Effective Presentation Methods for 3D Data Using JMP®

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Abstract

Presenting three-dimensional data in useful and effective ways offers challenges regardless of the visualization platform. This paper will explore several methods (and their combination) that can be used within JMP to simply and effectively present three-dimensional data sets.

1. Use of 3D ***surface***, ***mesh***, and ***scatterplots***. These projection-based tools commonly used for 3D visualizations and analyses within JMP are first explored using a complex undulating surface defined precisely by a mathematical function.

2. Use of ***contour*** plots to flatten a three-dimensional data set to two dimensions. The same function-based data used to present surface, mesh, and scatterplots is then plotted as a contour plot. A contour plot slices the data into planar groupings and produces outlines/regions that define the boundaries/contours produced by those slices.

3. Use of a ***color scale*** to represent the third dimension. To demonstrate this technique, data representing wear scar development on a calibrated precision gauge block is presented with position as one dimension, calibration cycle number (time history) as the second dimension, and wear scar depth as the third (color) dimension.

4. Use of ***grouping*** to show progression along a third dimension. For this demonstration, the gauge block wear scar data is presented again using grouping over time in order to show how the gauge block starts with no wear and then is progressively worn through its repeated use. The grouping, in this case, acts as a form of averaging over defined intervals of time.

5. Use of ***marker transparency and size*** to produce a pseudo-density as the third dimension. To demonstrate this technique, multiple scan data sets acquired with a tactile profilometer are overlaid in order to show the repeatability of the measurement system. When the multiple data sets overlay closely, markers will completely or partially hide other markers causing knowledge of data density (and consequently scan agreement) to be lost via marker saturation. In cases like this, use of marker transparency and size can help to highlight the agreement and deemphasize outlier and/or errant readings. The plot produced is effectively a density plot where marker transparency and size are used in combination as a mechanism to generate a density dimension.

6. Use of ***time (animation)*** to represent a third dimension. For the final example, two-dimensional scan data sets from repeated CMM (Coordinate Measuring Machine) calibrations are concatenated into a single large JMP table. Each scan data set shows the condition of the probe tip (as measured in a single planar slice) using a reference sphere. Over time, wear scars develop on the probe tip due to its use at preferred contact angles. The development of these wear scars is animated within JMP through the use of the Local Data Filter.

Several of these methods (both individually and in combination) are easy to perform within the JMP Graph Builder. Due to its versatility and intuitive user interface, the JMP Graph Builder should be one of the first platforms the JMP user launches for data visualization, analysis, and exploration.

Table of Contents

Table of Figures

Introduction

Numerous opportunities arise in data analytics for visualizing multi-dimensional data sets. Within the broad domain of manufacturing, and across the many R&D disciplines which help shape and redefine it, it is quite common to require visualization of data which is comprised of at least three simultaneous (but not necessarily spatial) dimensions. The effective presentation of multi-dimensional data is often challenging for the data scientist. This is primarily because:

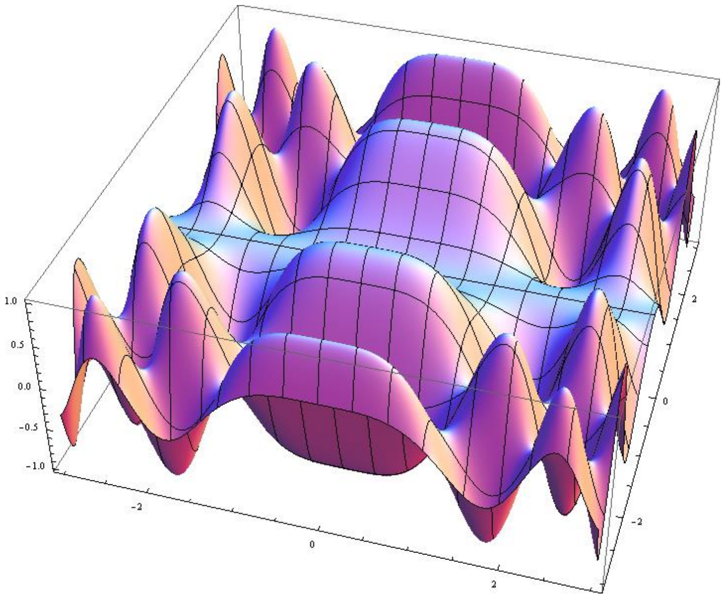
1. The most common computer display and print technologies are, from a spatial context, fundamentally two-dimensional mediums.

2. Effectively presenting multi-dimensional data within the limits of two spatial dimensions requires some sort of transformation or mapping beyond simply zooming and panning.

3. Most importantly, for the visualization to be effective and memorable, it must elicit in the target audience an intuitive mapping into a cognitive context of the problem space. In other words, the individuals who view the data visualization, given other pertinent knowledge, should be able to construct a malleable mental image which serves as a bidirectional bridge between the data and at least some of what is understood about it.

Use of Projections

When a mathematician or engineer thinks about three-dimensional data, one of the first types of plots considered is a three-dimensional projection (as shown in Figure 1) where points in the three-dimensions are projected onto a two-dimensional surface via a set of transformations. The style of the plot produced can be a point cloud (scatterplot), a line plot (path), a needle plot, a mesh, a tessellated surface, any combination of those, or numerous variations. Virtually all mathematical and data analysis packages support such visualizations, and they can be enormously effective when used in the proper contexts.



$z = \sin(x^2) \cdot \cos(y^2)$

Figure 1: 3D surface plot of a function.

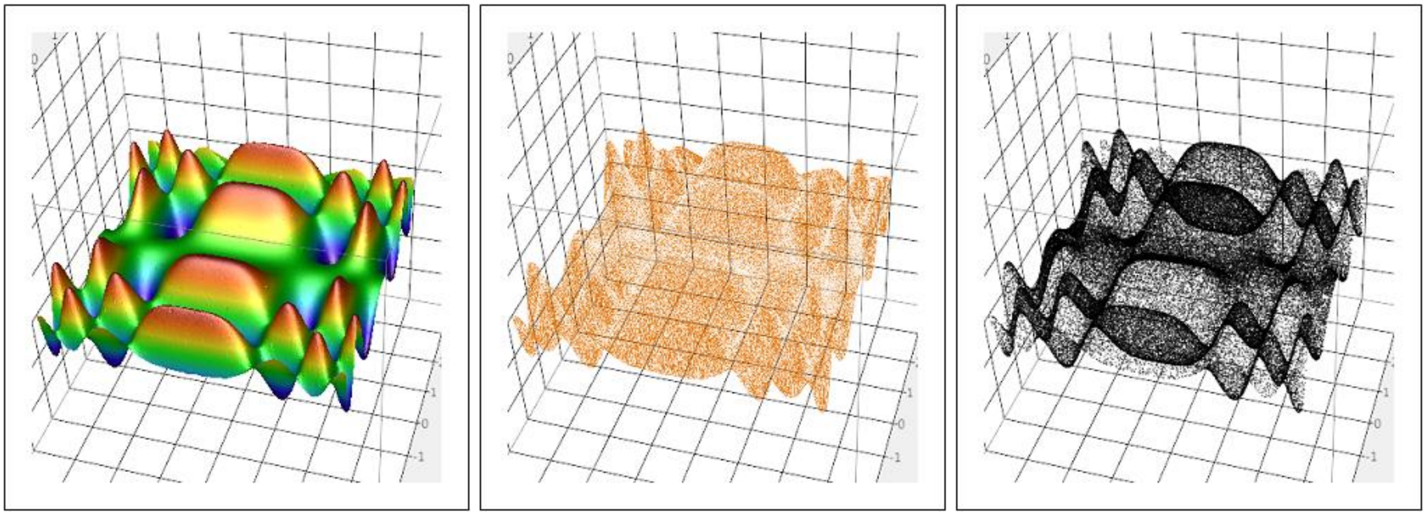
https://en.wikipedia.org/wiki/Three-dimensional_graph

JMP also supports three-dimensional projections in both the Scatter Plot 3D and Surface Plot platforms (both found on the Graph menu). For example, the 3D trigonometric function visualized above in Figure 1 can be reproduced in JMP using the following formula columns and the Surface Plot platform.

x ⇔ Pi() * Random Uniform(-1, 1)
y ⇔ Pi() * Random Uniform(-1, 1)
z ⇔ Sin(:x ^ 2) * Cos(:y ^ 2)

To generate the sample dataset, simply start with a new table, create the three columns (named x, y, and z), apply the column formulas, and then add 100,000 rows to the table. JMP will compute 100,000 uniformly random points over the domain $-\pi < x < \pi$ and $-\pi < y < \pi$.

Once the data set is created, we can use the Surface Plot platform to produce surface, mesh, and scatterplot (point cloud) graphs like those shown below in Figure 2.



