right Hand
RH5	Head of fifth metacarpus (base of pinkie) - Right Hand
RPF1	Head of proximal pinkie finger bone - Right Hand
RPF2	Head of proximal pinkie finger bone - Right Hand
RPF3	Tip of pinkie finger - Right Hand
RH6	Base of fifth metacarpus - Right Hand

Table 1 Right hand markers positioning

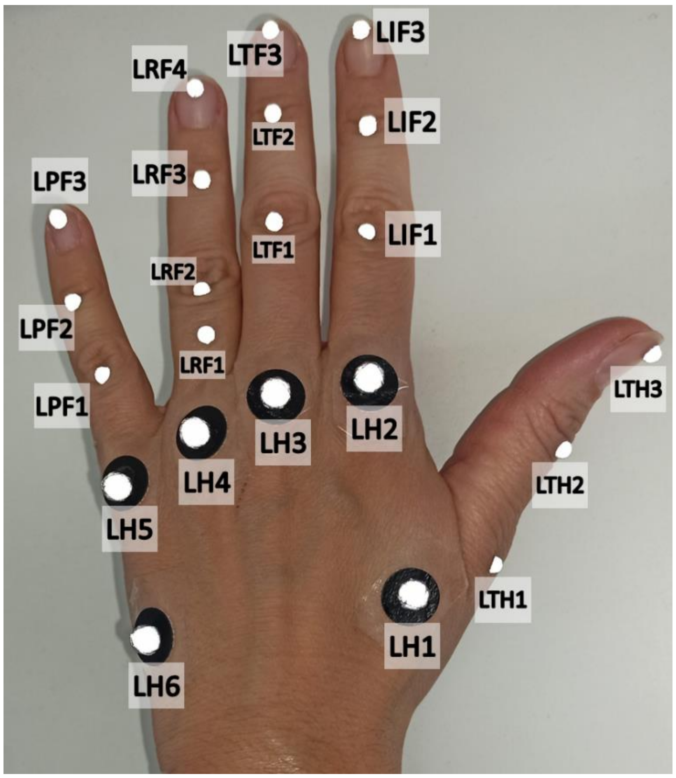


Figure 2 Left hand markers positioning

Marker Label	Definition
LH1	Base of second metacarpus - Left Hand
LTH1	Head of first metacarpus (base of thumb) - Left Hand
LTH2	Head of proximal thumb bone - Left Hand
LTH3	Tip of thumb - Left Hand
LH2	Head of second metacarpus (base of index finger) - Left Hand
LIF1	Head of proximal index finger bone - Left Hand
LIF2	Head of middle index finger bone - Left Hand
LIF3	Tip of index finger - Left Hand
LH3	Head of third metacarpus (base of third finger) - Left Hand
LTF1	Head of proximal third finger bone - Left Hand
LTF2	Head of middle third finger bone - Left Hand
LTF3	Tip of third finger - Left Hand
LH4	Head of fourth metacarpus (base of ring finger) - Left Hand
LRF1	Middle of proximal ring finger bone (position of ring) - Left Hand
LRF2	Head of proximal ring finger bone - Left Hand
LRF3	Head of middle ring finger bone - Left Hand
LRF4	Tip of ring finger - Left Hand
LH5	Head of fifth metacarpus (base of pinkie) - Left Hand
LPF1	Head of proximal pinkie bone - Left Hand
LPF2	Head of proximal pinkie bone - Left Hand
LPF3	Tip of pinkie - Left Hand
LH6	Base of fifth metacarpus - Left Hand

Table 2 Left hand markers positioning

Processing data with the Hand Model

Capturing and processing with the Hand Model involves the following stages:

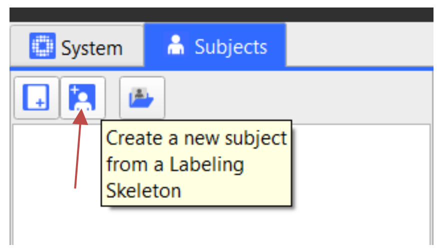
1. Creating a subject
2. Capturing and Processing a Static Trial
3. Capturing and Processing Dynamic Trials
4. Computing HM angles in Dynamic Trials

The following sections assume that you are familiar with Vicon Nexus. You can find more detailed instructions on preparing subjects capturing and processing trials in the documentation for your chosen Vicon software.

Creating a Subject

First of all, you will need to create a subject using the Vicon Skeleton Template file, installed with the HM plugin.

