Error Map Explorer Users Guide

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Introduction

The Error Map Explorer utility was written to allow users to view the effects of compensation map data on a coordinate measuring machine. The correction values are calculated to the position of the active probe stylus and should be identical to methods used by most CMM inspection software.

The correction that is applied to machines from the compensation error map can be very difficult to visualize especially if more than one parameter is active at any one time. This utility was written to help make it easier to understand compensation data interpretation. Individual errors or combinations of errors can be activated or deactivated without having to create a new compensation map file and a visual display of the corrections can be shown that is very useful for understanding how the data is interpreted.

Test data can be recorded and then subsequently played back if numerous test points are needed. This feature was added for testing where many combinations of errors and probe offsets are needed to fully evaluate a compensation error map. This feature is particularly useful for testing unknown compensation methods used by third parties.

The Error Map Explorer utility can load compensation maps from a variety of manufacturers. A sample error map with is provided with this utility for evaluation purposes. A sample test sequence was also created for this error map to demonstrate the capabilities.

Where suitable, the interpretation of the compensation error map matches that of the manufacturer. Some compensation maps use features such as non zero rotation points which can have advantages in certain situations. The effect of features like this can be easily seen in the correction data.

This utility is cross platform compatible and can be run on GNU/Linux, OSX, and Windows.

Overview

The purpose of the Error Map Explorer utility is to load an existing coordinate measuring machine error compensation map and perform a simulated move through the volume. The amount of correction that is applied for any position in the machine is shown as the difference between the two sets of coordinate displays.

The left side of the main window is for the axis limits where the right side has all the options related to the active compensation error map. Three sliders are used to set the position of the simulated CMM in the machine volume. The range and step size of the sliders are defined in the limits section. The kinematic axis order and active errors is controlled from the options section of the Error Map Explorer.

Two sets of coordinate displays show the uncompensated and compensated position of the simulated CMM. Both coordinate displays can be offset by the active probe which mimics how most CMM software deal with probe offsets.

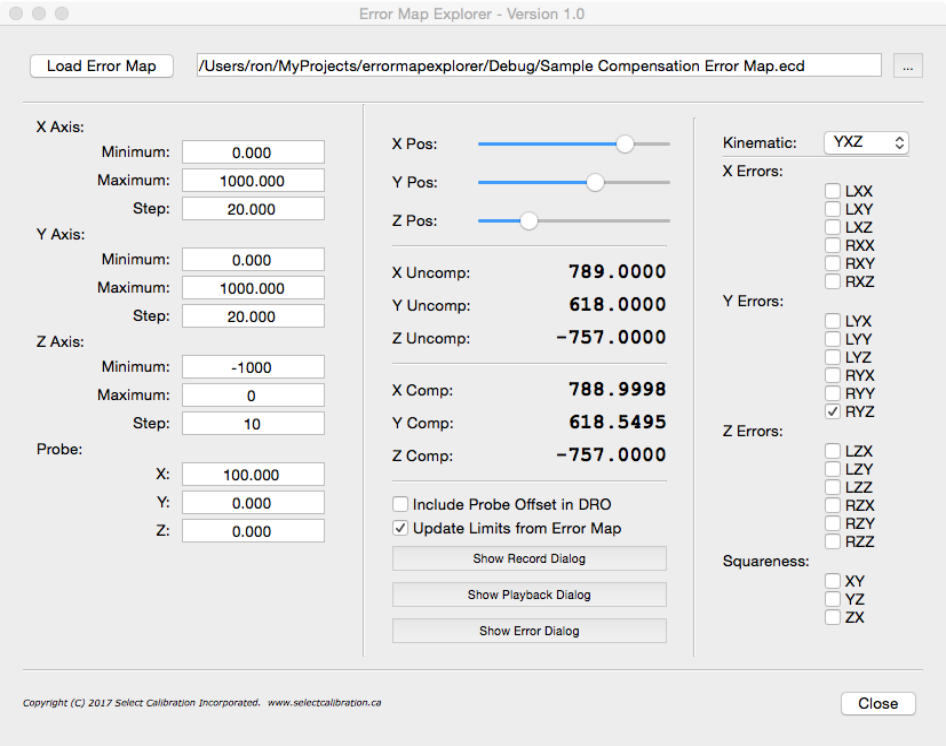
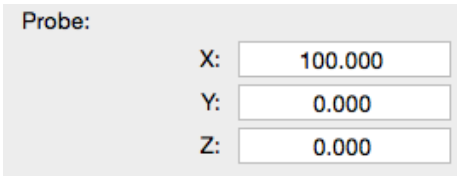
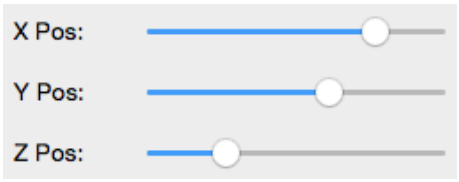
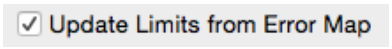
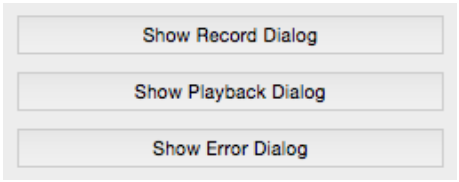