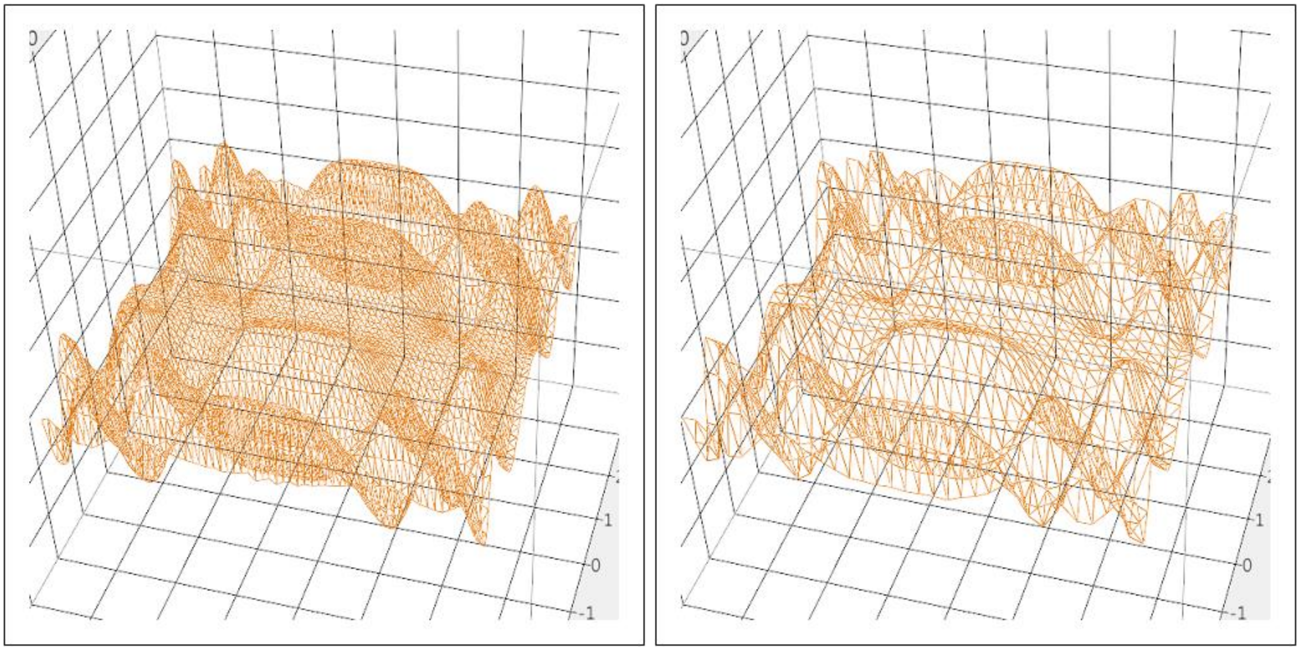
Surface Mesh Points

Figure 2: JMP's Surface Plot platform can produce 3D surface, mesh, and scatterplot views.

Note, however, that the mesh plot produced using our example data will not be especially functional because JMP's Surface Plot platform apparently does nothing to take the randomly spaced points we generated and interpolate between them using a user-defined mesh spacing. One way in which to resolve this issue with our example data is to map the x and y coordinates to the nearest user-defined mesh boundaries. We can do this with the following additional columns for xx and yy (highlighted) which respectively round the x and y values using the table variable called Mesh Size.

x ⇔ Pi() * Random Uniform(-1, 1)
y ⇔ Pi() * Random Uniform(-1, 1)
z ⇔ Sin(:x ^ 2) * Cos(:y ^ 2)
xx ⇔ :Mesh Size * Round(:x / :Mesh Size)
yy ⇔ :Mesh Size * Round(:y / :Mesh Size)

Figure 3 below shows the mesh plot of variables xx, yy, and z using a Mesh Size of 0.1 and 0.2. Now we have a mesh visualization that we can work with. Of course, JMP users would prefer to have the mesh size option within the Surface Plot platform, thereby eliminating the need to create additional formula columns. Ideally, this enhancement would be implemented as a dynamic control with the ability to combine the independent axes (single mesh size control) as was done here, or separately round each independent axis (using multiple controls).



Mesh Size = 0.1

Mesh Size = 0.2

Figure 3: JMP’s mesh plotting requires mesh-compatible data.

The Scatterplot 3D platform can also be used to visualize our example three-dimensional data. The Scatterplot 3D platform does not have a surface or mesh option, but it does allow points to be connected in various ways (grouped or ungrouped). This can be useful in some situations, but because our example dataset is produced randomly, the option to connect points is not useful in this context. Nevertheless, this platform can also be an option for displaying multi-dimensional data as shown below in Figure 4.

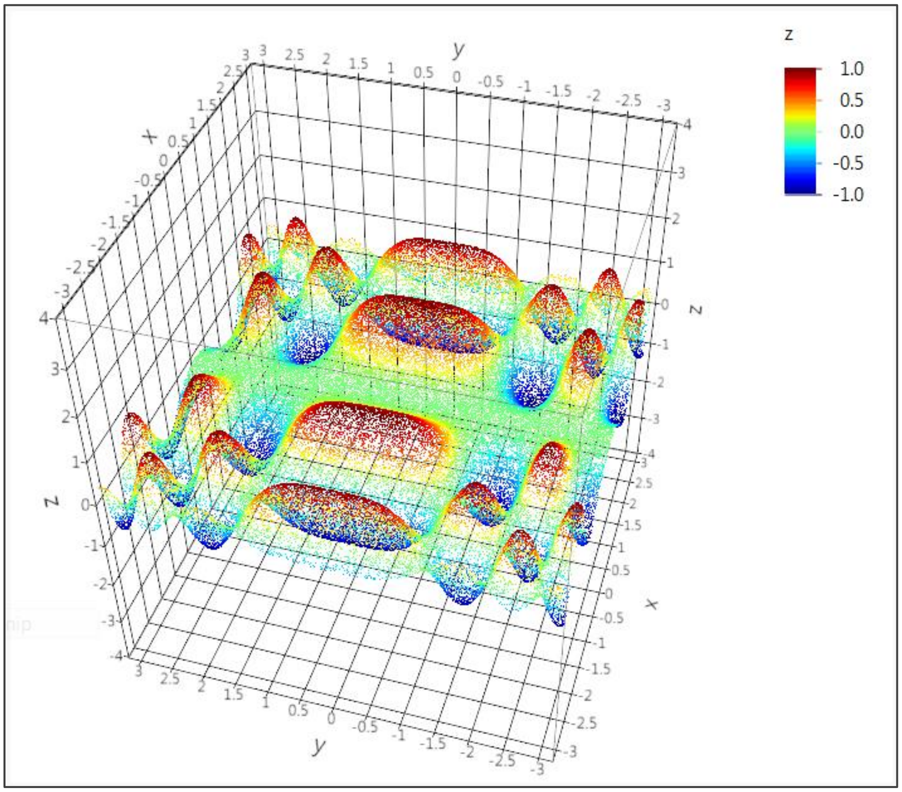
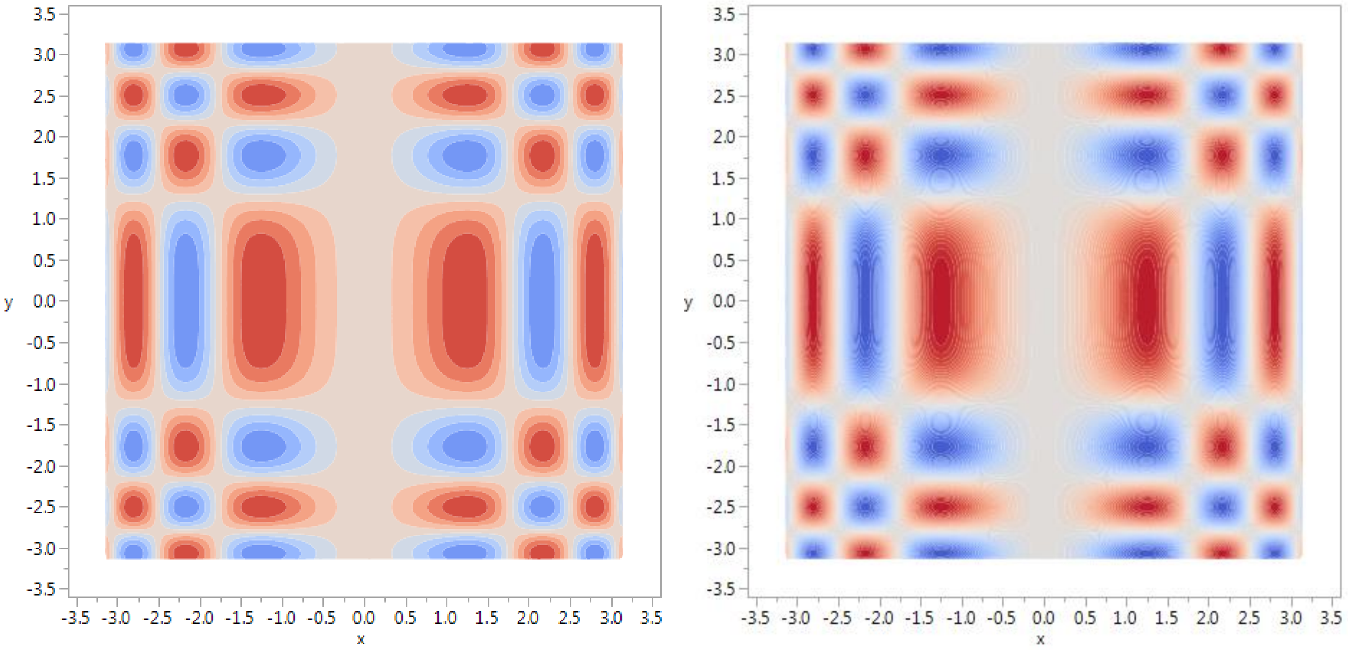


Figure 4: JMP’s Scatterplot 3D platform can also be used to display point clouds.

Use of Contour Mapping

Also found on the Graph menu, the Contour Plot platform can be used to visualize three-dimensional data by mapping the third axis to a discrete number of groupings (referred to as contour levels) and applying color mapping to those contour levels. For example, Figure 5 below shows two contour plots of the same data already presented with the dependent variable z mapped to 10 contour levels on the left and 50 contour levels on the right. Both contour plots are colored using the Blue White Red color gradient.



