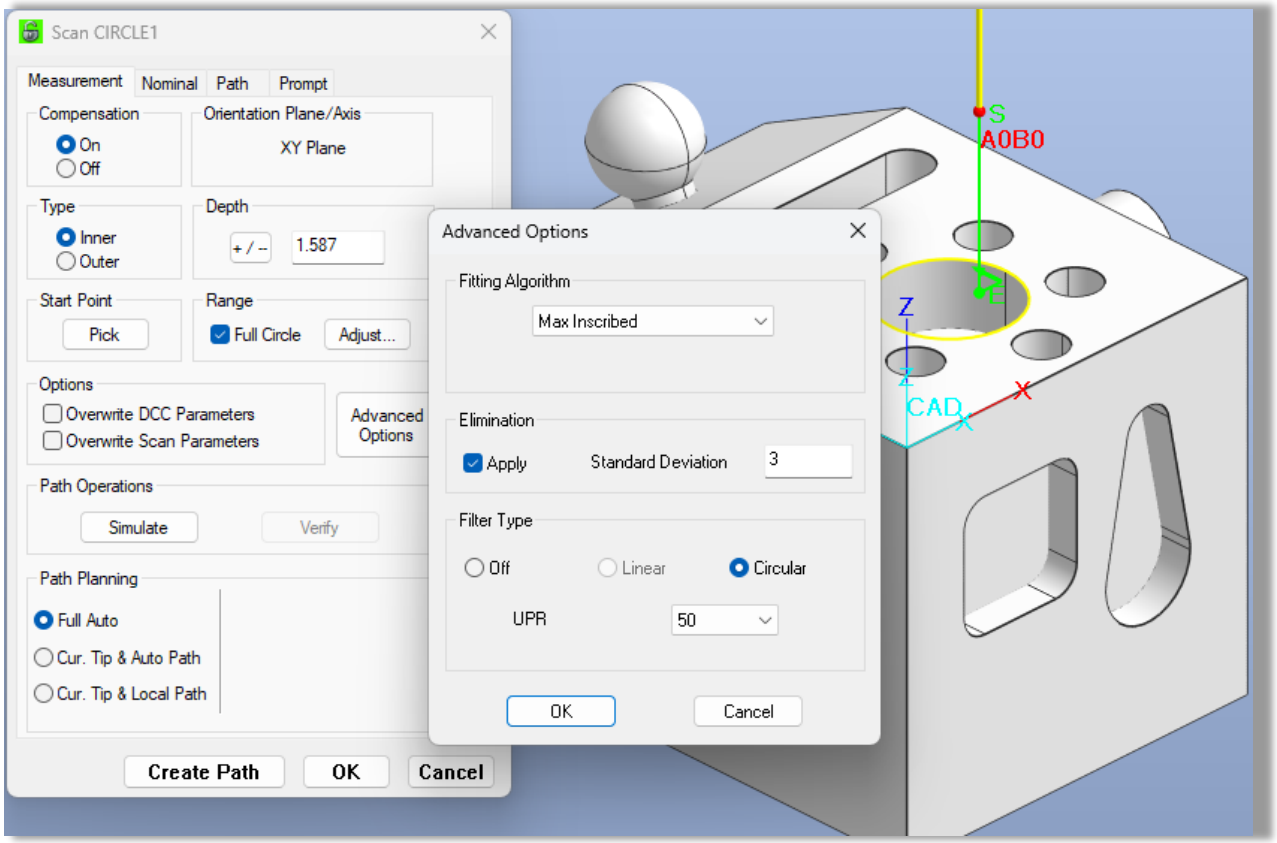
2/20/2025

Understanding Filtering and Outlier for CMM Manager Application



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CMM QUARTERLY

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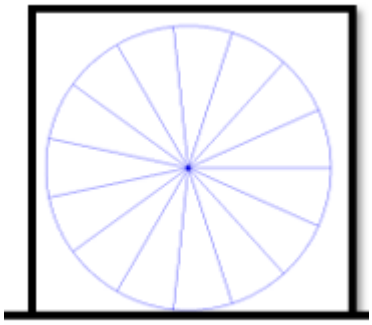
Terminology

UPR

Undulations Per Revolution is a unit to describe how many times a wave occurs around a circumference in a given revolution. Circular features such as circles, cylinders, etc…should have the UPR filter type applied. When using a low pass filter, the higher the UPR the more harmonics we keep. The lower the UPR the more data is filtered or smoothed.

