

Robot Signature Calibration



Robot signature calibration is performed to compensate for robot motion inaccuracies between the real and simulated robot. These inaccuracies are caused by inexact link lengths, link offset, and link twist parameters in the open loop linkage of the robotic device. Signature calibration is done by either specifying the joint offsets or delta vectors.

Joint-level calibration errors account for 80% of the inaccuracies in a typical robot workcell. For greater accuracy, delta vector parameters are used to model the complete kinematic signature of the robot. These signature parameters are used by DELMIA software to modify robot forward kinematics as well as the nominal solution configurations returned by robot forward kinematics.

The combination of forward kinematics and inverse kinematics is used during uploading and downloading to the real robot to compensate for its signature. Delta vector calibration shows better proportionality to kinematic errors at each joint without the singularity problems.



Set Signature Status

See [Set the Signature Status](#)



Joint Offsets

See [Viewing Joint Offset values](#)



Delta Vectors

See [Viewing Delta Vector Values](#)



Auto ID

See [Auto ID](#)

We will be using this scenario.



Set the Signature Status

1. From the Signature Calibration toolbar, click **Set Signature Status** .
2. From the PPR tree or the 3D view, select a Robot device. The **Select Status** dialog box appears.



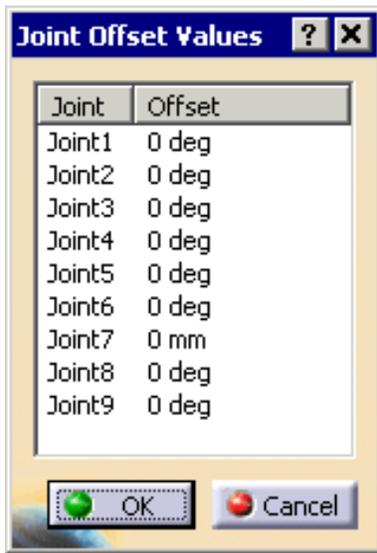
- In this scenario, Select the **Joint Offsets** option and click **OK**.



To view joint offset values:

- Select the Joint Offset options in the **Select Status** dialog box.
- In the Signature Status toolbar, click **Joint Offsets** .

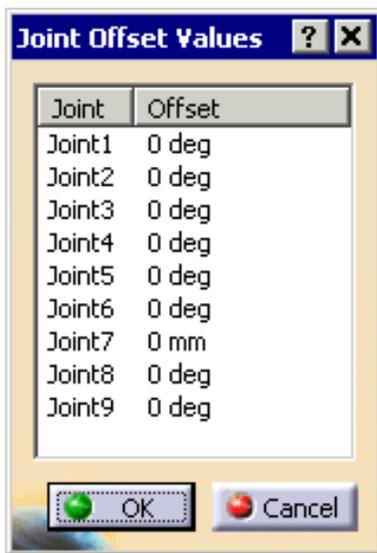
- The **Joint Offset Values** window appears displaying the offsets for each joint.



- Select **OK** or **Cancel** to close this window.