10 Levels

50 Levels

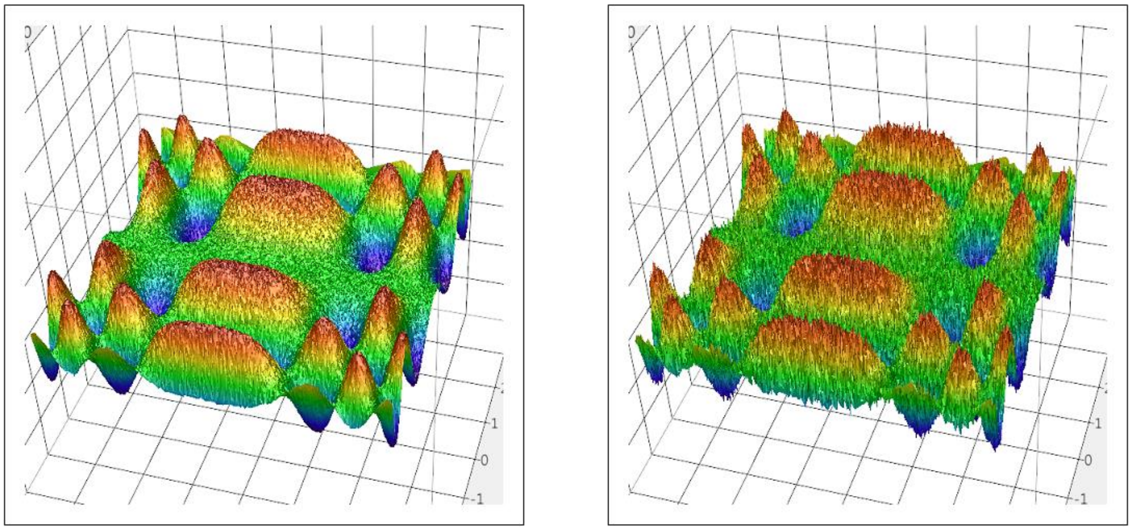
Figure 5: JMP's Contour Plot platform can be used to visualize the third dimension as levels.

Impact of Noisy Data

These are all very powerful visualization tools provided within JMP, but they are not the only ways to visualize three-dimensional data and may not always be as effective, intuitive, or user friendly as other approaches. But before looking at the other approaches (and data sets based on real measurements), it is beneficial for our understanding to take our arbitrarily precise function-generated dataset and add some Gaussian noise to it.

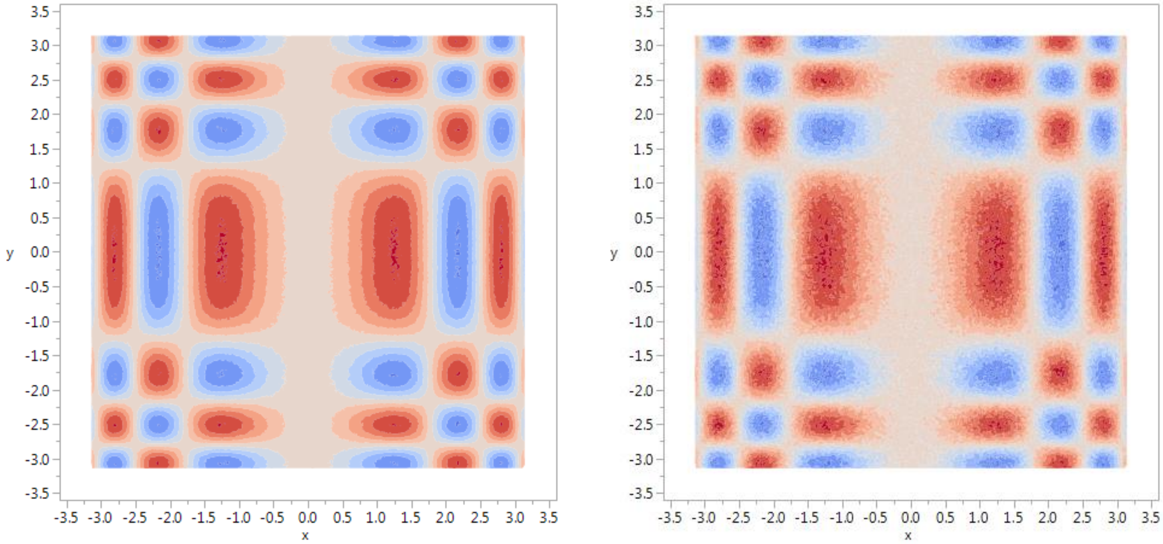
```
x   ⇔ Pi() * Random Uniform( -1, 1 )
y   ⇔ Pi() * Random Uniform( -1, 1 )
z   ⇔ Sin( :x ^ 2 ) * Cos( :y ^ 2 ) + Random Normal( 0, :Noise Sigma )
xx  ⇔ :Mesh Size * Round( :x / :Mesh Size )
yy  ⇔ :Mesh Size * Round( :y / :Mesh Size )
```

Noise Sigma used in the above formula is another table variable. For each z coordinate, a noise contribution is added to the noiseless function. The noise contribution is based on a randomly determined value selected from a normal distribution which has a mean of zero and standard deviation equal to Noise Sigma. Below, in Figure 6, Figure 7, and Figure 8, we can see how the surface and contour plots are impacted by different noise levels. On the left, the graphs were created with Noise Sigma set to 0.02. On the right, it was set to 0.1. As shown, it becomes more difficult to visualize the average behavior in the surface plots with high levels of noise. On the other hand, the contour plots can still be interpreted for average behaviors in the presence of high levels of noise.



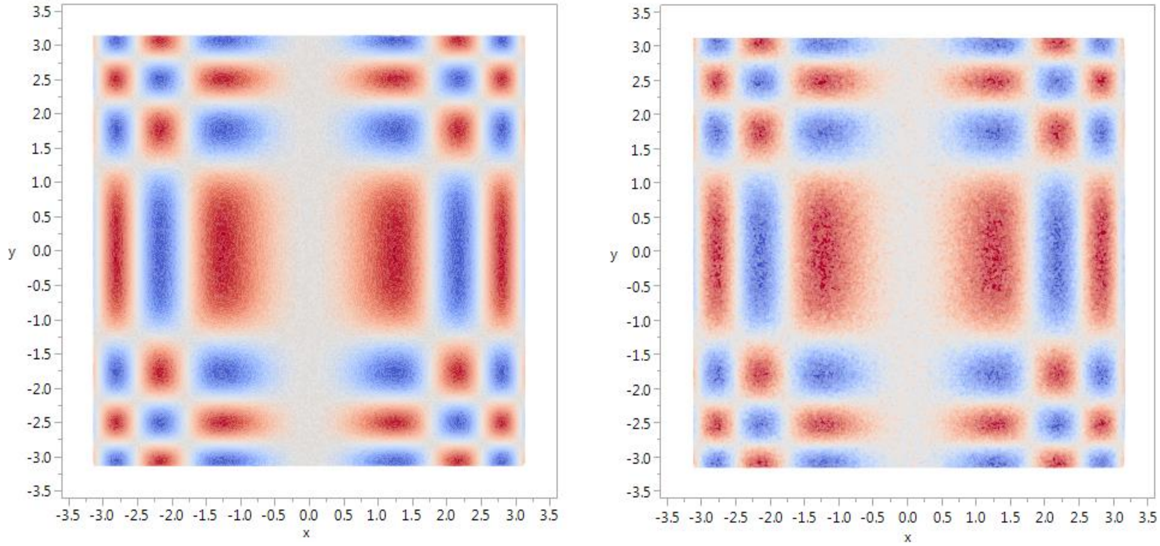
Noise Sigma = 0.02　　　　Noise Sigma = 0.1

Figure 6: Surface plots with noisy data.



Noise Sigma = 0.02　　　　Noise Sigma = 0.1

Figure 7: 10-Level contour plots with noisy data.



Noise Sigma = 0.02　　　　Noise Sigma = 0.1

Figure 8: 50-Level contour plots with noisy data.

Gauge Block Wear Scar Example

In the course of my work at The Timken Company, I have had the occasion to measure small, shallow, and barely visible wear scars introduced into Zirconia (ZrO_2) gauge blocks (see Figure 9 below). These gauge blocks are scanned repeatedly as part of a daily calibration cycle on a custom CMM (Coordinate Measuring Machine). Every eight hours, the installed gauge block is scanned (via tactile, force-based, profilometry) using a force-sensing probe with a 1 mm diameter, nominally spherical ruby (Al_2O_3) probe tip. This scanning (of both planar faces) establishes both the location of the probe tip and the location of the gauge block within the CMM coordinate system. The scans are approximately 3 mm long (vertical direction) and 0.5 mm long (horizontal direction). They are orthogonal to each other. The gauging force applied during the scans is low, only 8 grams, which is fairly typical for these coordinate measuring conditions.

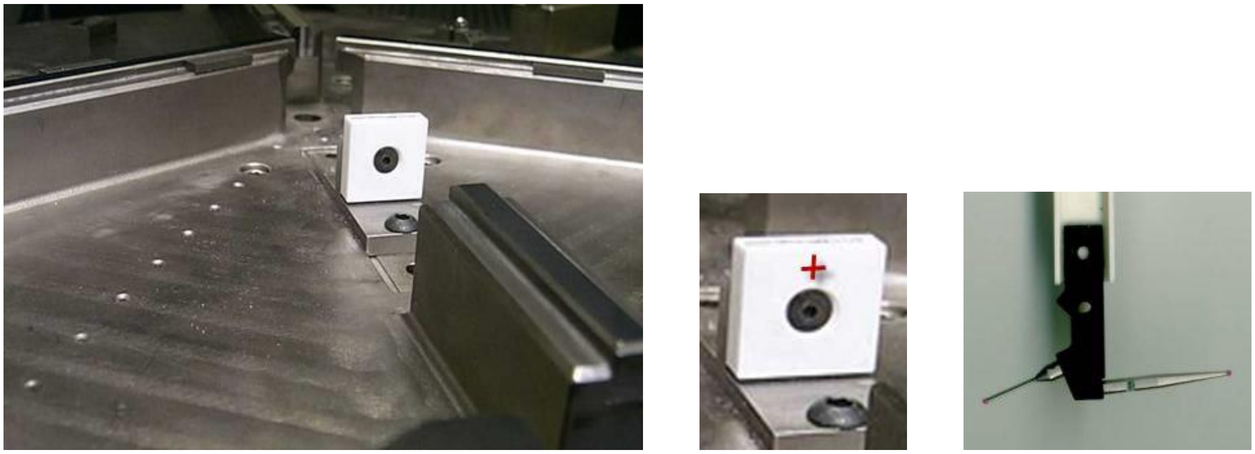


Figure 9: Gauge block installed on a custom CMM and scanned as depicted by the red cross.