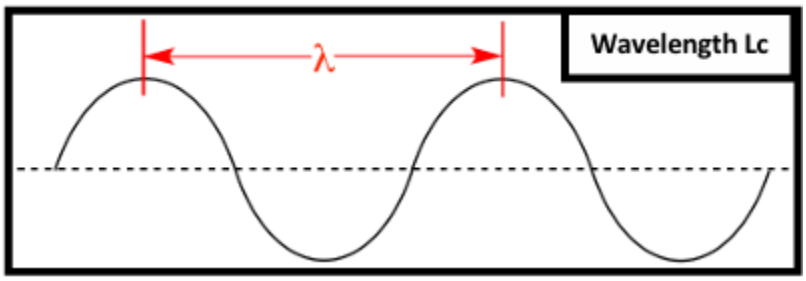
Choosing the correct UPR filter based on the bore size will divide the 360° bore by the UPR value. Shown here is the 15UPR to the bore diameter creating 15 sections. We will further explore how many points we need in each section.



15 UPR(15 sections per 360)

Wavelength

With cutoff wavelength you are choosing size of the Gaussian filter that will be applied to every point. The higher the cutoff value the more smoothing or filtering occurs. This is the inverse of the UPR filter type.



Number of Points to Be Taken

There must be a minimum of 7 points per wavelength or undulation. If writing the program in Native DMIS change the value from 7 to 10 per the DMIS Standard.

Circular Features: A minimum of points equals the number of Undulations Per Revolution x 7.

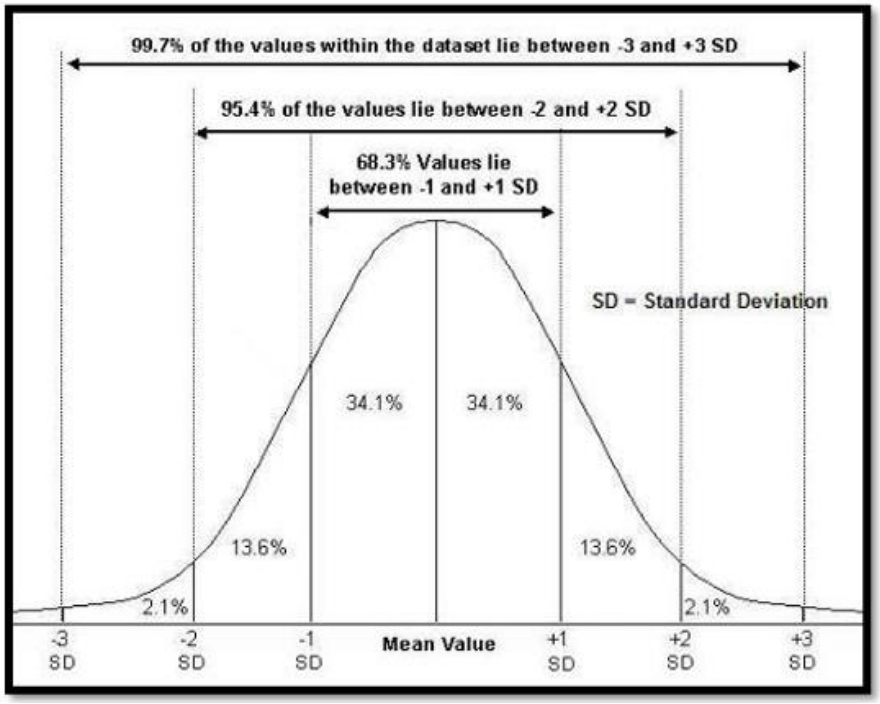
- Ø8mm with 15UPR needs a minimum of 105 points. (15UPR x 7 points per undulation)

Linear Features: A minimum number of points equals the length x 7 points per wave/ Cutoff wavelength.

- Length of 100mm and a cutoff or 2.5 Lc needs a minimum or 280 points. (100mm in length x 7 points / 2.5)

Normal Distribution

Normal distribution: In filtering, it is important to consider the concept of normal distribution. Normal distribution describes how many measured points are located within dispersion width areas.