Viewing Joint Offset Values

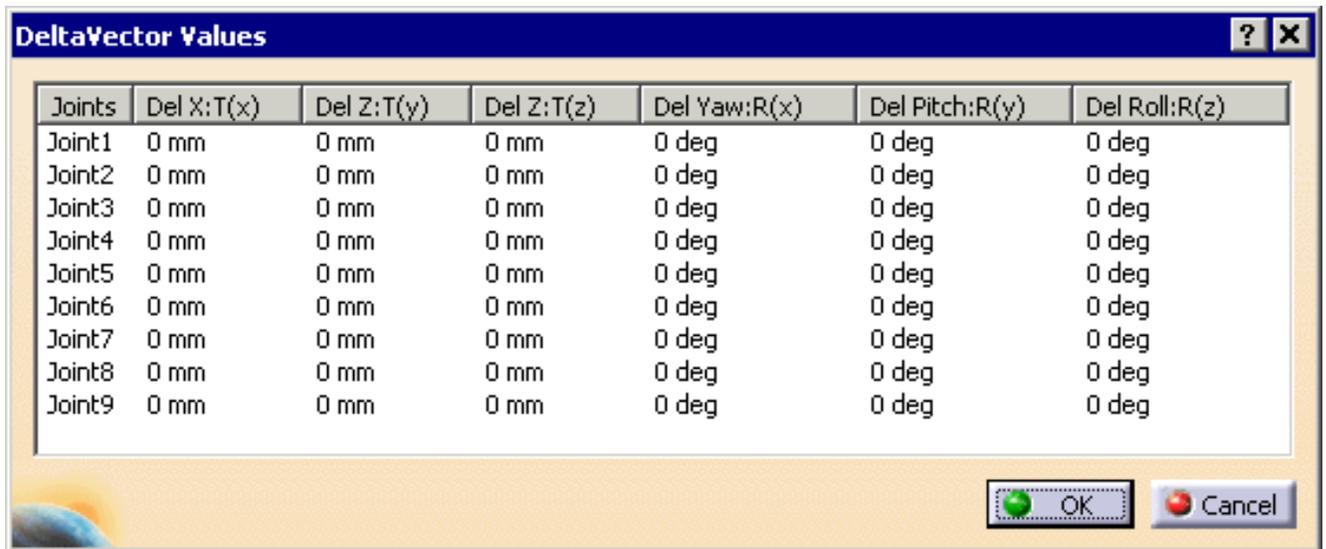
- (The **Set Signature status** must be set to Joint Offsets before using the Joint Offsets). Select the Joint Offset option in the **Select Status** dialog box.
- In the **Signature Status** toolbar, click **Joint Offsets** .
- The **Joint Offset Values** window appears displaying the offsets for each joint.



4. Click **OK** or **Cancel** to close this window.

Viewing Delta Vector Values

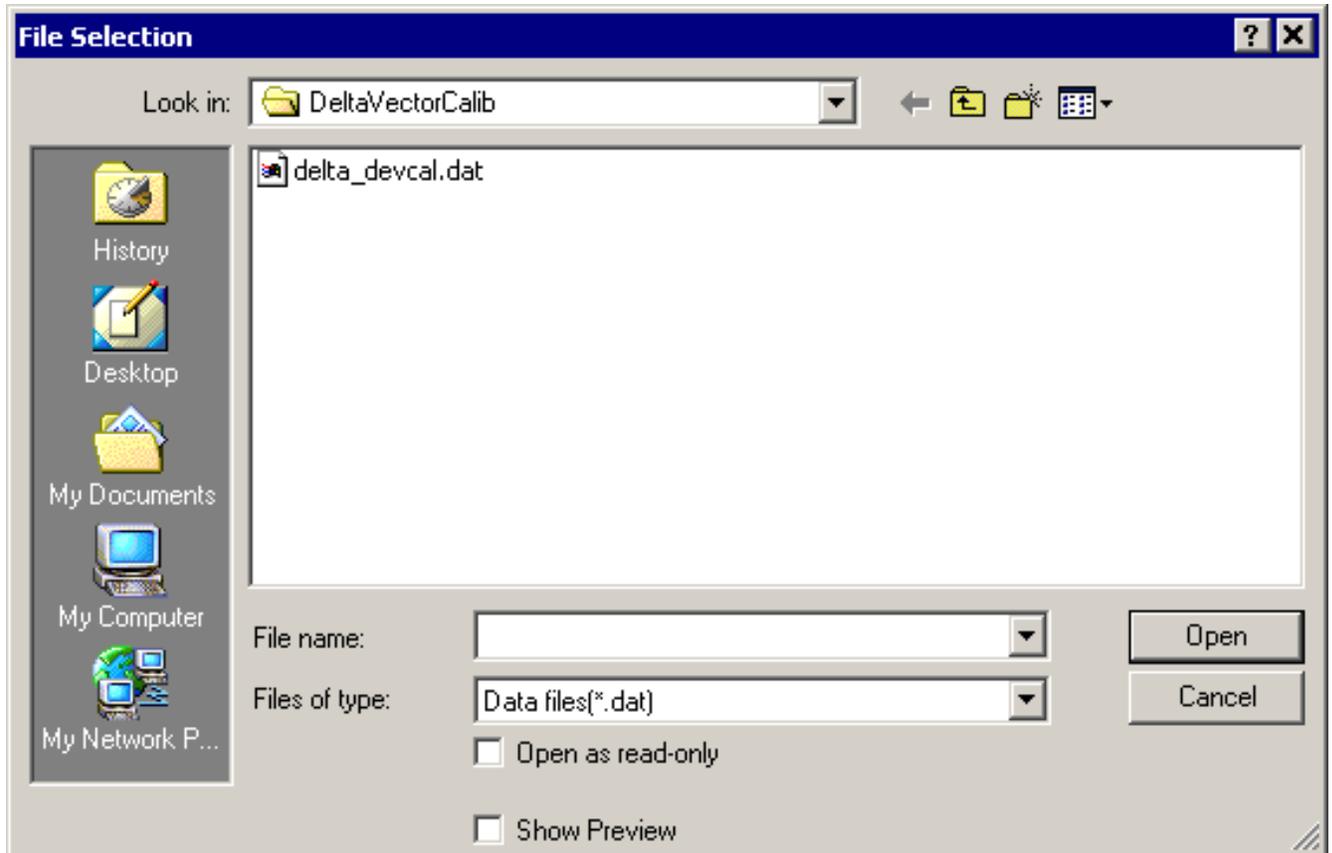
1. (The [Set Signature status](#) must be set to Delta Vectors before using the Delta Vectors). Select the Delta Vectors option in the **Select Status** dialog box.
2. In the Signature Status toolbar, click **Delta Vectors** .
3. The **Delta Vector Values** window appears displaying the delta vector values for each joint.