One would think that such low probing forces would be insufficient to create a noticeable wear scar, but several conditions lead to the accelerated development of a wear scar on the gauge block faces:

1. ***Abrasion*** – Abrasive particles can become embedded in or attached to the ruby probe tip accelerating wear of the Zirconia gauge block. These abrasive particles typically originate on hardened steel production parts which are measured by the CMM.

2. ***Facets*** – The nominally spherical ruby probe tip is worn flat at certain preferred locations due to its use measuring cylindrical and conical product features. The unevenly distributed usage pattern causes facets to develop (and therefore edges) increasing the ability of the probe tip to gouge the gauge block during the horizontal scans (which occur via rotation of the gauge block relative to the probe).

3. ***Repetition*** – Each face of the gauge block is scanned a minimum of four times each eight hour shift at nearly the exact same location. In one year, each scan line would be traversed a minimum of 4,000 times.

4. ***Time*** – Wear scar development was evaluated over a period of nearly five years (corresponding to a minimum of 20,000 scans at each location).

5. ***Scale of Interest*** – Wear scar depth which is important in this context is measured in tens of nanometers. The wear scar depth measured in this example is only 200 nm at the conclusion of the study. That sort of depth is very small, only half of the wavelength of the shortest wavelength of light visible to humans (violet light is about 400 nm). With a lattice parameter of roughly 0.5 nm, the 200 nm wear scar depth developed over roughly five years represents only about 400 lattice units.

The pictures presented below (Figure 10) show what these wear scars look like under an optical microscope. The images have been contrast enhanced to highlight the wear scars and scratching. Unfortunately, these optically-produced images do not effectively present wear scar depth. However, the wearing, scratching, and gouging in the gauge block face is evident by the cross-shaped pattern where the scanning occurred.

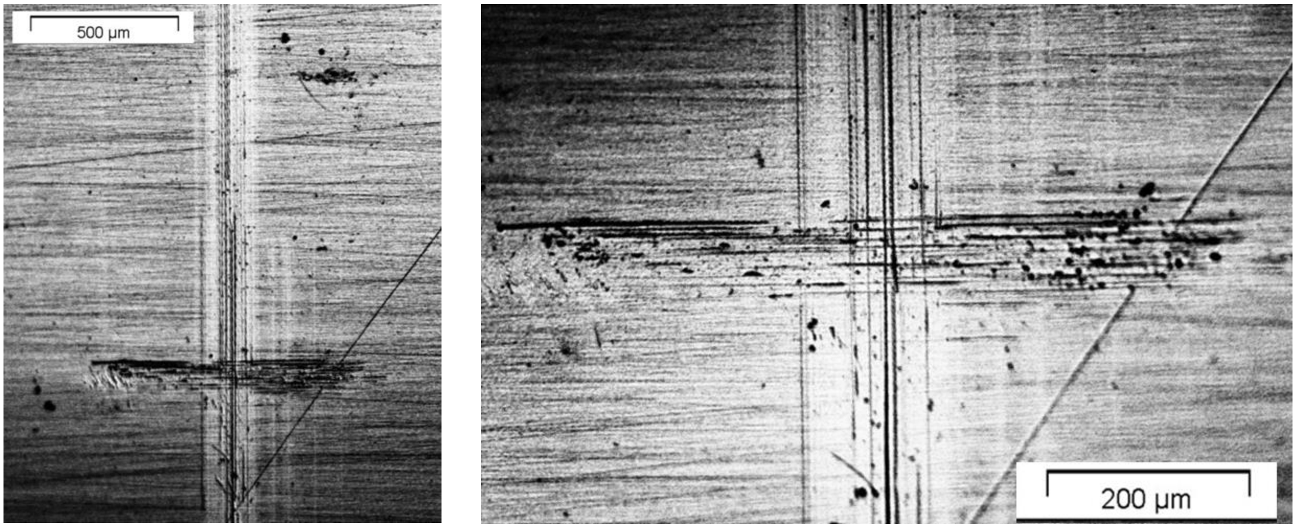
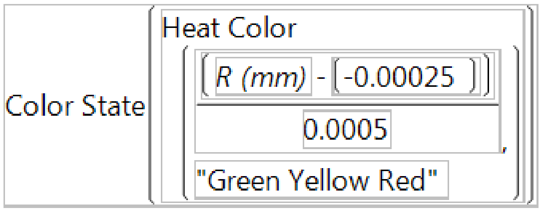


Figure 10: Optical images of Zirconia gauge block surface highlighting cross-shaped wear scar.

To analyze the CMM scan data in JMP, the data for each vertical scan acquired by the CMM were concatenated into a single large JMP data table with the following three columns:

1. Calibration Cycle
2. R (mm) – Deviation of probe tip as it traverses up the face of the gauge block. Measure of scar depth.
3. Z (mm) – Location of probe tip as it traverses up the face of the gauge block.

In order to keep the marker colors consistent across all graphical views, a Color State column was created using the following formula (Figure 11). The formula maps the R coordinate (wear scar depth) to a Green-Yellow-Red color gradient where green represents -250 nm (points below surface), yellow represents 0 nm (points on the unworn surface), and red represents +250 nm (points above the surface, i.e. caused by debris, noise, surface roughness, and/or measurement errors). A similar column was created for a Blue-White-Red color mapping.

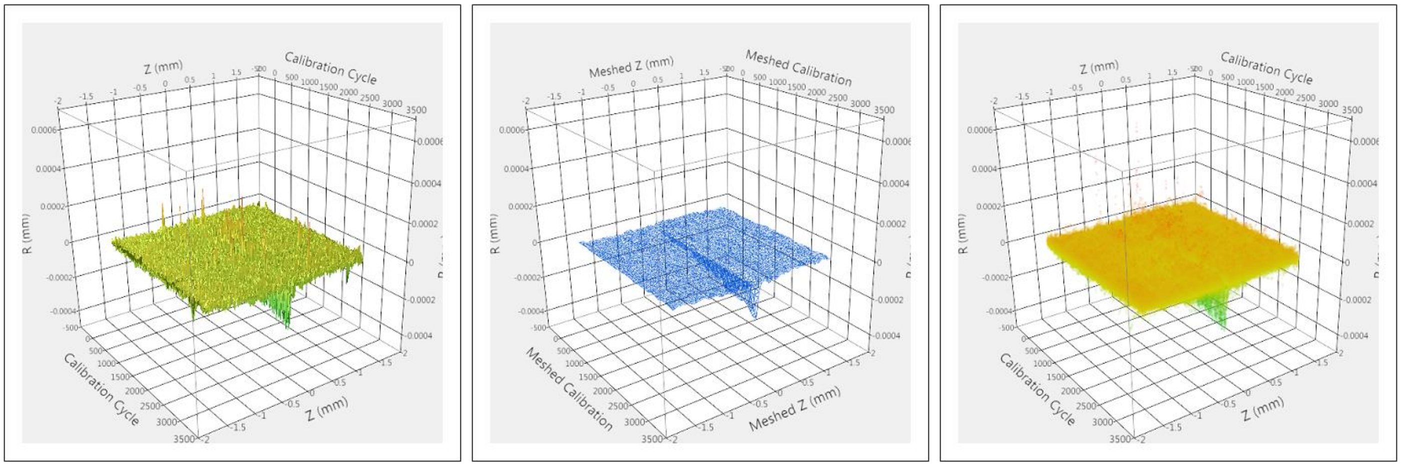


Color State = Heat Color($\frac{R\ (mm) - (-0.00025)}{0.0005}$, "Green Yellow Red")

Figure 11: Defining a Color State column formula.

Color gradient mapping, -250 nm to +250 nm mapped to Green-Yellow-Red gradient.

As was presented in the earlier function-based example (refer to Figure 2), from this large table of gauge block wear scar data (containing nearly 800,000 rows), very impressive projection-based 3D surface, mesh, and point clouds can be produced as shown in Figure 12 below. These graphs present a 3D picture of increasing wear scar width and depth as more calibrations are performed. In the rotational orientation shown, the increasing number of calibrations is shown as progression toward the front of the 3D projection. The meshed image is probably the most useful of the three for showing how the wear scar increases in both width and depth as more calibrations are performed. Its utility is that it is immune to the noise, surface roughness, and outlier points and it is semi-transparent as a function of the mesh size and line width used.



Surface Mesh Points

Figure 12: JMP’s Surface Plot platform used to produce 3D projection plots of wear scar data.

It is evident from the above that 3D projection can be a useful and informative presentation of this data. This is especially so for dynamic presentations where the viewer can interact with the 3D plot. However, these plots have a few significant disadvantages:

1. They must be rotated and zoomed in order to provide optimal interpretation. A static report might require multiple rotations, perspectives, and/or lighting conditions to be shown in order to highlight interesting features in the data.

2. JMP’s 3D Surface Plot and 3D Scatterplot platforms have a fixed cubic presentation volume which is not flexible enough for all presentation needs. For example, it might be desirable in this data to stretch the calibration cycle number axis and shrink the R deviation axis such that the cubic form of the presentation volume is changed to that of a long, flat, right rectangular prism. At least in JMP 12.0, there are no options in the 3D viewer to do that.

3. Zooming, panning, and customizing the axis scales in the JMP’s 3D plots is generally less intuitive and less friendly than JMP’s Graph Builder platform. For example, there is no capability (that I could find) to right click on an axis in order to set minimum, maximum, number of major and minor grids, number format, etc.

4. A few controls are buried under the Settings menus which would be better exposed in the main panel (and/or with keyboard/mouse functions). For example, it should be easier to zoom in and out of the 3D scene. Using the Z command to bring up the magnifier control will crash JMP every time.

All-in-all, the 3D projection-based graphing capability enabled in JMP 12.0 is a good start, but needs further development to be rave-worthy.

