Measurement Staging Users Guide

Table of Contents

Introduction

The *Measurement Staging* utility allows the user to combine two or more step gauge measurements along a machine axis and generate a set of corrections that can be directly added to the existing compensation map data. Combining two or more step gauge measurements is common when mapping a machine axis when the machine axis length is significantly longer then that of the step gauge. The approach used by the *Measurement Staging* utility prefers measurements that overlap each other but measurements in opposite directions or even measurements with gaps between the positions are acceptable inputs. The individual positions can be filtered to help clean up effects of measurement noise on the data.

The traditional method to handle staged measurements is to measure the different positions in order where the error of the last point of the first position offsets all the errors of the next position and so on. There are many assumptions made when using this method where the most common is placement of the subsequent measurement position relative to the previous measurement position.

Overview

The *Measurement Staging* utility consists of a main window with a number of tool widgets performing different functions. Illustration 1 shows an example of the *Measurement Staging* utility with three measurements loaded along the Y axis.

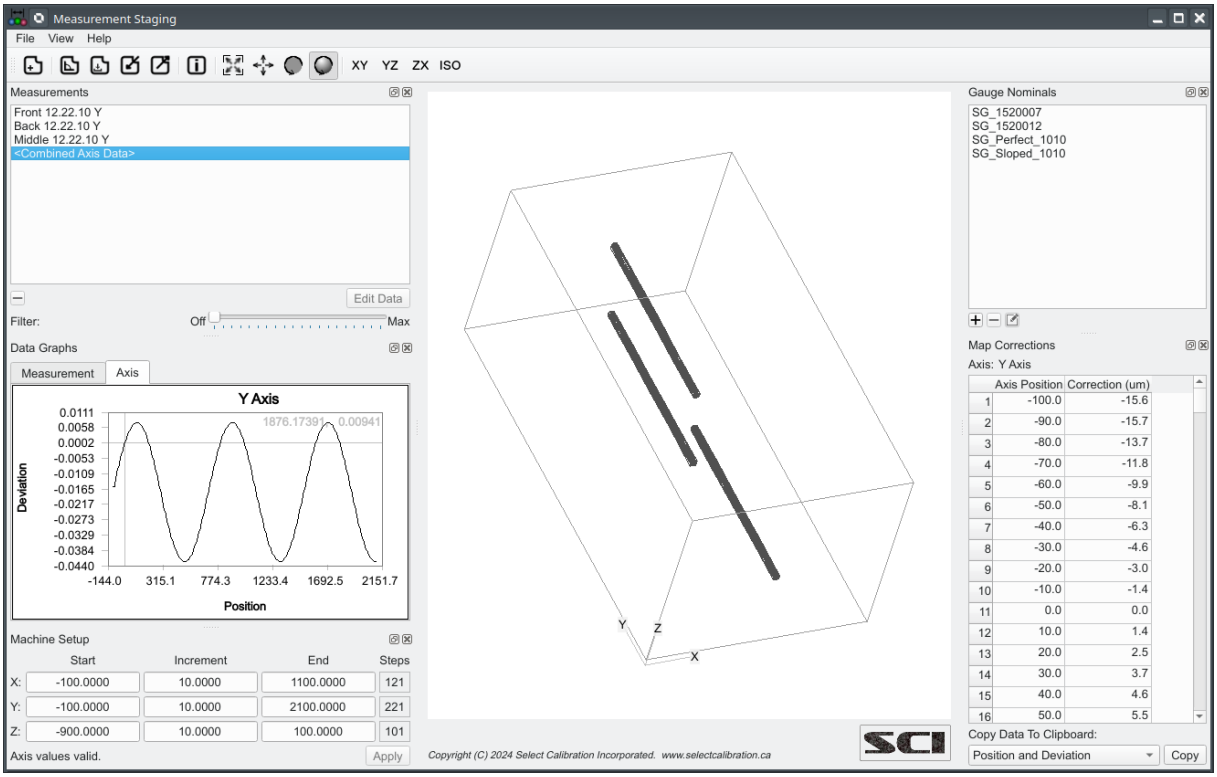

Illustration 1: Measurement Staging utility main window with three, overlapping, measurements.