4. Click **OK** or **Cancel** to close this window.

Auto ID

1. (The [Set Signature status](#) must be set to Delta Vectors before using the Auto ID). From the Signature Calibration toolbar, click **Auto ID** .
2. Select the robot device in the 3D window or the PPR tree. The **File Selection** dialog box appears and the system prompts you to select the file on your computer with experimental joint values, a .dat file.



3. Select the .dat file to read the experimental joint values. The **Branch Type** dialog box appears. See the [Delta_Devcal.dat file breakdown](#) for more information about this file.

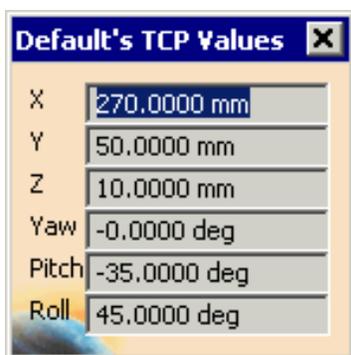


- o **Main Branch:** Only the main kinematic chain (from the device base part to the kinematic mount part) will be identified.
 - o **Auxiliary Branch:** Only the auxiliary kinematic chain (from the device base part to the auxiliary mount part) will be identified.
4. Select the **Main Branch** option and click **OK**. The **Select Utool** dialog box appears if there

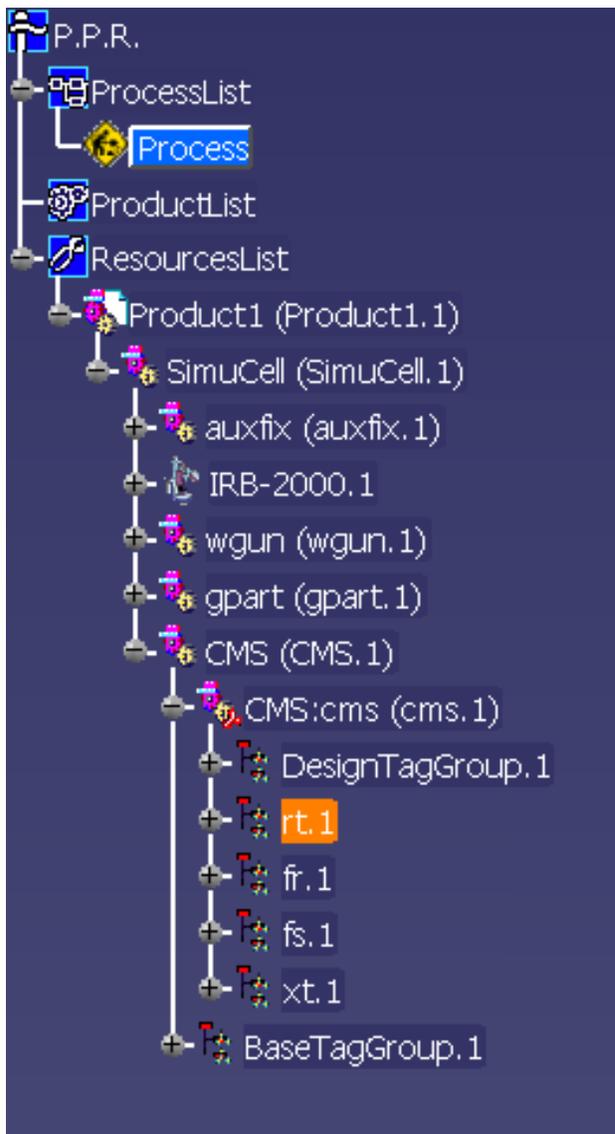
is multiples you will see the Utool, or the default.