Illustration 1: Main window of the Error Map Explorer utility with an error map loaded. The limits section is on the left and the compensation options are on the right.

Some features of the Error Map Explorer utility such as the Error and Playback Dialogs can be shown or hidden as necessary. These windows will float independent of the main window of the Error Map Explorer utility. These windows are modeless dialogs and can be opened and manipulated without preventing access to any other part of the program.

Options

Item	*Description*
Load Error Map	Load the error map from the file shown on the right of this button. *Compensation maps can be loaded by dragging and dropping the file onto the Error Map Explorer utility program as an alternate method.*
...	Browse for a compensation map to load. This will open the standard file selection dialog.
Minimum: 0.000 Maximum: 1000.000 Step: 20.000	Minimum, maximum, and step for each of the three coordinate measuring machine axis. The position of the machine is controlled from the axis position sliders and these fields are used to define the range of the three sliders. *The step value is set to the absolute increment value of the*

Item	*Description*
	map axis. This value controls the step size of the axis sliders.
	Probe offset for the simulated probe connected to the simulated CMM. The compensation is applied to the end of the probe stylus which is defined by this offset. *A representation of the probe will be drawn in the error display window.*
	Sliders used to position the simulated coordinate measuring machine. *The slider increments are forced to integer precision so it is not possible to move to sub millimeter locations for any axis. This is intentional as it is easier to see the calculated compensation errors which are typically less than 1 mm..*
	Position of the machine prior to compensation. These values are set from the position of the three axis sliders and always have a resolution of 1 mm.
	Position of the machine after compensation. *The probe offsets are always included in this compensated position even if the probe offset is not included in the display readout (DRO).*
	The display coordinate windows can include the offset of the probe if this option is checked. The probe offsets are typically included with the coordinate display on a real CMM but are not necessary for the purpose of the Error Map Explorer utility.
	When a compensation map file is loaded the Minimum, Maximum, and Step values for each axis will be automatically changed to match the compensation file if this option is checked.
	Options useful for testing and visualization. These options are described in more detail in the following sections.
	Selection of the kinematic axis order. This option is set automatically when the file is loaded but can be overwritten to any supported axis order.

Item	*Description*
X Errors: ☐ LXX ☐ LXY ☐ LXZ ☐ RXX ☐ RXY ☐ RXZ	Options to enable or disable specific errors from the loaded compensation map. When checked, the option is active. *Toggling individual error map options with a 3D model active is a good way to visualize how that particular parameter is interpreted.*
Close	Close this program and all open windows.

Kinematic Axis Order

The kinematic axis order describes how the three axis of a coordinate measuring machine are connected to each other. A typical bridge CMM will have the Y axis travel along a fixed base and this becomes the supporting frame for the X axis. The Z is connected to the X and the probe is mounted at the bottom of the Z. The kinematic axis order of the CMM shown in illustration 2 would be YXZ since the Y axis is the first moving axis, the X is connected to the Y, and Z is connected to the X.

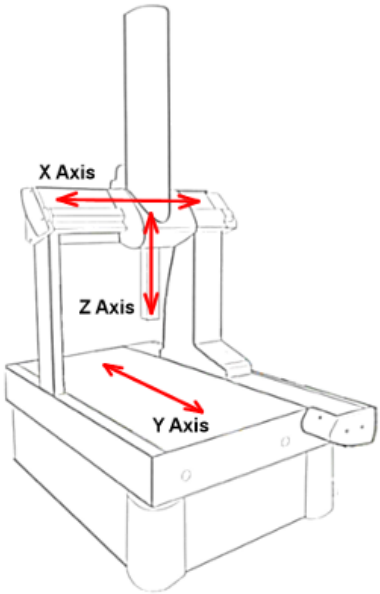


Illustration 2: Example of a machine with a kinematic axis order of YXZ.