The graph of the correction data shown in illustration 1 was created by simulating three different

measurements of a step gauge that overlapped each other. The original test signal is shown in illustration 2 and is identical to the correction output with only a vertical offset related to where the axis zero point is in relation to the test data zero point.

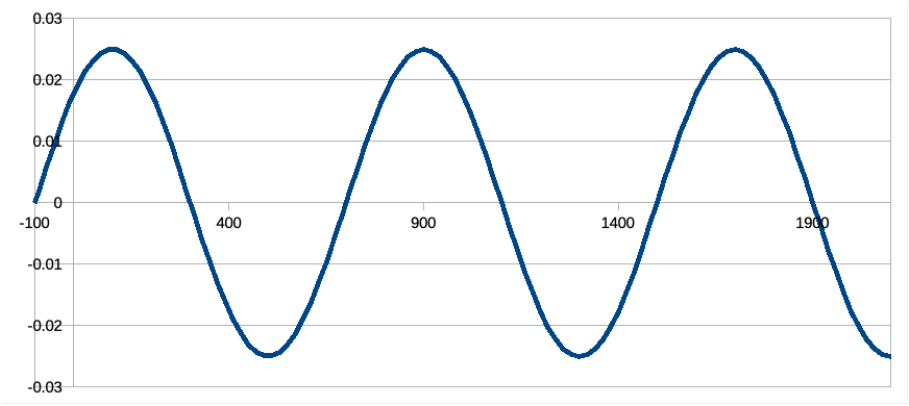

Illustration 2: Signal generated for testing.

Without the third overlapping measurement as shown in illustration 1 it would not be possible to recreate the shape of the input signal precisely. Extrapolation between step gauge positions or extrapolation from the start or end of the measurement group to the axis start or end of the axis will always be a straight line.

Toolbar:

Icon	*Description*
	Create a new measurement by deleting all existing data.
	Open a previously created staging file.
	Save the current measurement data.
	Import measurement data. The only data that can be imported is measurements of a step gauge as defined by ASME B89.4.1:1997 LDA measurements. Measurements can be imported using drag and drop.
	Export correction data to a text file.
	Information and version of the *Measurement Staging* utility.

When importing step gauge positions the axis and output is automatically configured based on the input data. The measurement direction must be within 15 degrees of any machine axis to be accepted. All imported measurements must be along the same machine axis and cannot be mixed. Step gauge measurements do not need to be measured in sequence or even in the same direction provided the measurement is roughly parallel to the machine axis

The axis of a suitable measurement must be within 15 degrees of any machine axis.

Graphics Display

The graphics display of the *Measurement Staging* utility uses a custom widget that does not use hardware acceleration. The advantage of this is a smaller foot print and reduced requirements from the operating systems that run this utility. There are many disadvantages from not using a 3D graphics library such as solid views or depth testing but for the purpose of the *Measurement Staging* utility this is not important.