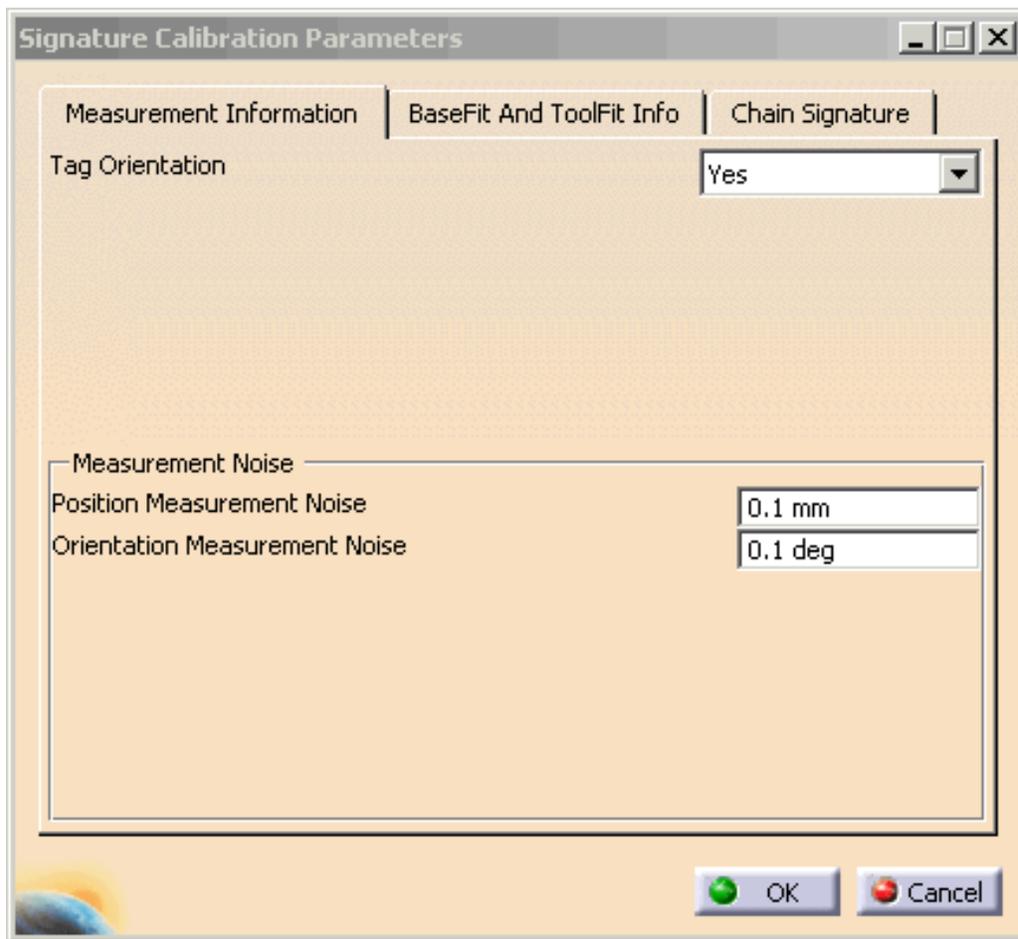
5. Select the Utool (tool profile) if required, and click **OK**. The values for the selected tool profile are displayed in the **TCP Values** dialog box.



6. Expand the PPR tree to review the Signature Calibration Parameters.



7. Double-clicking on the **rt.1** displays the **Signature Calibration Parameters** dialog box. See the [Set the Joint Offset Calibration Parameters below](#).