But there is no shortage of visualization tools within JMP. JMP's Contour Plot platform can also be used to present the wear scar data as shown in Figure 13. Notice the narrow green line (or more visible blue line in the second plot) which develops toward the right of the contour plot as the number of calibrations performed increases and the wear scar depth increases. Although the contour plots have the advantages of not requiring special rotations, being suitable for static presentations, and allowing aspect ratio to be stretched as needed, they also have several disadvantages:

1. Contour levels are determined by discrete bands.
2. Increasing the number of contour levels for finer resolution can sometimes become problematic.
3. At least in this plot, the contour levels hide gaps in the data which occurred due to missing calibrations.
4. Contour plotting in JMP 12.0 has usability limitations within the Graph Builder so often requires that the user switch platforms (from Graph Builder to Contour Plot) in order to produce usable contour plots.

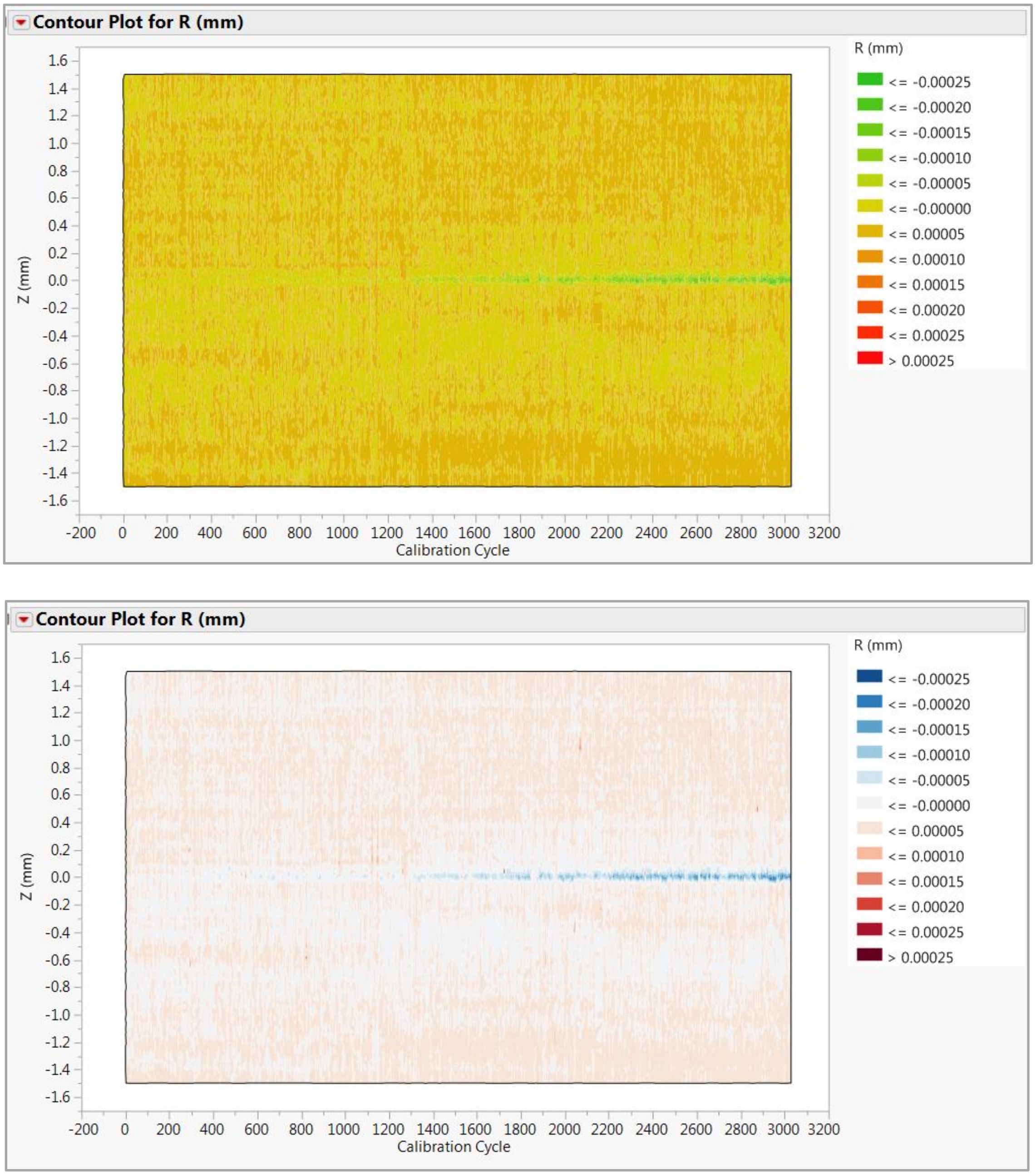


Figure 13: JMP's Contour Plot platform used to present gauge block wear scar data.

As opposed to 3D projections and contour plots, there is another approach which can be used to produce plots that are very similar to contour plots (using color gradients to show level) but which also have a pseudo-density dimension produced through the choice of marker size, marker type, and marker transparency settings. Moreover, these plots can be produced directly within JMP's powerful and intuitive Graph Builder platform.

Much like the contour plots in Figure 13, the graphs shown below in Figure 14 present the gauge block wear scar data very effectively. In this case, Graph Builder was used in scatterplot (point/marker) mode. The graphs were produced by dragging the column variables to the drop zones as follows:

X ⇦ Calibration Cycle
Y ⇦ Z (mm)
Color ⇦ R (mm)

Point mode was selected and the marker size and marker transparency were adjusted to suit the presentation. Choice of marker size and marker type affects the tiling via overlap. For example, if markers are spread out too sparsely, a larger marker size can be selected to better tile the unsampled regions of the variable space. Likewise, in some cases, it might be desirable to change marker type from circular to square, rectangular, or diamond-shaped markers in order to better tile the space. Importantly, marker transparency can be used to soften the image, average coincident points, and deal with excessive marker overlap. In the images below, marker transparency was set to 0.3 (where 1.0 is <u>not</u> transparent and 0.0 is fully transparent).

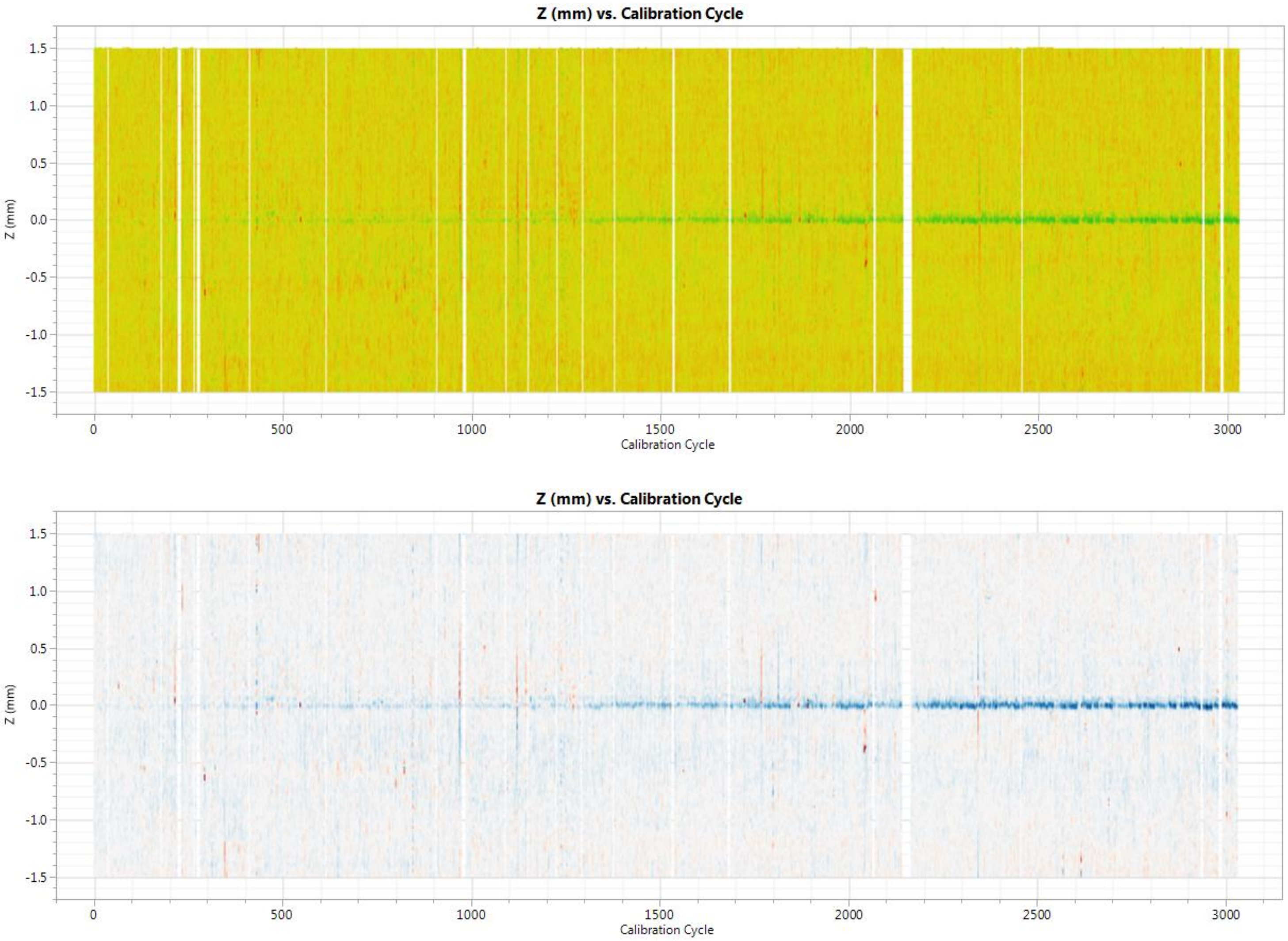


Figure 14: JMP's Graph Builder platform used to present gauge block wear scar data.