Some compensation error maps include the kinematic order as part of the compensation data. Usually for this situation the compensation is calculated based on this data and independent of any settings in the inspection software. When the kinematic order is not defined inside the compensation error map the inspection software must define this at some point.

When a compensation error map is loaded the Error Map Explorer will automatically configure the kinematic order option to suite the loaded error map. The kinematic order can be changed to any

of the supported formats after loading the compensation file.

The common kinematic axis orders for bridge machines are XYZ and YXZ. For horizontal arm CMM's the kinematic order commonly used is XZY. Any combination of axis can be used but only certain combinations seem to appeal to general use.

The Error Map Explorer supports the kinematic axis orders of XYZ, YXZ, XZY, and YZX.

Compensation error maps that were never intended to be used with certain kinematic axis orders will still work in the Error Map Explorer utility.

Visual Display of Errors

The button *Show Error Dialog* will open a window that visually displays the effect of the error compensation that is currently active. The display recreates the selected kinematic axis order of the machine in a generic way. The simulated CMM position is animated with the axis sliders.

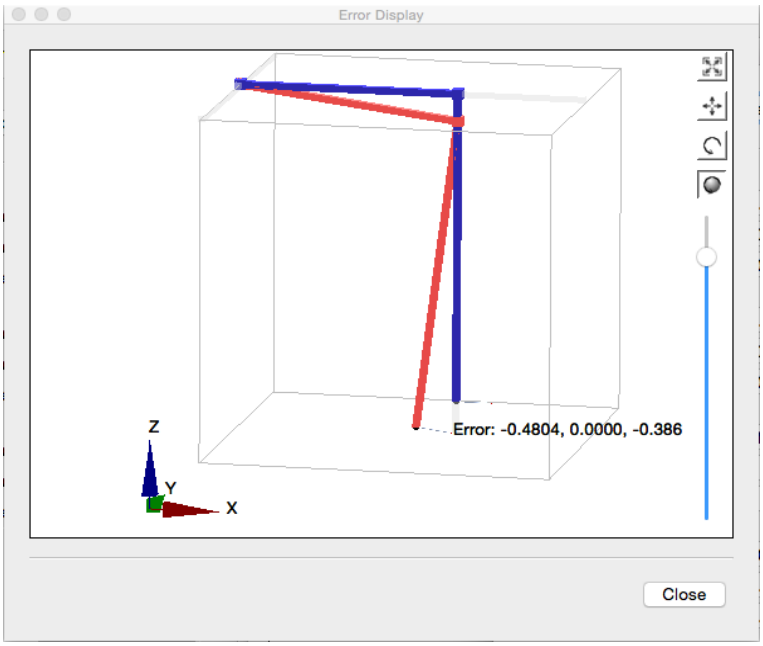


Illustration 3: Example of angular error RYY from the first axis of a CMM shown visually.

The Error Display window shows the following information:

Option	*Comments*
Translucent Grey Frame	This is the outline of the machine volume as well as the total range of each axis. In illustration 3 the total X axis travel can be seen near the top of the image.
Blue Frame	The nominal position of each axis of the machine. This starts at the position of the first kinematic axis and extends to the end of the third axis where the probe is connected.

Option	*Comments*
Red Frame	The position of each axis after applying error compensation. The position of the red frame relative to the blue is exaggerated using the magnification slider.
Probe	Both the nominal and compensated machine positions have a probe drawn at the end of third axis.
Error: <x> <y> <z>	Display of the sum of the error corrections at the probe tip from all axis in the kinematic chain and the effect from the probe offset.

Visual Display Controls

The Error Display window is not fixed and can be manipulated in a variety of ways. The kinematic axis model is displayed on the idea of a projection frustum to mimic the relative size of objects based on the distance away from the viewer to provide a slightly more realistic rendering of the volume of the data.