The Delta_Devcal.dat file breakdown

Signature calibration infers the best-fit signature parameters for the robot Device based on an experimental procedure using the real robot and tool. It also infers the best-fit base and tool parameters (x, y, z, yaw, pitch, roll) based on the experimental data. The robot device must have the signature parameters enabled (to Delta Vectors). The identification may be done only for the 'Main' kinematic chain (from the device base part to the kinematic mount part) and not for an 'Auxiliary' kinematic chain (from the device base part to the auxiliary mount part).

The calibration procedure consists of selecting a robot device, a device representing the coordinate measurement system (CMS) in the workcell and a path of tag points. The path of tag points represents the tool tip positions in moving to the measurement points as located by the external CMS. These tag points have to be obtained from a real workcell setup and given as input (in the form of a 'dat' file) for signature calibration. These tag positions are read from the file and they are generated in the Delmia product by creating a tag group attached to the CMS. If the CMS can measure the tool tip orientation, then the tag points of this path are significant in position as well as orientation.

The calibration requires the user to specify whether or not the experimental tag points contain tool tip orientation measurement information. It also requires the following information from the user:

- Base Translate X, Y, Z (Free/Fixed): specifies the directions in which the CMS to device base transform may be translated during adjustment.
- Base Rotate X, Y, Z (Free/Fixed): specifies the directions in which the CMS to device base

transform may be rotated during adjustment.

When the signature status is set to Delta Vectors:

- Joint 1->DOF (Free/Fixed/Trans/Rot): specifies which joint signature parameters may be adjusted. If the joint is defined to be 'Free' then all the parameters at that joint are adjusted. If the joint is defined to be 'Trans' or 'Rot' then only the translation or rotational signature parameters at that joint are adjusted.
- Tool X, Y, Z (Free/Fixed): specified the components of the tool position, which may be adjusted.
- Tool Yaw, Pitch, Roll (Fixed/Free): specifies the components of the tool orientation, which may be adjusted.

Based on the selections, the CMS to device base transform, the joint signature, and the utool are adjusted to obtain the best fit for the parameters. Upon convergence, an analysis of the results is displayed:

- Number of iterations: the number of iterations required by the numerical identification method.
- Number of fitting points: the number of points used for the least squares fitting procedure.
- Root mean square fitting error: the root mean square fitting error on the points after adjusting the parameter to the best fit possible.
- Max uncertainties:
 - Base X, Y, Z: the maximum of the uncertainties for the fit on the base X, Y, Z parameters for the given observations.
 - Base Yaw, Pitch, Roll: the maximum of the uncertainties for the fit on the base Yaw, Pitch, Roll parameters for the given observations.
 - Signature (Translational): the maximum of the uncertainties for the fit on the translational signature parameters for the given observations.
 - Signature (Rotational): the maximum of the uncertainties for the fit on the rotational signature parameters for the given observations.
 - Tool X, Y, Z: the maximum of the uncertainties for the fit on the tool X, Y, Z parameters for the given observations.
 - Tool Yaw, Pitch, Roll: the maximum of the uncertainties for the fit on the tool Yaw, Pitch, Roll parameters for the given observations.

These best fit parameters are then applied to the forward and Inverse kinematics of the robotic device to account for the inaccuracies.

This file has recorded experimental joint values and tag positions from real world robot. The inputs taken are:

- Number of DOFs (Degrees of Freedom) involved
- Name of the tag group
- Tag with the x,y,x,r,p,y
- DOF target - DOF values for the target device

See the [Sample_Delta_Devcal.dat](#) file (can be opened using notepad)

The format of the file:

- **Header**
The first line of the input file specifies the number of Degrees of Freedom being calibrated.

```
dofcount 9
```

- **Tag Group Name**

The second line in the input file specifies the name of the tag group that will act as a reference.

```
taggroup rt.1
```

- **Tag Information**

The third line is the Tag information.

```
rt1 2734.65 411.576 2070.51 -95.45576 7.182724 -61.87403 -51.300510 -1.675503
    -12.872430 134.013199 57.800449 218.641998 995.518982 7.901890 -42.683689
```

- All the tag information is specified in separated columns
 - First column: Name of the tag
 - Second column to seventh column: x,y,x,r,p,y of the tag
 - Rest of the columns: DOF targets (thetas) to be used in calibration.

Select the Measurement Device and the Tag Group

The system prompts you to select the measurement device. In the 3D view or the PPR tree, select the device representing the co-ordinate measurement system (CMS).