Within Graph Builder, there are other options for adding additional dimensions to a plot. In the example shown in Figure 15, Graph Builder was configured as follows:

X ⇦ Z (mm)
Y ⇦ R (mm)
Color ⇦ R (mm)
Points ⇦ Enabled
Smoother ⇦ Enabled
Transparency ⇦ 0.2
Group Y ⇦ Calibration Cycle

Here, the use of grouping by calibration cycle number enables the presentation of the gauge block wear scar development in successive slices of the calibration history. The use of color is optional here. However, the use of transparency is necessary as it helps to provide density information. For example, outlier points are visible, but do not draw significant attention away from the more important wear scar development. The dark smoother spline running through the data helps to emphasize the increasing depth of the wear scar over the calibration history.

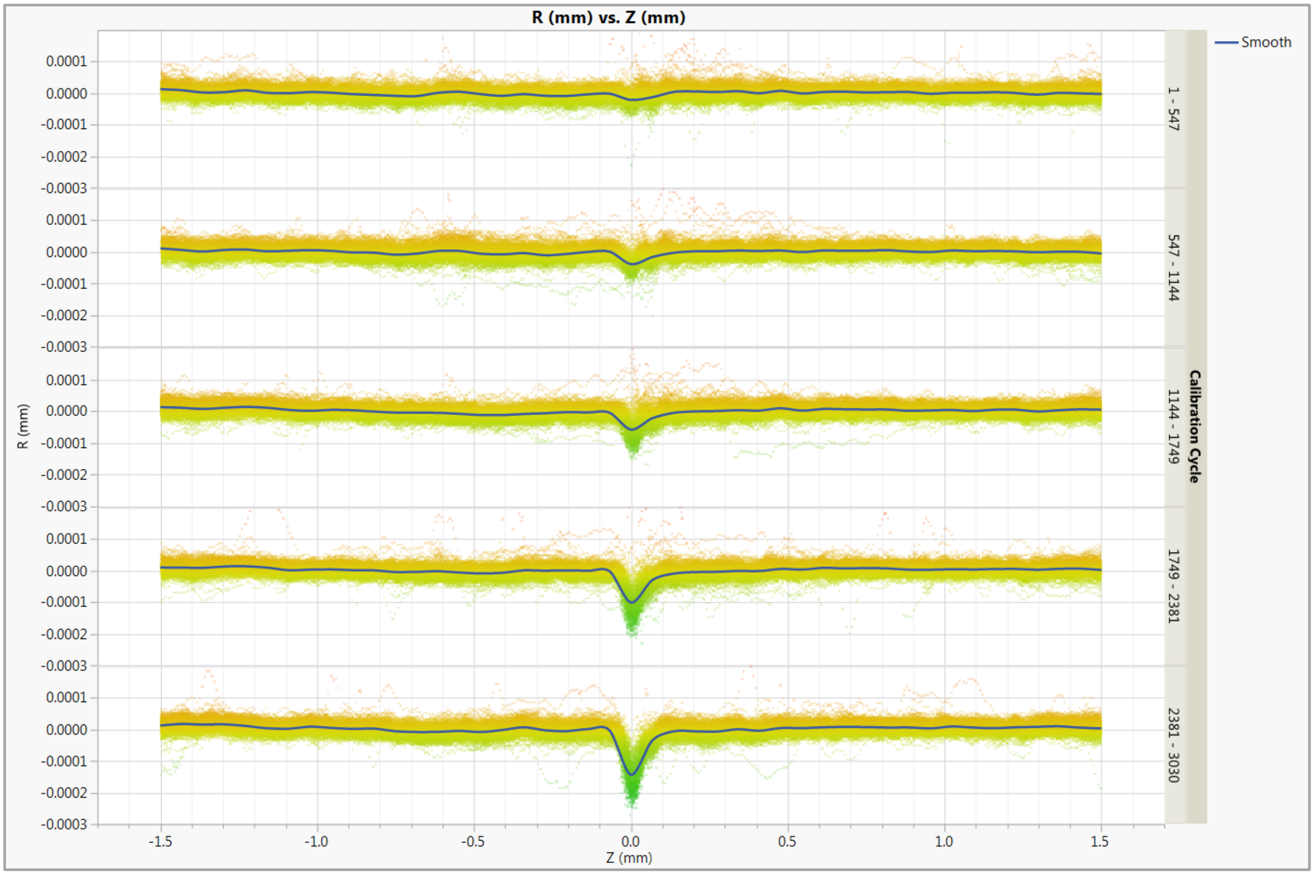


Figure 15: JMP's Graph Builder platform with grouping to show wear scar development.

A very important consequence of presenting the data in this fashion is that one can easily animate the wear scar development within Graph Builder by locking the X and Y scales, specifying any number of Y grouping levels desired, selecting only one level to be displayed at a time, and then scrolling down through the Y grouping levels. With third-party open-source software named CamStudio (https://sourceforge.net/projects/camstudio), these single-frame screen images can then be combined into a movie and presented as an animation. Time is then added to the presentation of the data as the third dimension!

Profilometer Scan Repeatability Example

The Timken Company (www.timken.com) is an international manufacturer of rolling element bearings of various styles, sizes, and configurations (see Figure 16 for just two of several catalogs available). Consequently, one of the quality control activities within Timken's numerous manufacturing plants is the measurement and analysis of bearing race profile geometry. A bearing race serves to distribute load across the underlying material. Bearing races exist wherever two load-bearing components make contact and move relative to each other.

Figure 16: The Timken Company manufactures various styles of rolling element bearings.

Bearing races can be either straight or curved depending on the bearing design and application. Bearing race geometry is a critical design parameter and often impacts engineering design optimization. In many applications, the surface geometry of the bearing races will have a significant impact on the performance and/or life of the bearing. For that reason, bearing races are carefully controlled within Timken's manufacturing plants. Likewise, the various contact and non-contact profilometer instruments used to measure the profiles must be tested and evaluated for repeatability, reproducibility, reliability, and accuracy.

The data plotted in Figure 17 shows a typical crowned bearing race profile (arbitrarily scaled so as to protect intellectual property). Six densely sampled profilometer scans were performed, three in the forward direction and three in the backward direction. Each of the six trace data sets contains about 17,500 points. The table contains 105,216 total rows. All 105,216 points are displayed in overlaid fashion (by trace) in Figure 17. Markers in this plot are opaque (marker transparency=1.0, the default), making it difficult to see most of the data. One way to improve this presentation is to tune the marker transparency setting. In Figure 18, the marker transparency setting was changed from 1.0 to 0.1. This has the effect of changing the plot to evoke a pseudo-density dimension. With semi-transparent markers, markers no longer hide other markers. The more markers that are drawn on top of each other, the darker the image gets at that location. In Figure 19, the points are no longer overlaid by the trace identifier so they are all drawn black but with 0.1 for the marker transparency. This is a very useful display for looking at the actual race profile independent of trace non-repeatability since the trace non-repeatability is deemphasized via the transparency setting and density helps to emphasize the repeatable characteristics. All of this is performed without adding any special calculations within the table.

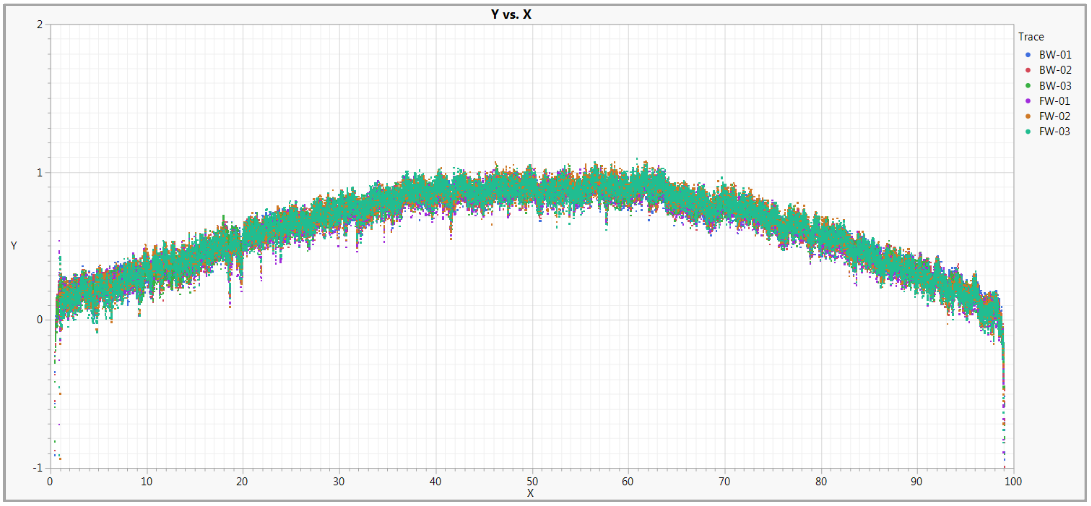


Figure 17: Three bidirectional scans of a typical bearing race profile overlaid (transparency=1.0).

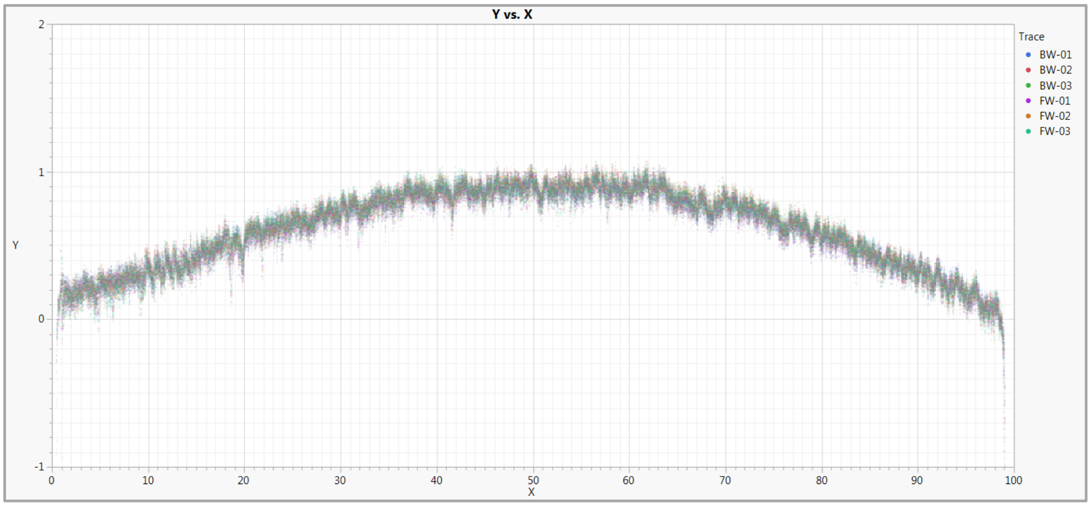


Figure 18: Three bidirectional scans of a typical bearing race profile overlaid (transparency=0.1).