Create or open a session in the database in which you want to store the trials and ensure that it is the active session by double-clicking on the session name in the Data Management window. In this session, go to Nexus Subjects tab and create a new subject, using the appropriate Vicon Skeleton Template file. Select the LeftHand or RightHand Skeleton Template depending on which hand you want to analyze, or see below for both hands.



As you will see from the subject templates list, there are two different Labeling Skeleton Templates:

Left_Hand:	This model provides marker's configuration for the left hand.
Right_Hand:	This model provides marker's configuration for the right hand.

According to your experimental protocol, you can capture data on one or both hands and process the captured data with the same pipeline operations.

In case you want to acquire both hands simultaneously, you will have to add one subject for the right and one subject for the left hand.

Capturing and Processing a Static Trial

This section outlines how to capture and process a static trial using the Hand Model: this involves capturing the subject in a stationary position, labeling the markers and process the trial in order to get the relevant parameters needed for processing the subsequent dynamic trials.

1. Ensure that the Vicon markers are attached to the subject according to Table 1 and Table 2.
2. Make sure that all the markers on the subject are visible in the 3D Live workspace, and that this is the only subject enabled for capture (i.e.: one hand only). Since markers are positioned at a short distance, you may need to reduce the *Reconstruction Minimum Separation* parameter in the System tab (see Figure 6 in Appendix) to visualize them properly.
3. Capture a static trial
4. Open the static trial and reconstruct the markers with your standard pipeline (usually, Nexus *Reconstruct*

pipeline). Since markers are positioned at a short distance, you may need to reduce the *Reconstruction Minimum Separation* parameter in the Pipeline Advanced Properties tab (see Figure 7 in Appendix), to reconstruct them properly.
5. Manually label the reconstructed markers.
6. Process the static subject calibration (running Nexus *Calibrate Labeling Skeleton Static* pipeline).
7. Save both the trial and the subject file. 8. Run the *GPEM – RIGHT Hand Model Static* pipeline or *GPEM – LEFT Hand Model Static*, depending on which hand you want to analyze. This operation will process the static part of the Hand Model.

If you are capturing both hands, you will have to run these steps on the two subjects separately, therefore one hand at a time. Repeat steps from 1 to 8 acquiring a new static trial with the other subject selected. Be careful, in step 8 **only** one subject must be enabled. Run the static pipeline (e.g.: *GPEM – RIGHT Hand Model Static*) on the corresponding trial with the Right Hand subject selected. Next, run the other pipeline (i.e.: *GPEM – LEFT Hand Model Static*) on the corresponding trial with **only** the Left Hand subject selected

Capturing and Processing Dynamic Trials

The third stage consists in capturing and processing one or more dynamic trials on which your analysis will be performed. You must first have successfully processed the static trial as described above.
To capture and process a Hand Model dynamic trial:

1. Ensure that the subject you created from the Hand Model Skeleton Template is enabled for capture. If you are acquiring data with both hands, ensure both subjects are selected.
2. In the capture volume, have the subject perform the required movements.
3. Capture a dynamic trial.
4. Reconstruct and automatically label the markers. After this operation <u>it is recommended to check that the labelling is correct</u>.
5. If needed, fill the gaps.
6. Optionally, filter the markers trajectories.
7. Save the trial.

If you are capturing data on both hands, make sure that both subjects are selected during the previous operations.

Computing model angles in Dynamic Trials

The final stage in using the Hand Model is computing the model outputs in the Dynamic Trials.
To run the Hand Model on a dynamic trial:

1. Open the dynamic trial you want to analyze (you must first have successfully processed the dynamic trial as described above).
2. Run the *GPEM – RIGHT Hand Dynamic* or *GPEM – LEFT Hand Dynamic*, depending on which hand you want to analyze. This operation will compute the joint angles (as described in the next section) and store them in the Model Output under subject.
3. If you want to process or analyze the trial data further in a software application other than Vicon Polygon, export the trial data to ASCII using the appropriate pipeline operation.

<u>Advice</u>: if you have a high number of trials to analyze, you can use the batch processing operation to

automate the processing procedure. Select the trials, mark them and choose the corresponding pipeline in the batch panel.

If you captured data on both hands, in order to compute the joint angles correctly you will have to process the Hand Model for each subject separately, i.e. one hand at a time. Enable **only** one subject (e.g.: Right Hand) and run the corresponding dynamic pipeline (i.e.: *GPEM – RIGHT Hand Dynamic*). Then, disable the first subject, enable **only** the other subject (i.e.: Left Hand) and run the corresponding dynamic pipeline (i.e.: *GPEM – LEFT Hand Dynamic*). Re-enable the first subject (i.e: Right Hand) to see both hands processed.