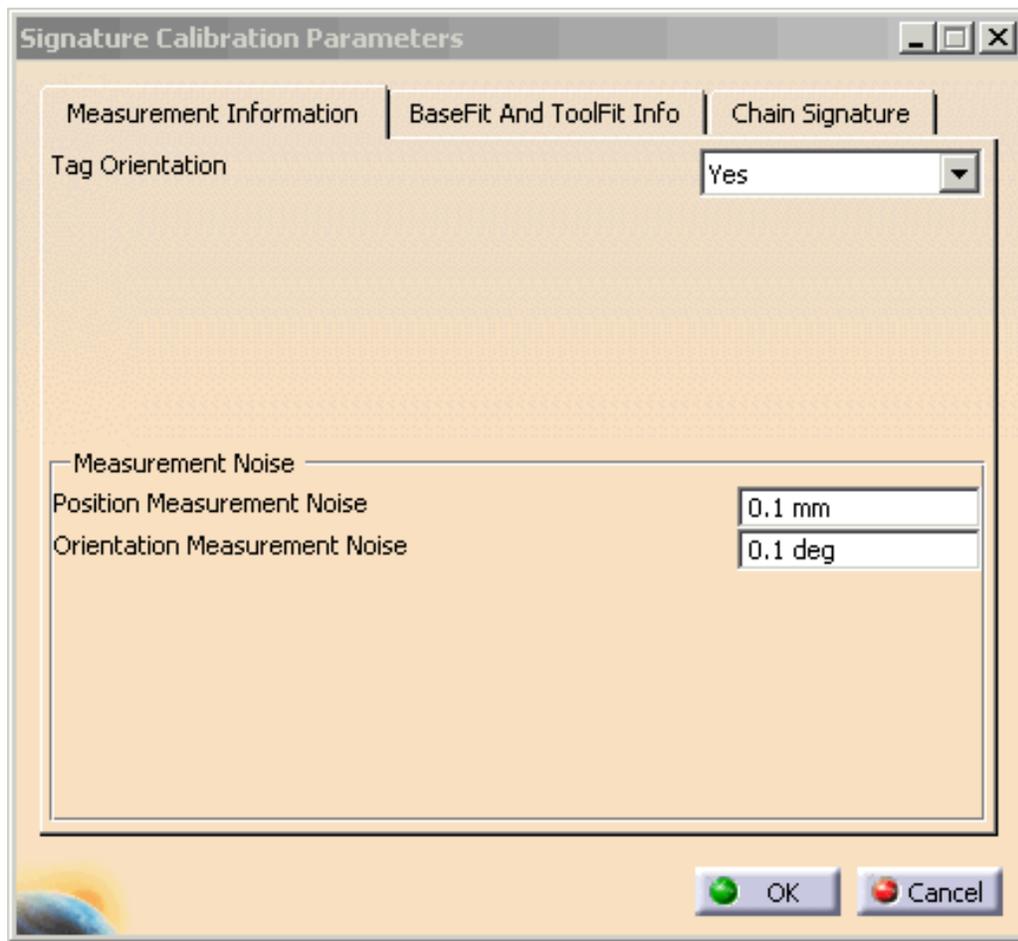
The system prompts you to select the tag group (tool tip locations). In the 3D view of the PPR tree, select the tag group. The Joint Offset Parameters Calibration dialog box appears.

Set the Joint Offset Calibration Parameters

Input the desired parameters and click **OK**. Based on the selections, the CMS-to-device base transform, the joint signature, and the utool are adjusted to obtain the best fit for the parameters.