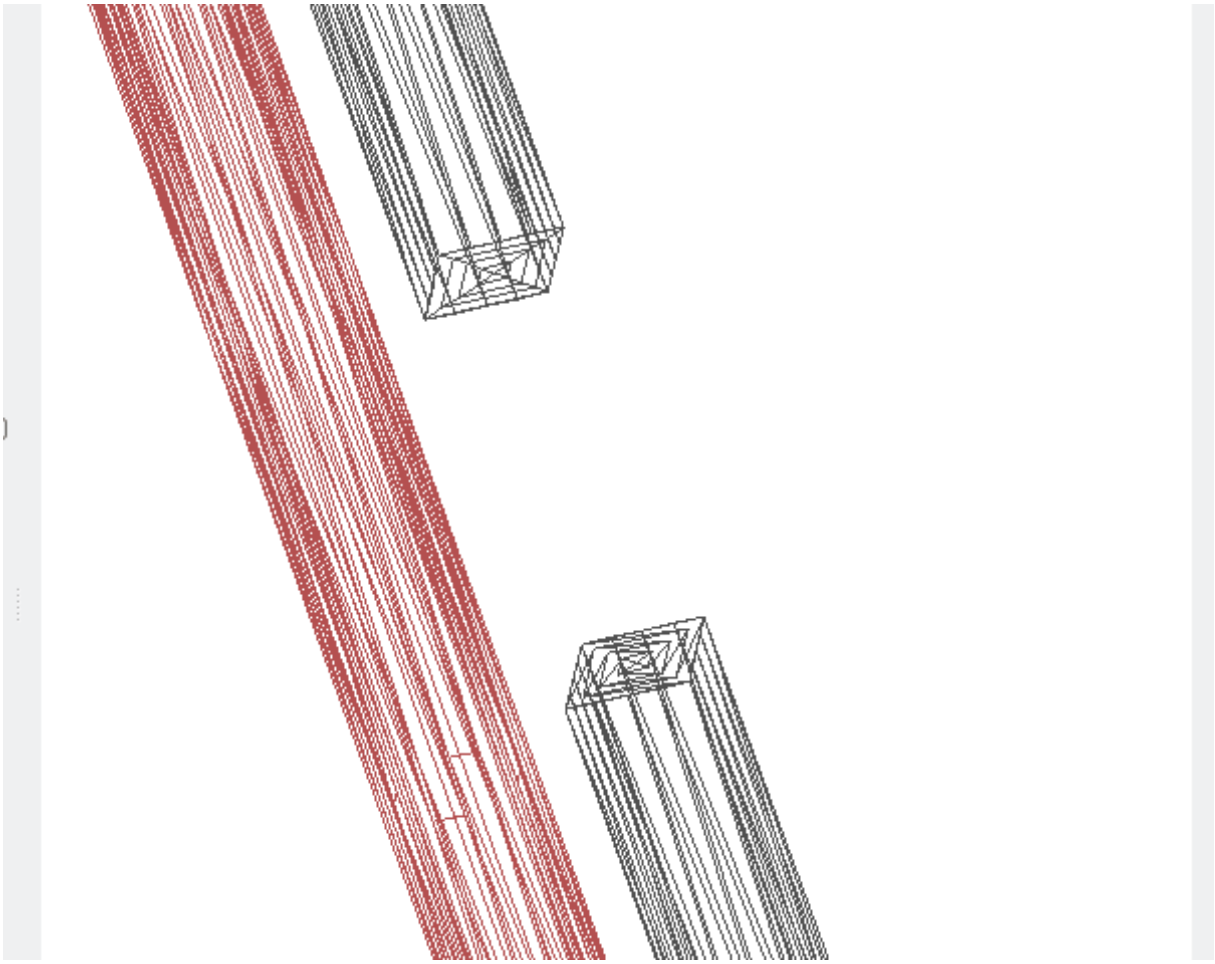

Illustration 3: Graphics display window. This image shows the gap between the front and back measurement and the overlapping measurement tying the two measurements together.

The graphics display is not fixed and can be manipulated in a variety of ways. The selected option of the main toolbar defines the action when using the right mouse button on the model display. For operating systems such as MacOS it is necessary to click the CTRL button to recreate the right mouse button.

Table 1: Graphics display toolbar options:

Image	*Description*
	Scale to fit. Adjusts the scale of the projection matrix to fit the visible data into the display viewport.
	Pan Mode. When enabled a right mouse button click and drag will move the position of the displayed model.
	Rotate 2D Mode. When enabled a right mouse button click and drag will rotate the model around the center of the viewport.
	Rotate 3D Mode. When enabled a right mouse button click and drag will rotate the model around the click position on the displayed model.
	Set the display to show the measurements in the XY projection plane.
	Set the display to show the measurements in the YZ projection plane.
	Set the display to show the measurements in the ZX projection plane.
	Set the display to show the measurements in an isometric view.

The displayed measurements can be further inspected by drawing a box around sections of interest. The scale of the model can be increased or decreased using the mouse scroll button. A right mouse click above or below the horizontal center-line will zoom in or out of the model.

Measurements

The measurements imported into the *Measurement Staging* utility are listed in the *Measurements* widget. An example of this is shown in illustration 4.