Interpreting the Data

The Hand Model produces the following output angles, where R/L stands for Right or Left.

Angle name	Description
R/L-THJ1ProjAngle - Y	Thumb finger flex/extension
R/L-IFJ1ProjAngle – Y	Index finger flex/extension
R/L-TFJ1ProjAngle – Y	Third finger flex/extension
R/L-RFJ1ProjAngle – Y	Ring finger flex/extension
R/L-PFJ1ProjAngle – Y	Pinkie finger flex/extension
R/L-THJ1ProjAngle – Z	Thumb finger ab/adduction
R/L-IFJ1ProjAngle – Z	Index finger ab/adduction
R/L-TFJ1ProjAngle – Z	Third finger ab/adduction
R/L-RFJ1ProjAngle – Z	Ring finger ab/adduction
R/L-PFJ1ProjAngle - Z	Pinkie finger ab/adduction
R/L-THJ1ProjAngleNoOff - Y	Thumb flex/extension - offset removed
R/L-IFJ1ProjAngleNoOff – Y	Index flex/extension - offset removed
R/L-TFJ1ProjAngleNoOff – Y	Third finger flex/extension - offset removed
R/L-RFJ1ProjAngleNoOff – Y	Ring finger flex/extension - offset removed
R/L-PFJ1ProjAngleNoOff – Y	Pinkie flex/extension - offset removed
R/L-THJ1ProjAngleNoOff – Z	Thumb ab/adduction - offset removed
R/L-IFJ1ProjAngleNoOff – Z	Index ab/adduction - offset removed
R/L-TFJ1ProjAngleNoOff – Z	Third finger ab/adduction - offset removed
R/L-RFJ1ProjAngleNoOff – Z	Ring finger ab/adduction - offset removed
R/L-PFJ1ProjAngleNoOff - Z	Pinkie ab/adduction - offset removed
R/L-THJ2FlexExt	Flex/extension of second thumb segment
R/L-THJ3FlexExt	Flex/extension of third thumb segment
R/L-IFJ2FlexExt	Flex/extension of second index finger segment
R/L-IFJ3FlexExt	Flex/extension of third index finger segment
R/L-TFJ2FlexExt	Flex/extension of second segment of the third finger
R/L-TFJ3FlexExt	Flex/extension of third segment of the third finger
R/L-RFJ2FlexExt	Flex/extension of second ring finger segment
R/L-RFJ3FlexExt	Flex/extension of third ring finger segment
R/L-PFJ2FlexExt	Flex/extension of second pinkie segment
R/L-PFJ3FlexExt	Flex/extension of third pinkie segment

Table 3 Output angles description

Note: the offset refers to the ProjAngle computed during the static trial.

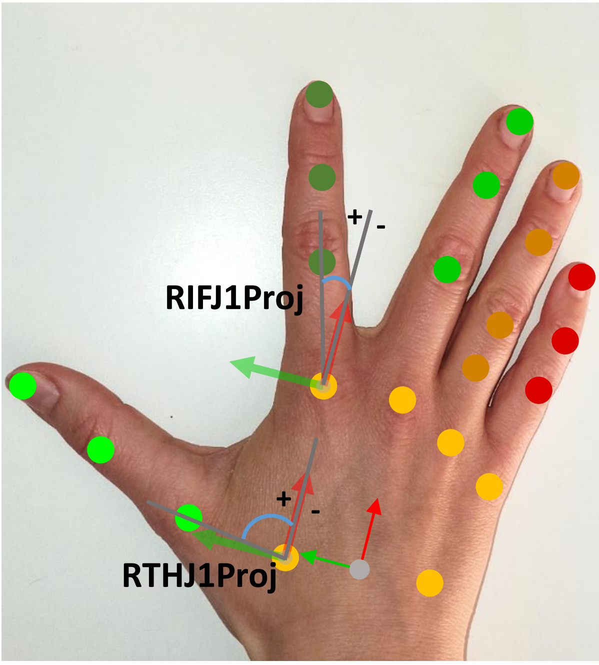


Figure 3 ProjAngles - Y component (ab/adduction)