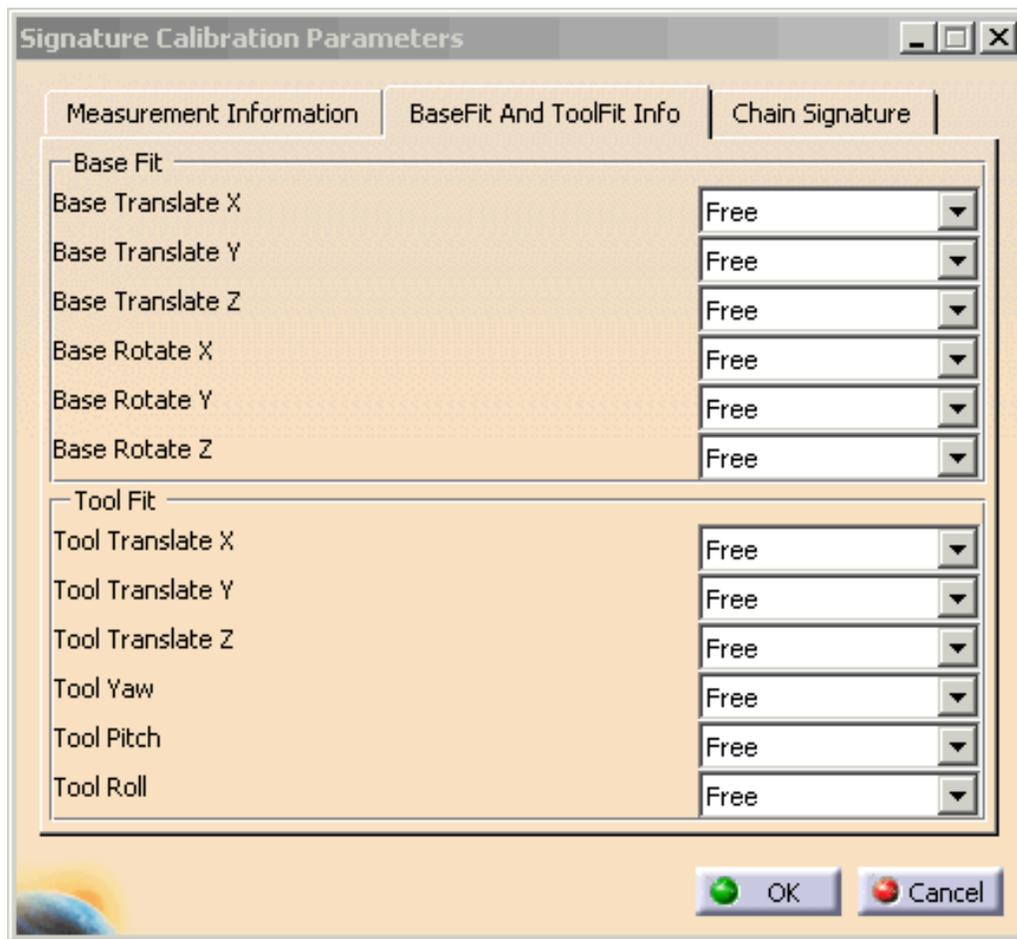
Measurement Information tab

- **Tag Orientation:** Do the experimental tag points contain tool tip orientation measurement information? Choose Yes or No.
- **Measurement Noise:**
 - **Position Measurement Noise:** An estimate of the uncertainty of the position measurements during the calibration experiment. This is measured in millimeters (mm).
 - **Orientation Measurement Noise:** An estimate of the uncertainty of the orientation measurements during the calibration experiment. This is measured in degrees (deg).