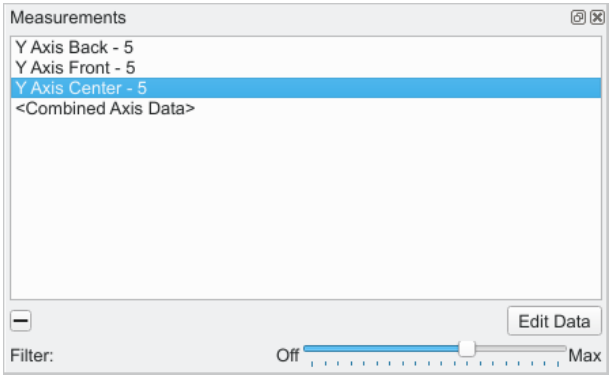

Illustration 4: Measurements Widget

Table 2: Measurement options:

Item	*Description*
	Remove selected measurement.
Edit Data	Allows modification of the nominal and actual data from the selected measurement.
Filter	Set the level of filtering of the input data. The impact of changes to the filter are immediate and can be visually seen in the graphics display.

Measurement Data Editor

The nominal and actual values of the step gauge measurement can be manipulated by clicking the *Edit Data* button in the *Measurements* widget. The data editor is shown in illustration 5. The nominal data is from the step gauge nominal information and should always be correct. The actual is the mean of all measurement values at any target position.

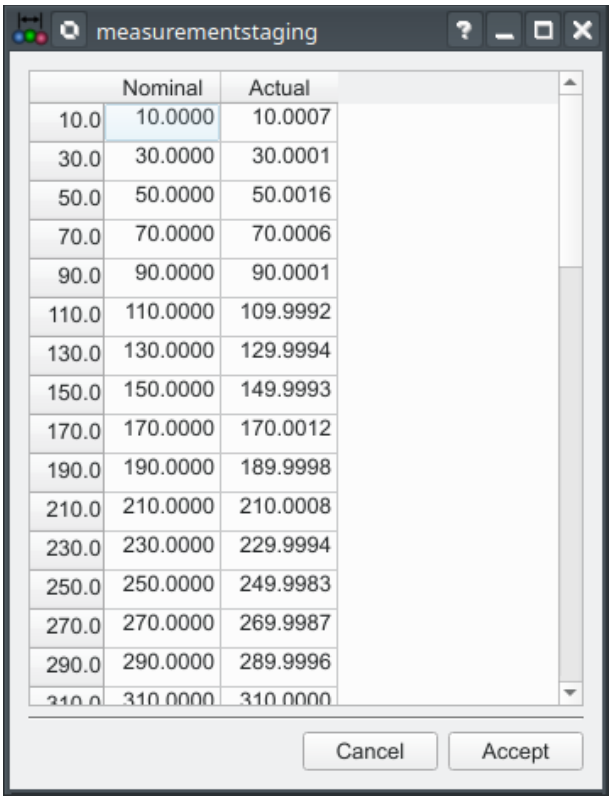

Illustration 5: Data editor for the selected measurement.

Data Filtering

The imported data can be filtered to smooth out noise. The amount of filtering is currently based on visual feedback. Proper filtering is an important topic when dealing with CMM data where the right level of filtering can be *magic* on a CMM. The ultimate goal of the filter is to remove measurement noise and not machine errors. Illustration 6 shows an example of filtered

measurement data from one of the input measurements.

The level of filtering is set from the *Measurements* widget. The filter level can be set individually or for all measurement positions at the same time depending on the selected item in the *Measurements* widget.