Image	*Description*
	Scale to fit. Adjusts the scale of the OpenGL 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. For systems with a single mouse button use Ctrl + Mouse.
	Rotate 2D Mode. When enabled a right mouse button click and drag will rotate the model around the center of the viewport. For systems with a single mouse button use Ctrl + Mouse.
	Rotate 3D Mode. When enabled a right mouse button click and drag will rotate the model around the click position on the displayed model. For systems with a single mouse button use Ctrl + Mouse.
	Error Multiplier. The relative error of the data can be increased with this slider. *The error multiplier will allow compensation errors to be exaggerated. Increasing the magnification increases the effect of the compensation map errors on the red kinematic machine model.*

In addition to the above controls areas of the kinematic model can be zoomed by drawing a box around any area of interest. The scale of the model can be increased or decreased using the mouse scroll button.

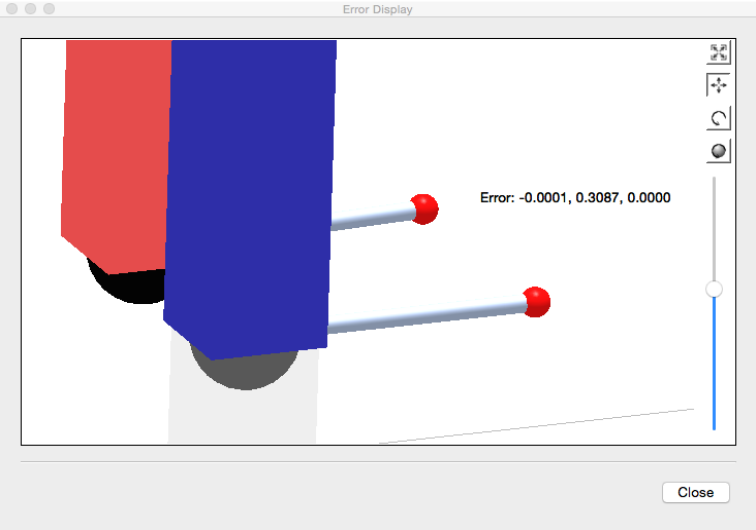


Illustration 4: Example showing the probe offset and error correction value at probe.

OpenGL

The error display data is drawn using OpenGL. The computer must have at least OpenGL version 2.x or higher in order to run this utility program with a functional visual display of the data.

Running the Error Map Explorer program on computers that only support OpenGL 1.x the visual display is replaced with an information window. An example of this information window is shown in illustration 5.

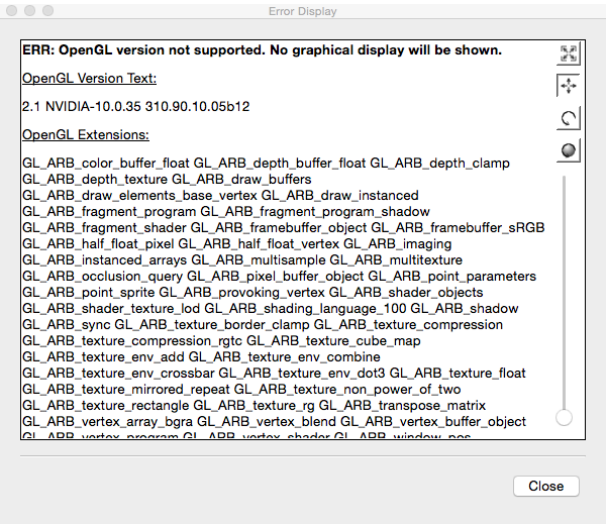


Illustration 5: Information screen that is displayed with unsupported OpenGL versions.

Record Sequence Dialog

The button *Show Record Dialog* will open a window that allows the user to create a file containing individual test positions that can be played back at a later date. The recorded information includes the actual error correction applied for each position and all related settings and is used as a comparison value for future tests. This information can be used for semi automatic validation tests of implementation methods of different compensation software.

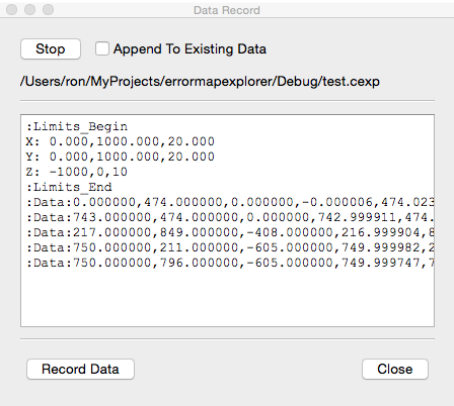


Illustration 6: Record data dialog showing captured information.