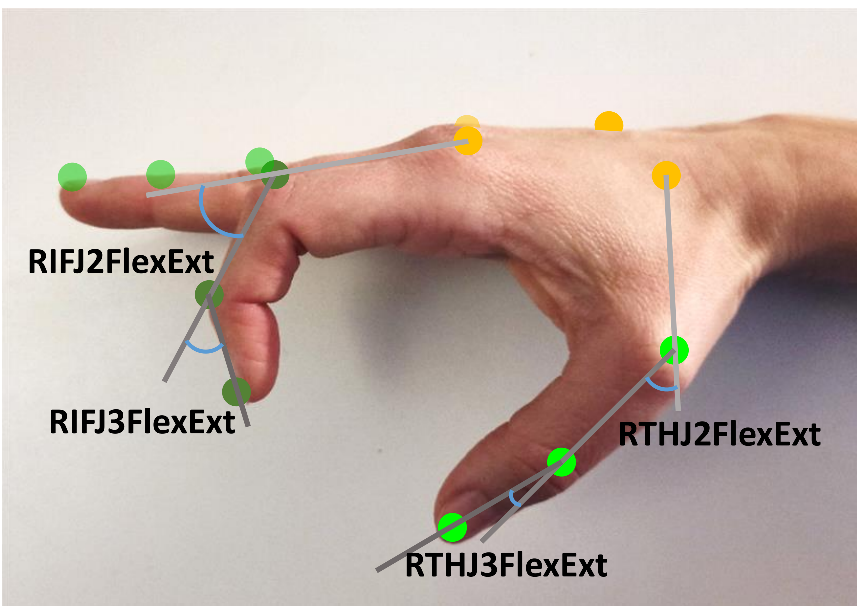


Figure 4 Flex/extension angles

Advanced Notes

This section provides background information on the development of the Hand Model and its implementation in Vicon Nexus. It is provided as an additional resource for users who want to gain a deeper understanding of the scientific basis of the model; it is not essential to use the Hand Model.
In the following paragraphs, L/R prefixes will be omitted (therefore H1 can stand for either LH1 or RH1, or both)

Model Description

The Hand Model treats the hand as a segment with its associated local coordinate system, which takes the middle point between H1 and H6 as its origin. Looking at the hand from above, the X axis points forwards (towards H3), the Y axis points toward left (Medio-Lateral) and the Z axis points upwards.

The Hand Model defines the following vectors associated to fingers, used to compute angles:

Thumb

Thumb1: from H1 towards TH1.
Thumb2: from TH1 towards TH2.
Thumb3: from TH2 towards TH3.

Index Finger

IndexFinger1: from H2 towards IF1.
IndexFinger2: from IF1 towards IF2.
IndexFinger3: from IF2 towards IF3.

Third Finger

ThirdFinger1: from H3 towards TF1.
ThirdFinger2: from TF1 towards TF2.
ThirdFinger3: from TF2 towards TF3.

Ring Finger

RingFinger1: from H4 towards RF1.
RingFinger2: from RF1 towards RF2.
RingFinger3: from RF2 towards RF3.

Pinkie Finger

Pinkie1: from H5 towards PF1.
Pinkie2: from PF1 towards PF2.
Pinkie3: from PF2 towards PF3.

Angles Description

The HM plugin provides three kind of angles: '*FlexExtAngle*', '*ProjAngles*' and '*ProjAnglesNoOff*'.

<u>*FlexExtAngles*</u>

These are computed as the absolute angle between two vectors (The angle (θ) is obtained inverting the cross product formula: $\vec{a} \wedge \vec{b} = \hat{n} * |a| * |b| * \sin\theta$).
Therefore, as examples:
THJ2FlexExt is the angle between Thumb2 and Thumb1.
THJ3FlexExt is the angle between Thumb3 and Thumb2.

ProjAngles

ProjAngles are computed as in [Cheng P.L., Pearcy M. (1998), A 3D Definition for the Flexion/Extension and Abduction/Adduction Angles.].

The flexion/extension is measured as the ϕ angle between the long axis of the finger (r) and its projection on the XY plane, and the ab/adduction is measured as the θ angle between the long axis of the finger (r) and its projection on the XZ plane (Figure 5).

ProjAnglesNoOff

ProjAnglesNoOff are computed exactly as ProjAngles, except from the offset removal. In fact, ProjAnglesNoOff are obtained subtracting the ProjAngles computed during the static trial to the ProjAngles computed during the dynamic trials.