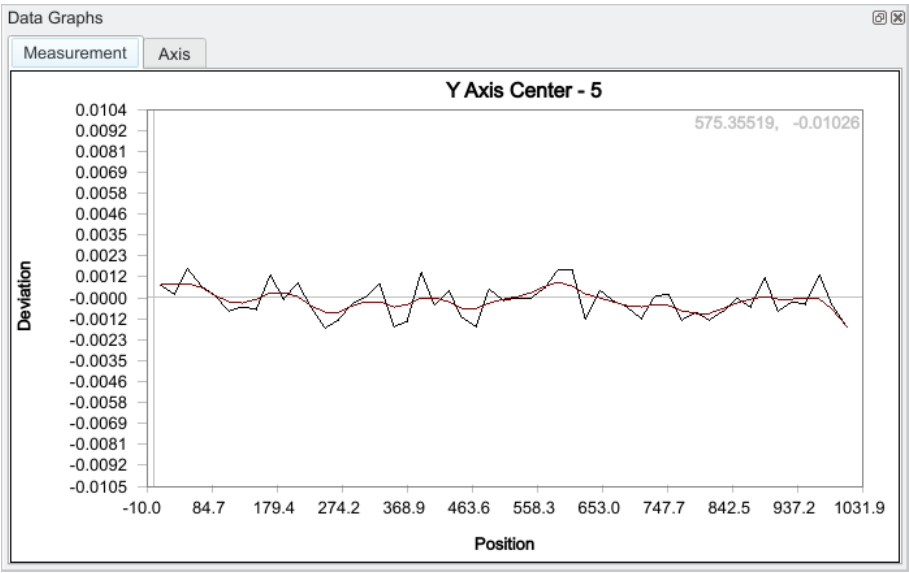

Illustration 6: Graph of a single measurement position with some level of filtering applied.

Adding filter options based on length or existing standards may be added in the future if it makes sense to do so (and a standard is found related to this).

It has been observed that the source of noise may be internal to the map data and not from an external source. Recognizing this is important to solve this kind of problem on a CMM.

Data Graphs

The individual or combined axis data is displayed graphically. When an individual measurement is selected the graph will show data from the selected measurement. The combined axis option from the *Measurement* list will show the correction data along the entire axis.

Machine Setup

The machine or map dimensions and desired output increment is defined in the *Machine Setup* widget. Illustration 7 shows an example of a 12.22.10 CMM with data increments of 50 mm for each axis. In this example the machines axis extends from the home position (XYZ zero) in two directions by a value that results in a total axis length of 1200 mm, 2200 mm, and 1000 mm.

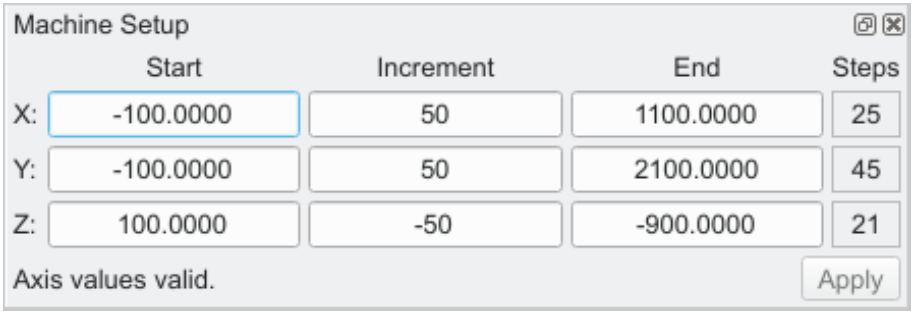

Illustration 7: Machine Setup widget.

Table 3: Machine Setup options:

Item	*Description*
Start	Starting position of the machine or map data for each axis of the CMM.
Increment	Increment of the map data for each axis of the CMM.
End	Ending position of the machine or map data for each axis of the CMM.
Steps	Number of steps from the starting position to the ending position with the defined increment.
Apply	When fields are changed the changes must be applied to have other windows updated.

When entries are changed the input is validated. In the event one or more entries are invalid the *Apply* button will be disabled and an explanation of the problem will appear at the bottom of the *Machine Setup* widget. In the above example all values and ranges are valid.

The end position of the axis is internally calculated based on the start and increment to be at or greater than that of the displayed end value. For example, if the starting position is 0 mm with the increment the 75 mm and the end position is 100 mm then three target points are use (0, 75, and 150 mm) regardless of what is displayed in the Machine Setup widget.

Gauge Nominals

The *Gauge Nominals* widget allows the user to assign nominal values to a step gauge used for measurements. In the example shown in illustration 8 there are four different step gauges that could be used.

Any number or combination of step gauges can be used for the measurement along a machine axis. Nominal data must exist for each measurement imported.