Option	*Comments*
Start / Stop	Start or stop the process of creating a sequence test file. When started a file dialog will appear allowing the user to input the name of the file to create or append to.
Append to Existing Data	If checked the new data will be added to the end of of an existing file.
Record Data	Store the current parameters as a file entry. Each entry is created by clicking on this button.
Close	Close the record dialog. If there is an open file the file is automatically closed.

File Format

The file format is a text file. The first section of the text file is expected to contain the data for the axis limits. Each subsequent line contains one entire set of data. The last value in each data line is an integer bit mask for all program options.

The following is an example of a record file:

```
:Limits_Begin
X: 0.000,1000.000,100.000
Y: 0.000,1000.000,100.000
Z: 0.000,1000.000,100.000
```

```
:Limits_End
:Data:1000.0,1000.0,1000.0,1000.0,1000.0,1000.0,0.0,0.0,0.0,134217736
:Data:1000.0,1000.0,1000.0,1000.0,1000.0,1000.0,500.0,0.0,0.0,134217736
:Data:1000.0,1000.0,1000.0,1000.0,999.9998,1000.500,0.0,500.0,0.0,134217736
```

Where:

```
:Limits_Begin     Beginning of the limits section of the sequence file.
:Limits_End       End of the section containing the axis limits.
X:                defines the minimum, maximum, and step size for the X axis.
Y:                defines the minimum, maximum, and step size for the Y axis.
Z:                defines the minimum, maximum, and step size for the Z axis.
:Data             <uncompensated>,<compensated>,<probe>,<flags>
```

Where:

```
<uncompensated>   comma separated XYZ values showing the uncompensated machine position
<compensated>     comma separated XYZ values showing the compensated machine position
<probe>           comma separated XYZ values for the active probe offset
<flags>           integer value for enabled options.  LXX=0b1, LXY=0b01, LXZ=0b001, ...
```

The extension used for the record file is *CEXP*.

Playback Dialog

The button *Show Playback Dialog* will show a window that is designed to execute test position sequences that were previously recorded. The playback can be step by step or automatically from start to finish. When playing all steps automatically there is a one second delay between steps to allow for viewing.

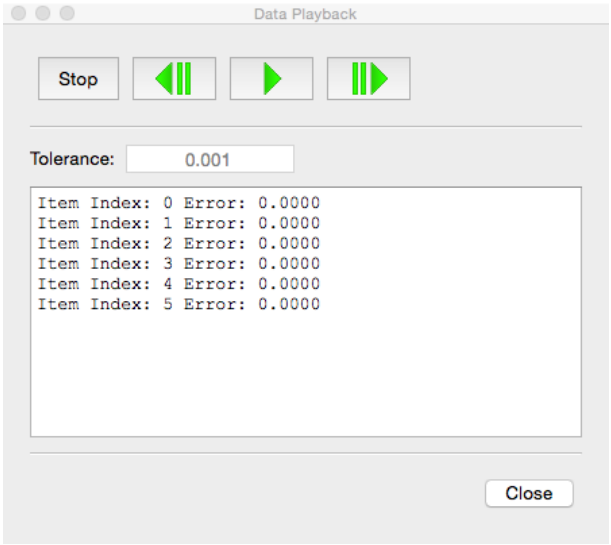


Illustration 7: Playback dialog. Each step will update the program based on the information from the record file.

Option	*Comments*
Start / Stop	Start or stop the process of of playing back a record sequence file.
Tolerance	Amount of error permitted between the errors from the record sequence file to the active data. When the tolerance is exceeded the entry in the log will show a series of asterisks on the end of the data line.
	Backward and forward buttons. These options allow the manual stepping through all the data in the playback sequence in either direction.
	Play all steps. The data is played back from the beginning to the end. Each step is automatically paused for one second allowing for quick review.
Close	Close the playback dialog.

Revision History

Date	*Version*	*Changes*
June 7, 2017	1.0	New Program
Nov 3, 2017	1.1	Interpretation change for LK horizontal arm CMM's. Fixed problem loading DEA type 4 maps with incomplete fourth axis header data.
Feb 18, 2017	1.2	Updated interpretation of maps with corrections such as a fourth axis or dual scale.