The normal distribution is a bell-shaped curve centered around the mean of a data set, and is divided by the sigma value, or standard deviation. The standard deviation is a measure used to quantify the amount of variation or dispersion in a data set. Approximately 68.27% of the data falls within ±1 standard deviation (σ) from the mean. Approximately 95.45% of the data lies within ±2 standard deviations, while approximately 99.73% falls within ±3 standard deviations. Data points beyond 3σ represent the remaining 0.27% of the data set and are typically considered outliers that may be excluded from analysis.

Concept	Details
Normal distribution	Bell-shaped curve centered around the mean of a data set
Standard deviation (σ)	Measure to quantify the amount of variation or dispersion in a data set
±1σ	Approximately 68.27% of the data
±2σ	Approximately 95.45% of the data
±3σ	Approximately 99.73% of the data
Beyond 3σ	Remaining 0.27% of the data, typically considered outliers

Low Pass Filter

When using a CMM, always apply the Low Pass filter if possible. This is crucial, especially with evaluation methods like minimum circumscribed or max inscribed, which rely on the extreme points of the data set. This filter allows low frequency data to pass through and ignores the roughness and waviness data found in higher frequencies. This shows the true form of the workpiece.

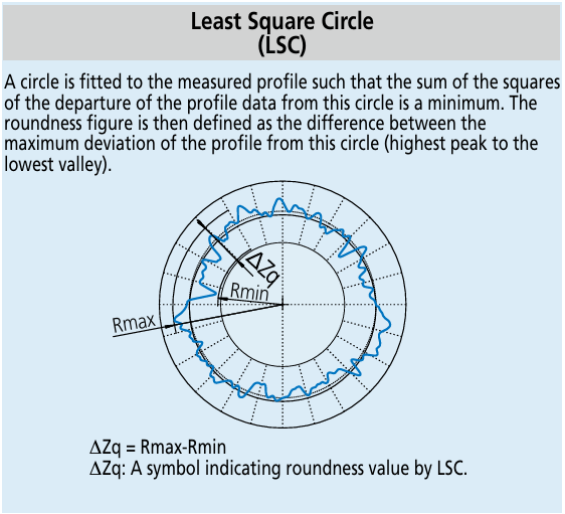
Diametrical Features

Reference Circle Selection

The programmer must select a fitting algorithm to be applied to the measured diameter. This will determine the reference circle applied to the measured data.

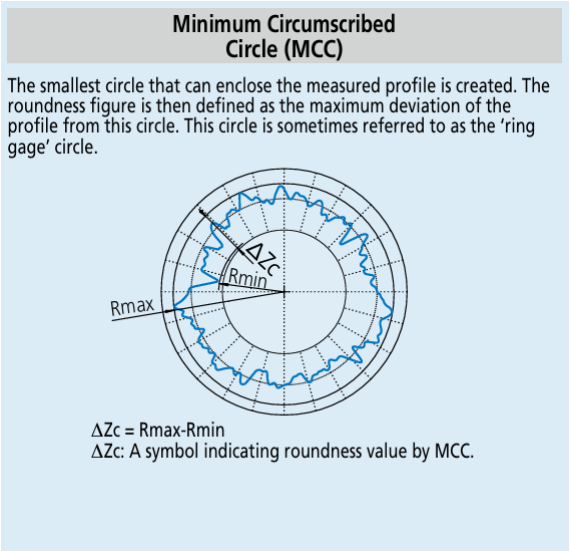
Roundness compares measured data with a computer-generated reference circle. Most measuring systems have four methods for comparing the measured data to a reference circle for evaluation. It is important to note the reference circle used should be related to the function of the finished component. The final numeric roundness result will be different with the different reference circles applied, so make sure the blueprint accurately reflects the desired result.

Least squares reference circle (LSCI**)** is the most commonly used reference circle. A line or figure is fitted to any data such that the sum of the squares of the departure of the data from that line or figure is a minimum. This also is the line that divides the profile into equal minimum areas. Out-of-roundness is then expressed in terms of the maximum departure of the profile from the LSCI, the highest peak to the lowest valley.