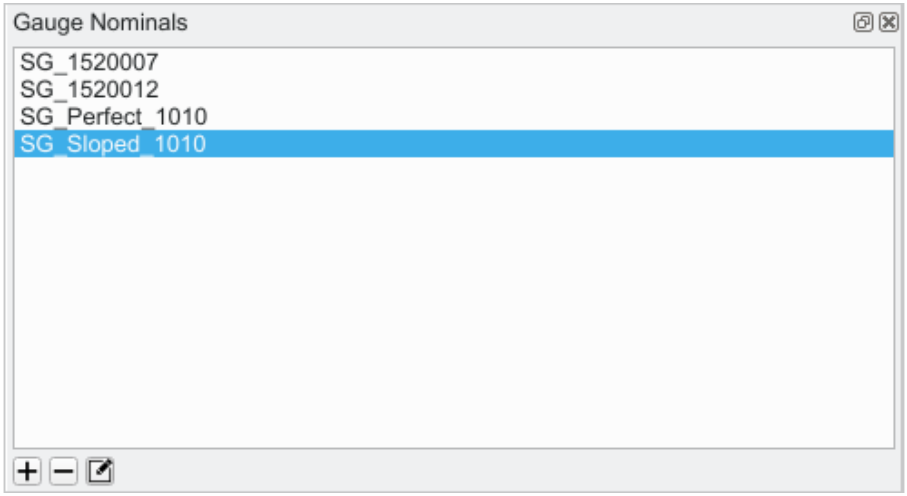

Illustration 8: Gauge Nominals widget.

Table 4: Gauge Nominals:

Image	*Description*
	Create a new step gauge nominal file. The serial number, dimensions, and known errors will need to be provided.
	Delete the selected step gauge nominal file.
	Edit the selected step gauge nominal file. This will open the step gauge nominal editor as shown in the following section.

Step Gauge Nominal Editor

The step gauge nominal editor allows modification of the nominal data for the selected step gauge. The step gauge nominal editor is shown in illustration 9.

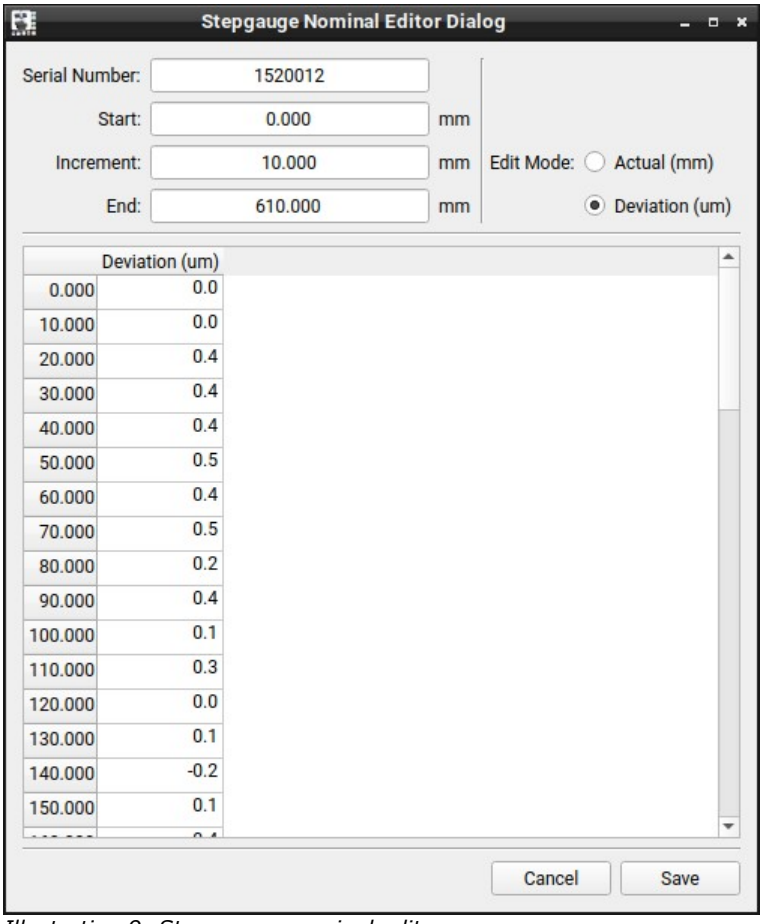

Illustration 9: Step gauge nominal editor.

