Carl Zeiss Industrial Metrology

Algorithms

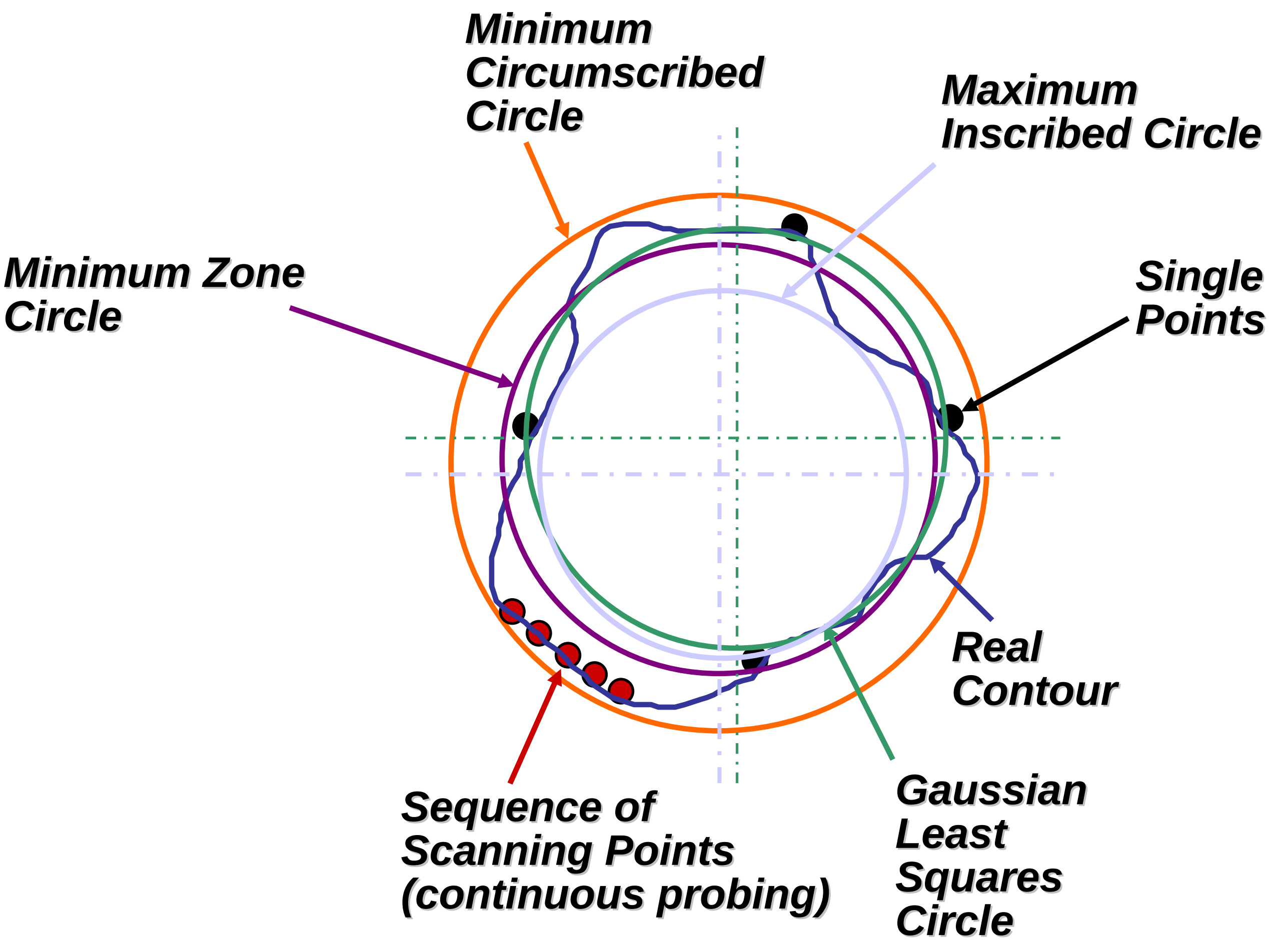
October 2005

National User Group Conference

Richard Knebel

VP Engineering – Carl Zeiss

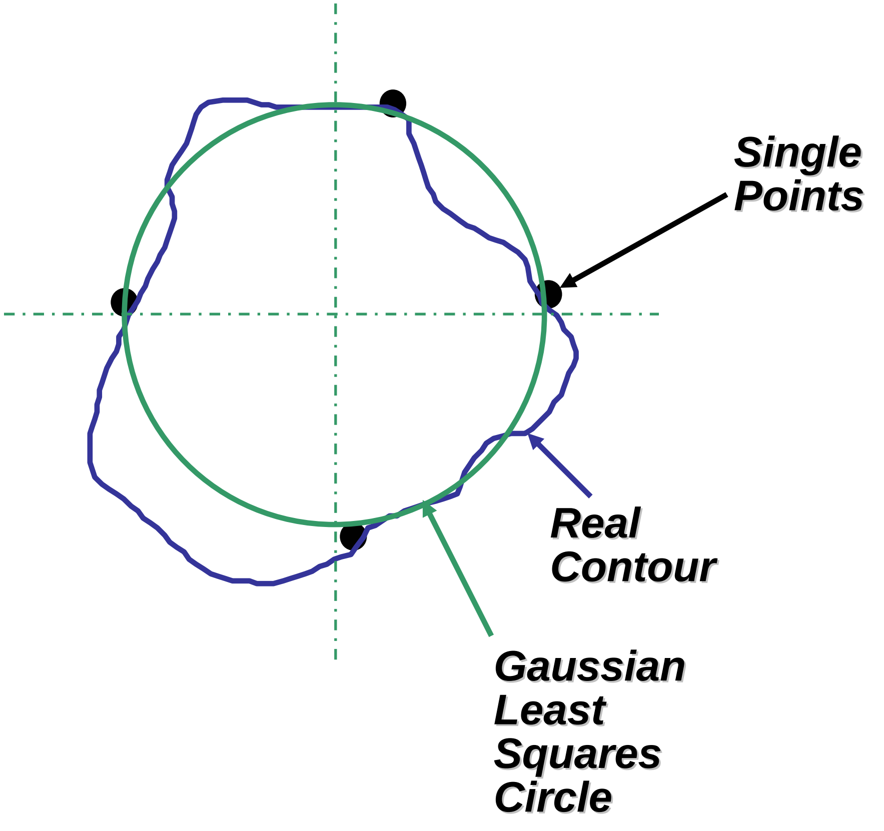
Algorithms


Minimum Circumscribed Circle
Maximum Inscribed Circle
Minimum Zone Circle