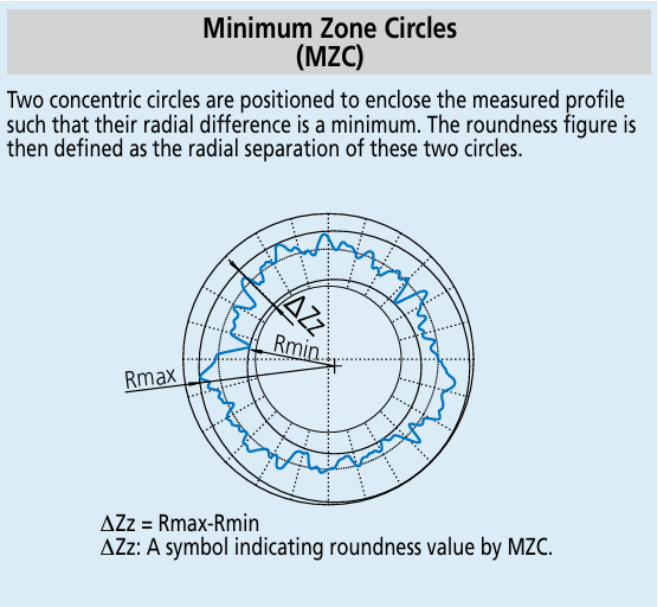
Minimum circumscribed circle (MCCI**)** is defined as the circle of minimum radius that will enclose the profile data. The out-of-roundness is then given as the maximum departure of the profile from this circle. MCCI is sometimes referred to as the ring gage reference circle.

This is a functional check as it is not as stable as LSQ.



Minimum zone reference circles (MZCI**)** or Chebyshev is defined as two concentric circles positioned to enclose the measured profile such that their radial departure is a minimum. The out-of-roundness value is then given as the radial separation of the two circles.

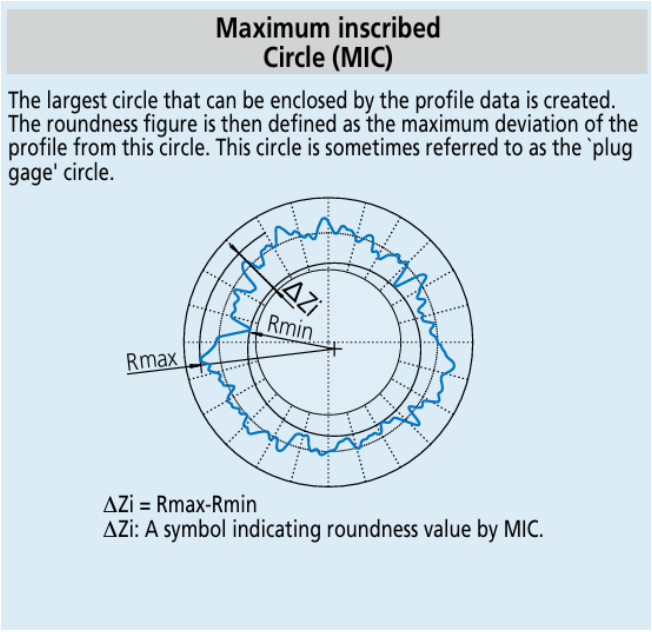
Less repeatable than LSQ as it fits around the feature's extreme points.



Maximum inscribed circle (MICI**)** is defined as the circle of maximum radius that will be enclosed by the profile data. The out-of-roundness is then given as the maximum departure of the profile from this circle. MICI is sometimes referred to as the plug gage reference circle.

This is a functional check as it is not as stable as LSQ.

Diagrams from Effect of Filter Settings on the Measured Profile - Mitutoyo



Tip Selection and Filter Selection

There is a direct correlation between the bore diameter and the value of the UPR that should be applied.

Tip Selection and Filter Selection		
Ø Bore	Filter Cut-off Value	Stylus Tip Diameter*
<8mm <0.3 in	15 UPR Gauss Filter	max 3mm
8 to 25mm 0.3 to 1 in	50 UPR Gauss Filter	max 3mm
26 to 80mm 1.1 to 3 in	150 UPR Gauss Filter	max 3mm
81 to 250mm 3.1 to 10 in	500 UPR Gauss Filter	5mm
>250mm >10 in	1500 UPR Gauss Filter	> 5mm
*There is a direct relationship between the stylus tip diameter, the component diameter and the recommended filter to use.		
All threaded bores should only have a 15 UPR applied to the filtering		

Filter selection

For a more precise UPR selection the below formula may be used

$$UPR = \frac{\pi d}{0.8}$$

Where d is bore diameter.