To create new step gauge nominal data enter the nominal increment and end position of the gauge. Once configured choose a suitable editing mode and enter the known values of the gauge in the fields provided. The type of data entered is based on the Edit Mode option:

Table 5: Edit Mode Options:

Edit Mode	*Description*
Actual	The data entries is the actual measured step positions without a nominal value. The actual positions are in millimeters.
Deviation	The data entries is the deviation from the nominal step position. The deviation values are in micrometers.

Data can be entered into the table using standard clipboard functions.

Map Corrections

The *Map Corrections* widget shows the axis, position, and deviation calculated from all imported measurements. Illustration 10 shows an example of the *Map Corrections* dialog.

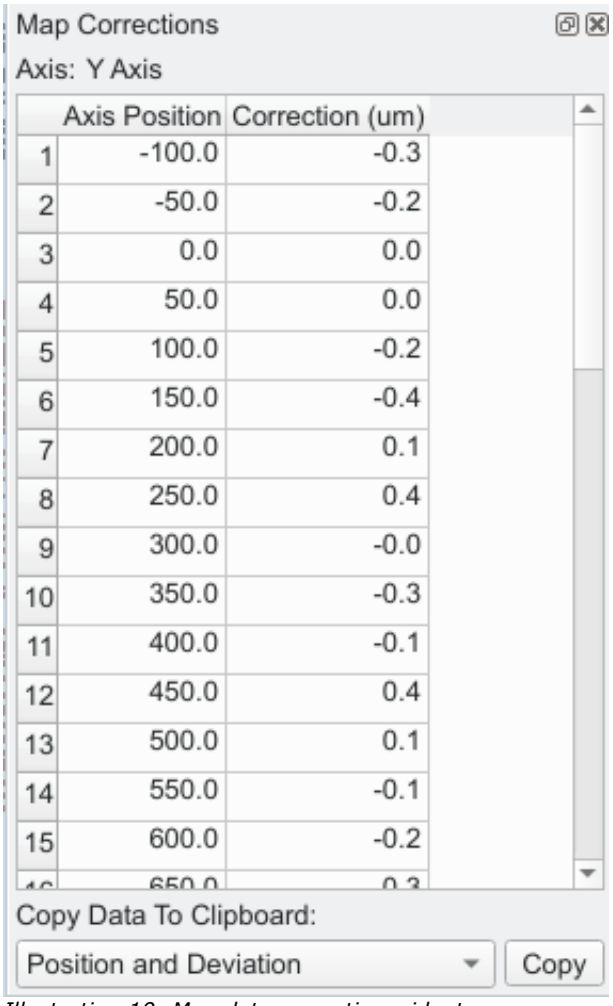

Illustration 10: Map data correction widget.

The data is aligned to the limits and increment from the *Machine Setup* widget. The axis is selected automatically based on the measurement axis of the input data. The data can be copied directly from the table but using the *Copy* function at the bottom is preferred as the data placed on the clipboard has more resolution than what is displayed in the table and it is possible to configure the type of data to copy to the clipboard.

Table 6: Copy Functions:

Edit Mode	*Description*
Position and Deviation	The clipboard data will contain the machine position and deviation.
Deviation Only	The clipboard data will only contain the deviation.
Position and Inverted Deviation	The clipboard data will contain the machine position and deviation. The deviation sign is reversed from what is displayed in the correction table.

Edit Mode	*Description*
Inverted Deviation Only	The clipboard data will only contain the deviation. The deviation sign is reversed from what is displayed in the correction table.

Measurement Formats

The data that can be imported into the Measurement Staging utility must be a step gauge *Linear Displacement Accuracy* measurement as described by the legacy ASME B89.4.1:1997 standard. Since there are no real standards for this kind of measurement (defacto or real) the format used by MeasureDirect is used instead.