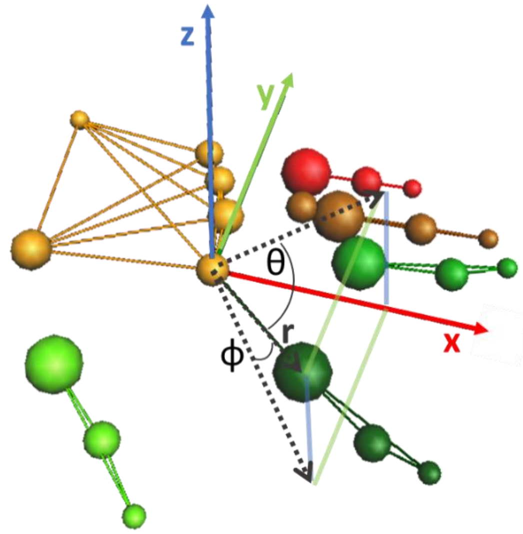


Figure 5 Angles computed as the projection of the finger vector

References

This research publication provide supporting information on the scientific basis of this Hand Model:
Cheng P.L., Pearcy M. (1998) A 3D Definition for the Flexion/Extension and Abduction/Adduction Angles.
Proc. 4th International Symposium on the 3D Analysis of Human Movement, July2nd-5th, Chattanooga, USA.

HM Appendix

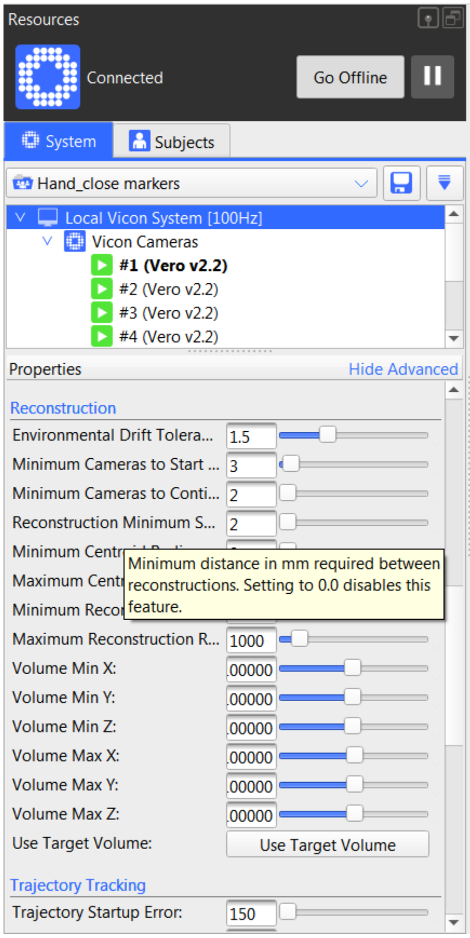


Figure 6 Live System tab

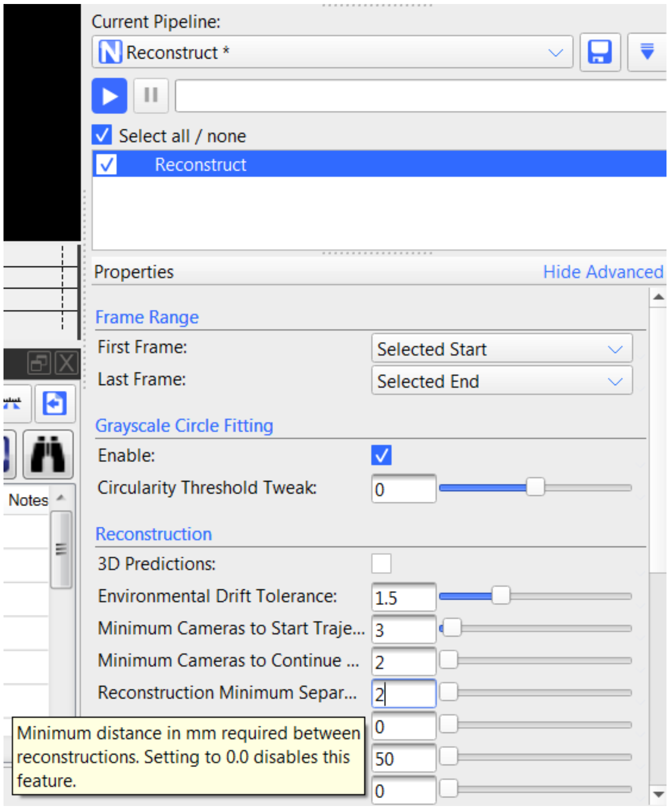


Figure 7 Reconstruction parameters