Tip Diameter Selection

The recommended stylus tip is 0.5mm radius or 1mm diameter for bores larger than 4mm in diameter, however when the bore diameter becomes quite small then the stylus tip diameter will need to be reduced.

The formula shows a calculation of the stylus tip when the diameter of the component becomes less than 4mm.

$$R = \frac{\pi d}{24}$$

Where R is the stylus tip radius and d is the bore diameter

Applying Filter/ Elimination/ Filter Type

Fitting Algorithm - See Reference Circle Selection

Elimination - Use the Elimination box to set up the standard deviation algorithm (±3 sigma is the standard setting) used to apply a filter to the data. This means that you can reduce noise and achieve a good approximation of the surface. Standard Deviation is the number of standard deviations above which points are considered to be noise. Above this, points are filtered out.

Filter Type – We are scanning a bore so the selection would be circular. The UPR selection would be based on the diameter of the bore. See Tip Selection and Filter Selection

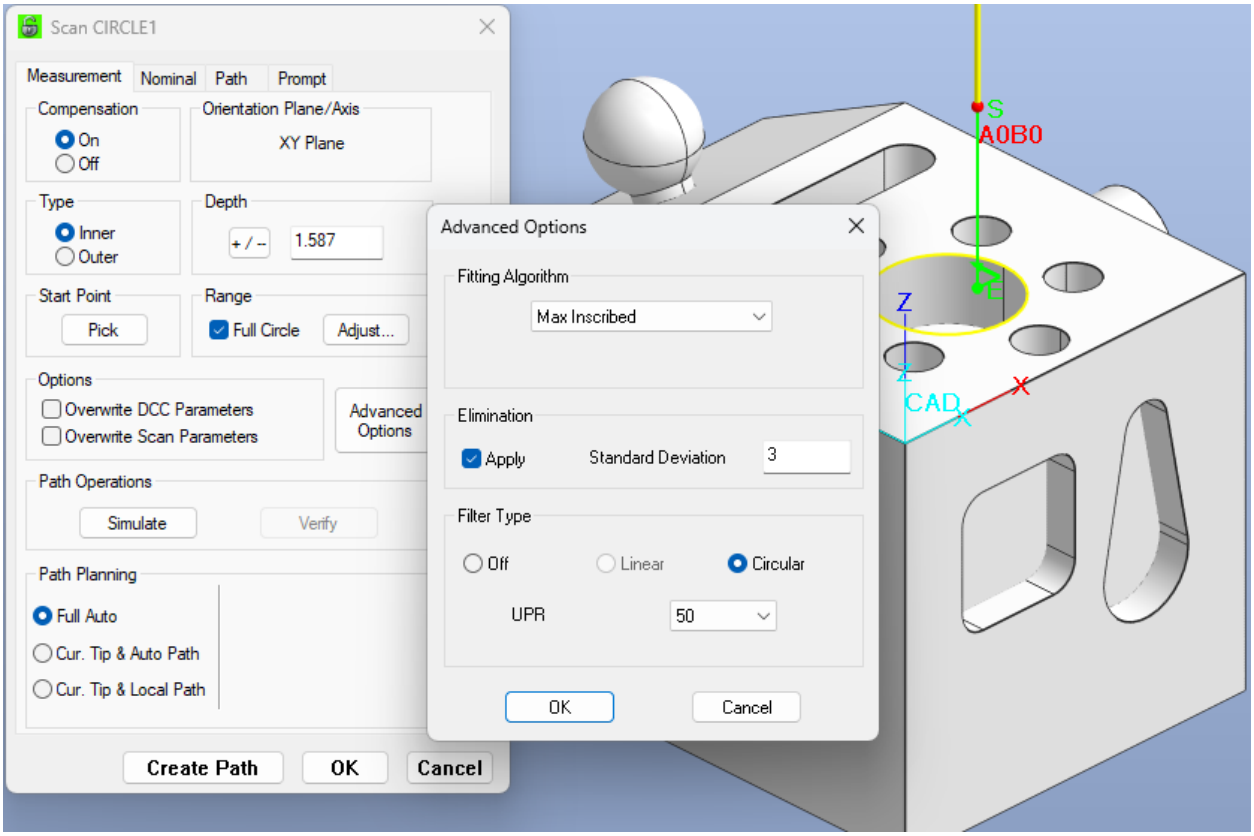


Figure 1 CMM Manager Advanced Options

Linear Features

The wavelength filtering must be set for linear features. As discussed before, the higher the value the more smoothing will be applied.