The following is an example of this measurement file:

```
B89.4.1_Raw_Measurement:Version=1:Type=Step_Gauge

Scales_Begin:
X_Expansion_Coefficient:11.5
Y_Expansion_Coefficient:11.5
Z_Expansion_Coefficient:11.5
Scales_End:

Equipment_Identification:Perfect_1010

Alignment_Begin:
X_Axis:-0.000000040404,1.000000000000,0.000000949387
Y_Axis:-0.999999993672,-0.000000040297,-0.000112500017
Z_Axis:-0.000112500017,-0.000000949392,0.999999993671
Translation:505.00014,534.99656,-609.99743
Alignment_End:

Temperature_Begin:
X_Scale:20.000
Y_Scale:20.000
Z_Scale:20.000
Gauge:20.000
Temperature_End:

Probe_Offset:0.0000,0.0000,-195.0700
Probe_Vector:0.000000000000,0.000000000000,-1.000000000000

Measurement_Begin:

Description:Y Axis Center - 5
Reference_Step_Position:0.000

Point:0,10.00023,4.00000,-4.00000
Point:0,30.00160,4.00000,-4.00000
Point:0,50.00220,4.00000,-4.00000
…
Point:0,970.00123,4.00000,-4.00000
Point:0,990.00078,4.00000,-4.00000
Point:0,1009.99762,4.00000,-4.00000

Point:1,10.00121,4.00000,-4.00000
Point:1,30.00104,4.00000,-4.00000
```

```
Point:1,50.00100,4.00000,-4.00000
…
Point:1,970.00024,4.00000,-4.00000
Point:1,989.99905,4.00000,-4.00000
Point:1,1009.99929,4.00000,-4.00000

Point:2,10.00056,4.00000,-4.00000
Point:2,29.99770,4.00000,-4.00000
Point:2,50.00147,4.00000,-4.00000
...
Point:2,970.00223,4.00000,-4.00000
Point:2,989.99875,4.00000,-4.00000
Point:2,1009.99815,4.00000,-4.00000

Measurement_End:
```

Other measurement formats may be added in the future if it makes sense.

The individual point data in the step gauge measurement file is shown relative to the alignment system. The alignment system always has +X axis along the step gauge axis. The zero point is typically the end face and the first reported point is typically the first step of the gauge.

From the alignment data section of the measurement file:

```
Alignment_Begin:
X_Axis:-0.000000040404,1.000000000000,0.000000949387
Y_Axis:-0.999999993672,-0.000000040297,-0.000112500017
Z_Axis:-0.000112500017,-0.000000949392,0.999999993671
Translation:505.00014,534.99656,-609.99743
Alignment_End:
```

The measurement of this particular step gauge is almost exactly along the Y axis of the CMM <-0.000000040404, 1.000000000000, 0.000000949387>. The zero position (end face) of the step gauge is at position <505.00014,534.99656,-609.99743>. The end face is not measured as all points are expected to be probed in the same direction on the step gauge so the first point in the data shows a position of 10.00023 mm which is at 544.99679 in the machines coordinate system.

```
Description:Y Axis Center - 5
Reference_Step_Position:0.000

Point:0,10.00023,4.00000,-4.00000
Point:0,30.00160,4.00000,-4.00000
Point:0,50.00220,4.00000,-4.00000
```

The entry for the *Reference_Step_Position* tells the software which step was chosen as the zero position. Typically the end face of the step gauge, which is the step gauge calibration zero position, is used as the measurement zero but, in some cases, a measurement zero position may be used that is different from the step gauge zero. This entry must reflect which step of the step gauge is used as the measurement zero in order to properly assign nominal values to the measured points.

A typical example where a non-zero step is used as measurement zero is when measuring the step gauge in the Z axis of a CMM where the step gauge zero face is on or close to the CMM's surface table. It is necessary to start the measurement a few steps up in this case.

Revision History

Date	*Version*	*Changes*
Jul 30, 2024	1.0	New Program
Aug 1, 2024	1.1	[bug fix] Save and export disabled after importing using drag-drop Removed Close option from menu and toolbar. Duplication of New. Added vertical spacer to Machine Setup widget.