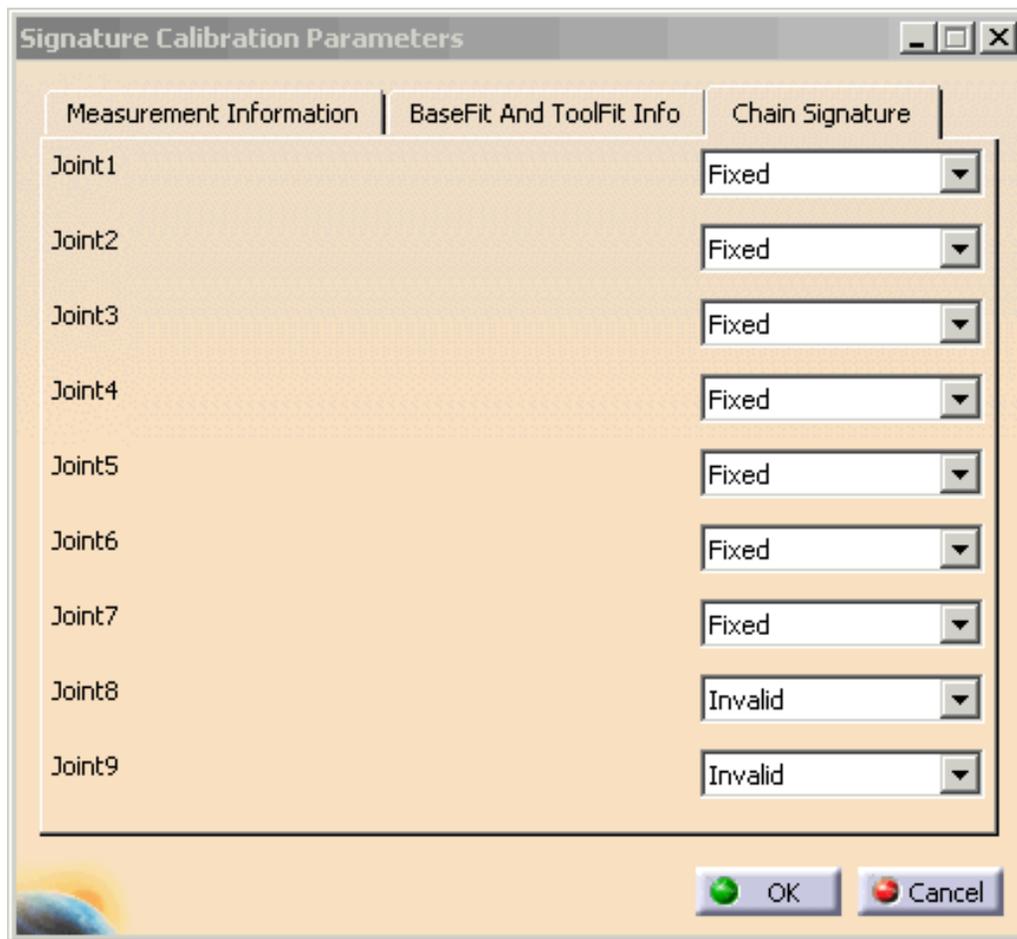
BaseFit and ToolFit Info tab

- Base Fit:
 - In the Base Translate X, Y, Z, (Free/Fixed) pull-down menus, specify the directions in which the CMS to device base transform may be translated during adjustment.
 - In the Base Rotate X, Y, Z, (Free/Fixed) pull-down menus, specify the directions in which the CMS to device base transform may be rotated during adjustment.
- Tool Fit:
 - In the Tool Translate X, Y, Z, (Free/Fixed) pull-down menus, specify the components of the tool position that will be adjusted.
 - In the Tool Yaw, Pitch, Roll (Free/Fixed) pull-down menus, specify the components of the tool orientation that will be adjusted.



Chain Signature tab

- This tab deals with the joints degree of freedom. In the pull-down menus, specify which joint signature parameters can be adjusted.
 - If the joint is defined as Free, all the parameters at that joint are adjusted.
 - If the joint is defined as Trans or Rot, only the translation or rotational signature parameters at that joint are adjusted.



Analysis Results

When the convergence is complete, (Clicking the OK in the Signature Calibration dialog box) the Signature Calibration Results dialog box appears displaying the analysis results. These best fit parameters are then applied to the forward and inverse kinematics of the robotic device to account for the inaccuracies.

Signature Calibration Results	
Max Uncertainties	
Base XYZ	0.084599mm
Base WPR	0.0021deg
Signature(Translational)	
Signature(Rotational)	
Tool XYZ	0.022938mm
Tool WPR	0.0204deg
Results	
Number of iterations to converge	5
Number of fitting tag points	24
Root Mean Square fitting error	1.703730152mm
<input type="button" value="OK"/> <input type="button" value="Cancel"/>	

Max Uncertainties

- Base XYZ: the maximum uncertainties for the fit on the base X, Y, Z parameters for the given observations.
- Base WPR (Yaw/Pitch/Roll): the maximum uncertainties for the fit on the base Yaw, Pitch, Roll parameters for the given observations.
- Signature (Translational): the maximum uncertainties for the fit on the translational signature parameters for the given observations.
- Signature (Rotational): the maximum uncertainties for the fit on the rotational signature parameters for the given observations.
- Tool XYZ: the maximum uncertainties for the fit on the tool X, Y, Z parameters for the given observations.
- Tool WPR (Yaw/Pitch/Roll): the maximum uncertainties for the fit on the tool X, Y, Z parameters for the given observations.

Results

- Number of iterations to converge: the number of iterations required by the numerical identification method.
- Number of fitting tag points: the number of points used for the least squares fitting procedure.
- Root mean square fitting error: the root mean square fitting error on the tag points after adjusting the parameter to the best fit possible.