Settings Based on Linear Size

Settings Based on Linear Size			
Plane Length	Stylus Diameter	Step Distance	Cutoff wave length
<25mm <1in	3mm	0.1mm	λc = 0.8mm Gaussian Filter
25 to <80mm 1 to 3in	3mm	0.1mm	λc = 0.8mm Gaussian Filter
80 to 250mm 3 to 10in	3mm	0.31	λc = 2.5mm Gaussian Filter
>250mm >10in	5mm and larger	1mm	λc = 8.0mm Gaussian Filter
The step distance and speed of the scan will vary on your probe sensor type and form deviation. Step distance will set the number of points of the scan.			

Datum Feature

It is highly recommended that multiple scan lines be used especially when creating a datum feature.

Scan at least 4 lines, 10% away from the edges. The exception would be if the plane is too narrow for 4 scan lines, then scan 2 lines. If the plane is still too narrow, then scan 1 line. A single line must never be used as a primary datum.

Settings Based on Surface Roughness

Settings Based on Surface Roughness ISO 4288-1996			
Roughness	Stylus Dia	Step Distance	Cutoff wave length
Ra ≤0.025µm Rz ≤0.1µm	max 3mm	0.031mm	λc = 0.25mm Gaussian Filter
Ra >0.025µm to 0.4µm Rz >0.1µm to 1.6µm	3mm	0.1mm	λc = 0.8mm Gaussian Filter
Ra >0.4µm to 3.2µm Rz >1.6µm to 12.5µm	3mm	0.31	λc = 2.5mm Gaussian Filter
Ra >3.2µm Rz >12.5µm	5mm and larger	1mm	λc = 8.0mm Gaussian Filter
The step distance and speed of the scan will vary on your probe sensor type and form deviation. Step distance will set the number of points of the scan.			

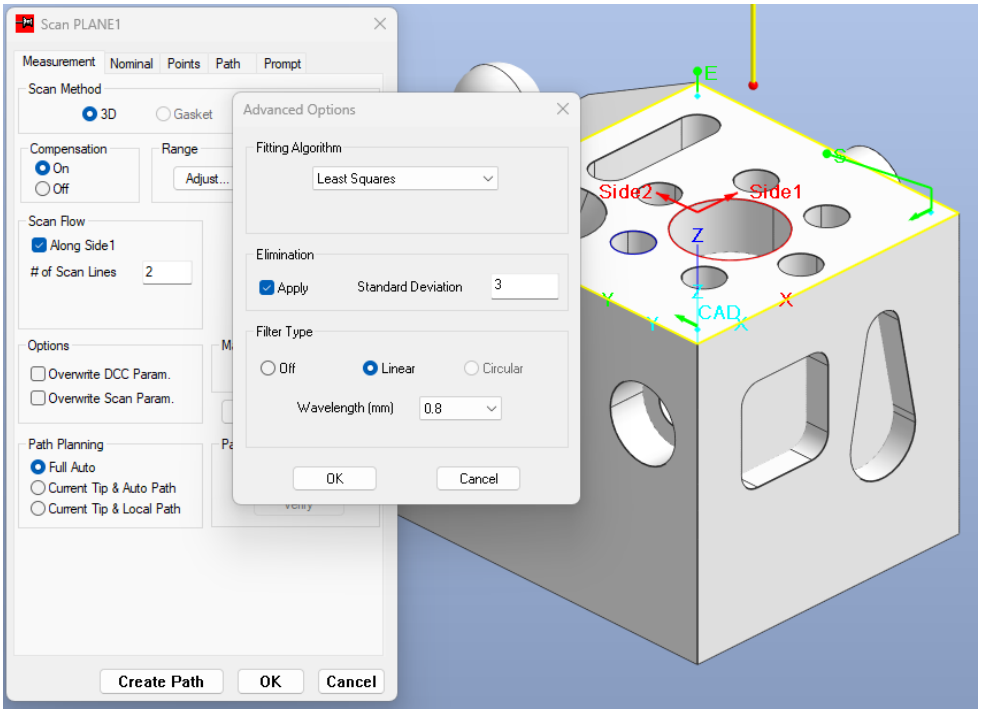


Figure 2 CMM Manager Linear Filtering