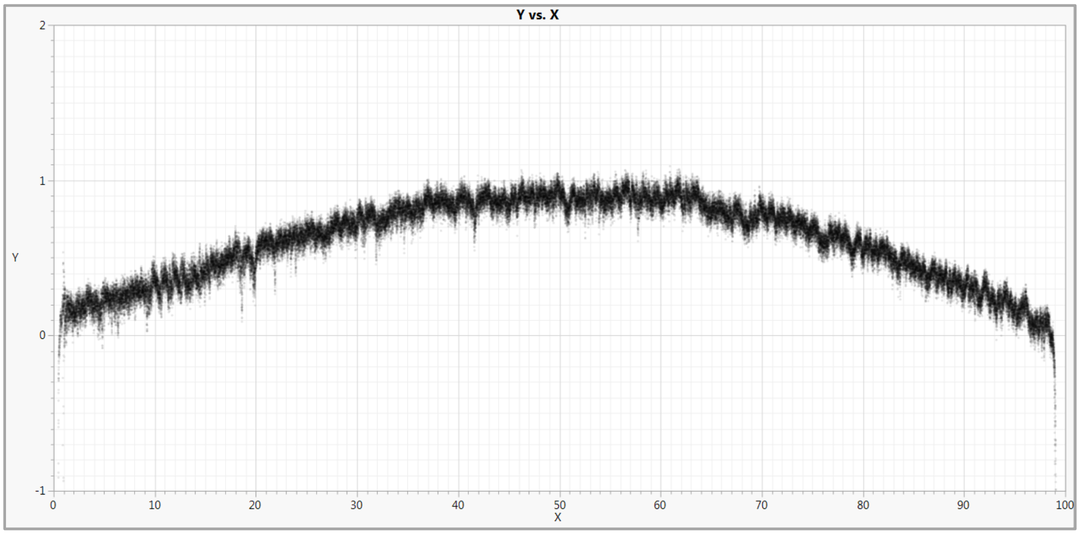


Figure 19: Three bidirectional scans of a typical bearing race profile, all points (transparency=0.1).

CMM Probe Tip Wear Example

Coordinate measuring machines which use contact-based profilometry in order to measure parts will also produce wear scars on the nominally spherical probe tips. These wear scars develop in specific locations due to preferential points of contact related to both the parts which are measured as well as the measuring strategies employed. For example, when cylindrical and conical features are measured using a CMM and a rotary axis is used to rotate the part as illustrated in Figure 20, wear scars will develop at specific angular locations on the CMM probe tips. In these cases, wear is concentrated in specific locations (the specific points of contact) and can be significant due to the large circumferential distances over which the scanning takes place. It is possible to observe this wear by capturing and analyzing the scan data which is collected whenever a calibration sphere is periodically checked.

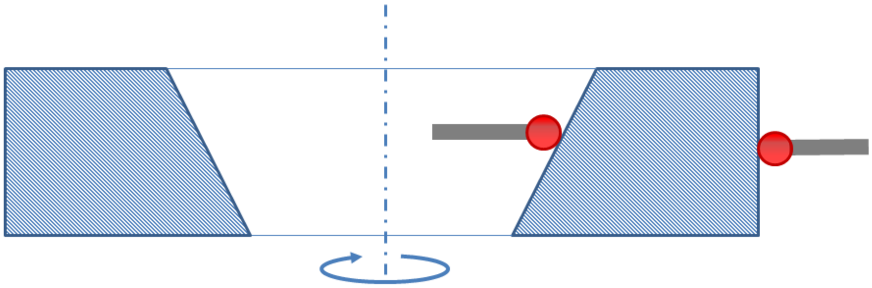


Figure 20: Cylindrical and conical features measured on a CMM using a rotary axis.

These sorts of analyses can become cumbersome due to the large number of data points involved. Some decimation is often required, even with JMP. Nevertheless, JMP is effective for such visualizations due to its efficient handling of large data sets and powerful visualization platforms.

For each CMM calibration, roughly 7300 points (fit residuals) were exported by the CMM and appended to a large .CSV file. The .CSV file was then imported into JMP. For this analysis, roughly 1300 calibration data sets were imported producing a table of nearly 10 million rows. This was then decimated (by calibration number) by a factor of five. As presented, the table has 1.6 million rows and the following columns:

- Tip - identifies inner or outer probe tip
- Scan Direction - identifies forward or reverse scan direction
- Servo Mode - identifies R or Z servo control
- R (mm) - identifies the R coordinate of the calibration scan residuals
- Z (mm) - identifies the Z coordinate of the calibration scan residuals
- Calibration - identifies the calibration number

Figure 21, Figure 22, and Figure 23 present a very small sample of the calibration sphere scans. Figure 21 shows no wear as both the inner and outer stylus were changed immediately before calibration #2195. After measuring many similar parts, wear began to develop as shown in Figure 22, calibration #2380. Figure 23 presents the calibration sphere data from calibration #2630. Two significant wear scars have developed and are visible in the calibration sphere residuals. These plots were produced using JMP's Graph Builder:

X ⇦ R (mm)
Y ⇦ Z (mm)
Color ⇦ Direction
Points ⇦ Enabled
Marker Size ⇦ Dot
Transparency ⇦ 0.3
Local Data Filter ⇦ Calibration Cycle

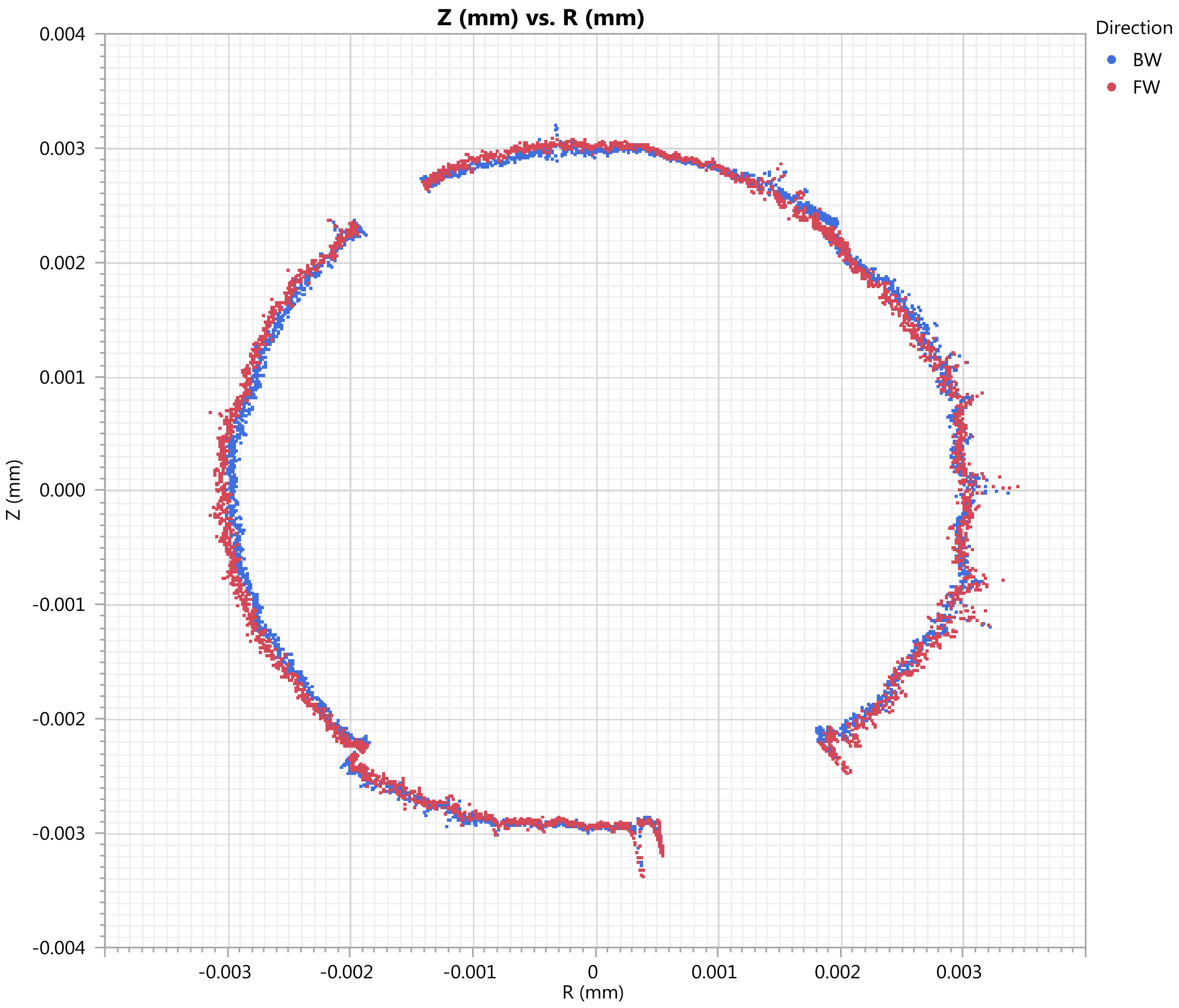


Figure 21: CMM calibration sphere residuals, calibration #2195. No wear scars.

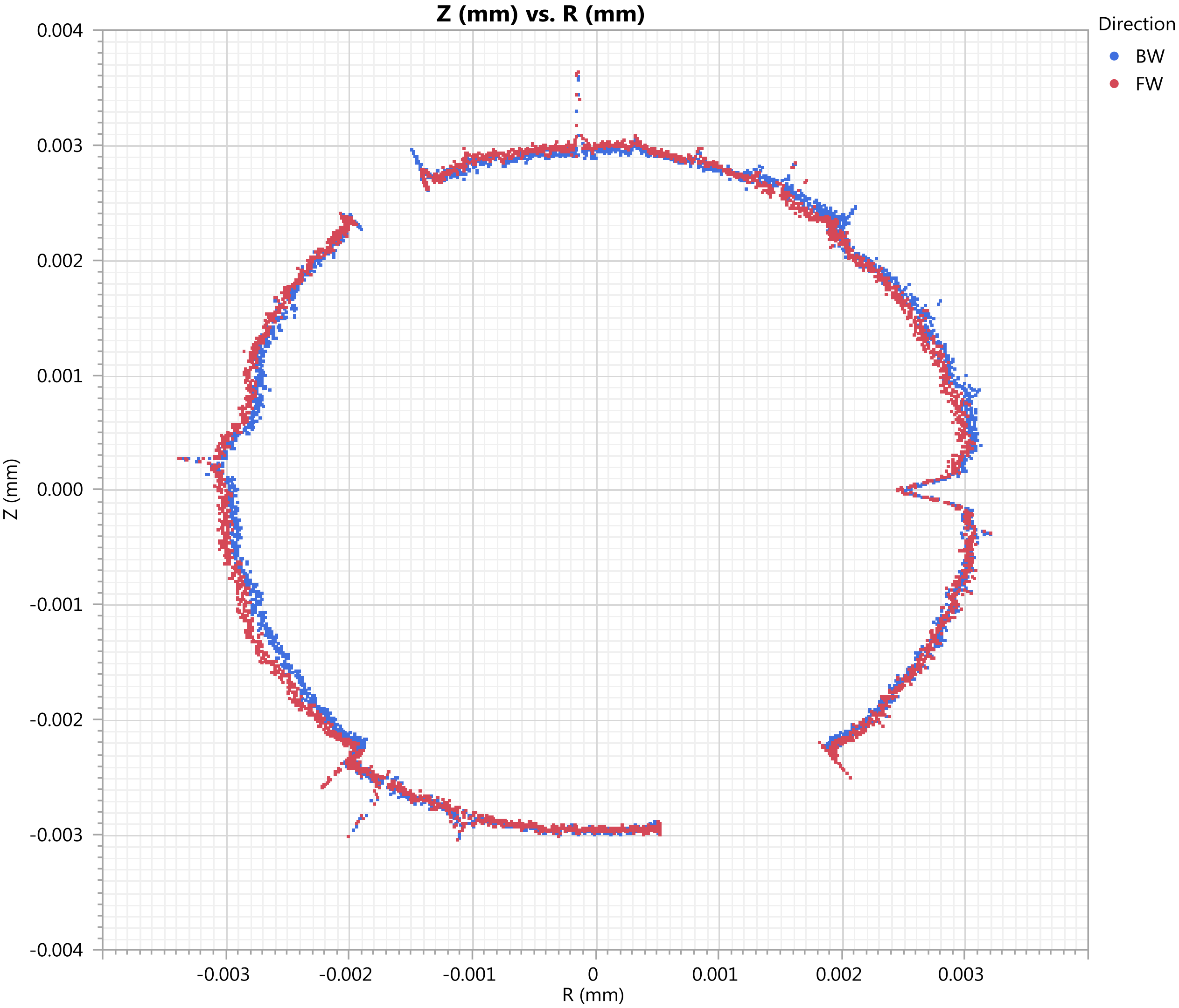


Figure 22: CMM calibration sphere residuals, calibration #2380. Wear scars developing.

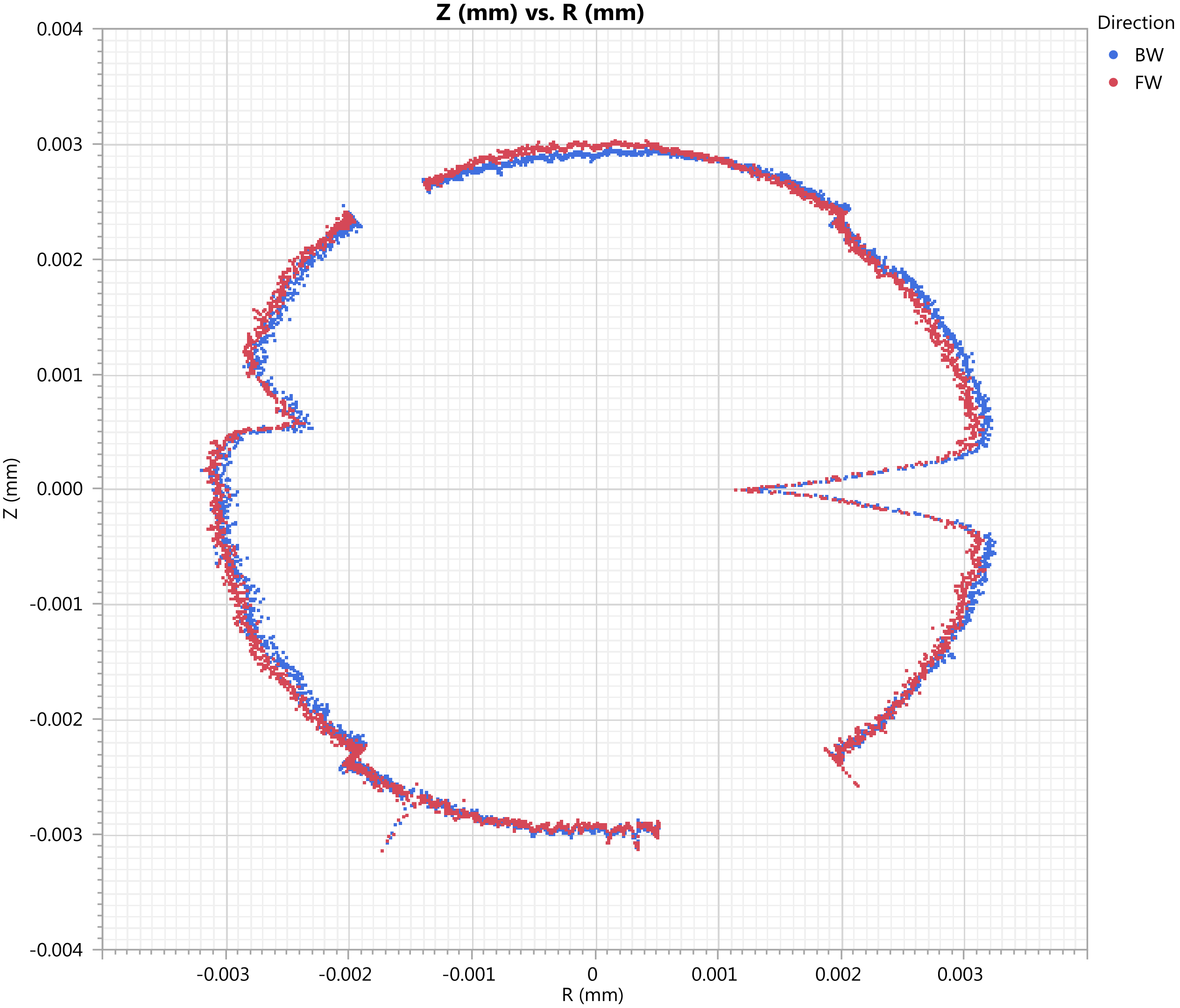


Figure 23: CMM calibration sphere residuals, calibration #2630. Two wear scars visible.

Of course, as already described in the earlier sections, there are many options for viewing these calibration sphere residual results. But one of the most effective ways to view these results is to animate them using the Local Data Filter animate function. This is a powerful way to visualize any dimension, but it is especially effective when applied to dimensions that have a temporal nature. Since calibration number is a proxy for time in this data set, the animation produced is an animation of the development of probe tip wear scars over time. This animation can also be captured using open source tools such as CamStudio (https://sourceforge.net/projects/camstudio).

Conclusion

Many challenges exist when trying to visualize multi-dimensional data. One of the more significant challenges is deciding how to map the third and higher dimensions in our data to the available options within the visualization tools available. But the challenges go further than simply mapping of variables to axes and the various other charting attributes. Good visualizations also require:

- judicious scaling
- suitable number formatting
- proper labeling of variables
- unambiguous designation of units
- helpful but unobtrusive use of grid lines
- overall presentation consistency
- a pleasant color palette (or grayscale where required or appropriate)

and many other decisions that make the process of data visualization an artful one.

To be most effective, the data scientist must be able to both analyze data and present it such that it has impact. We must be able to navigate the available toolsets both for our in-depth personal investigation as well as for presentations that are intended to rapidly and concisely inform and communicate with others.

Regardless of how many dimensions exist in our data sets, we should all strive to create visualizations that are both effective and memorable for one simple reason:

Visualizations are among the most important and memorable bridges
between a physical reality and our understanding of it.

Final Note

Although JMP has many data analysis and visualization platforms which should be explored and utilized, it is worth noting that JMP’s Graph Builder platform is one of the best visualization toolsets available, and actually quite revolutionary. It is intuitive to use, extremely fast, intelligently designed, allows one to quickly and easily reformulate mappings, groupings, and filters, and it has very broad coverage of the sorts of tools needed when visualizing data. For that reason, it is always my first choice when exploring new data. I excitedly welcome its further development and enhancement as JMP continues to evolve.

Appendix

JMP Tables Referenced

- ExampleSurfacePlot.jmp
- GaugeBlockWearHistory.jmp
- OverlaidScanData.jmp
- BallScanData.jmp

Additional Files

- ProbeTipWearScars.mp4