Single Points
Real Contour
Sequence of Scanning Points (continuous probing)
Gaussian Least Squares Circle

Why Least Squares ?

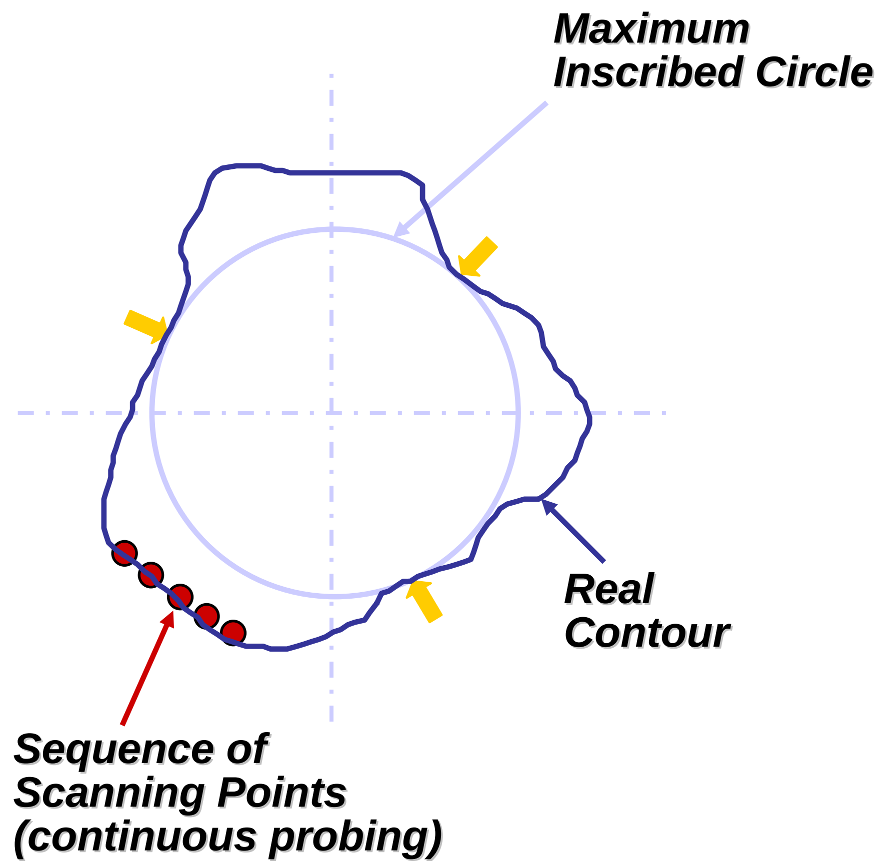
- **Provides a consistent, stable result**

- **Consistently provides the**
  - **Wrong Size**
  - **Wrong Location**
  - **Wrong Form**



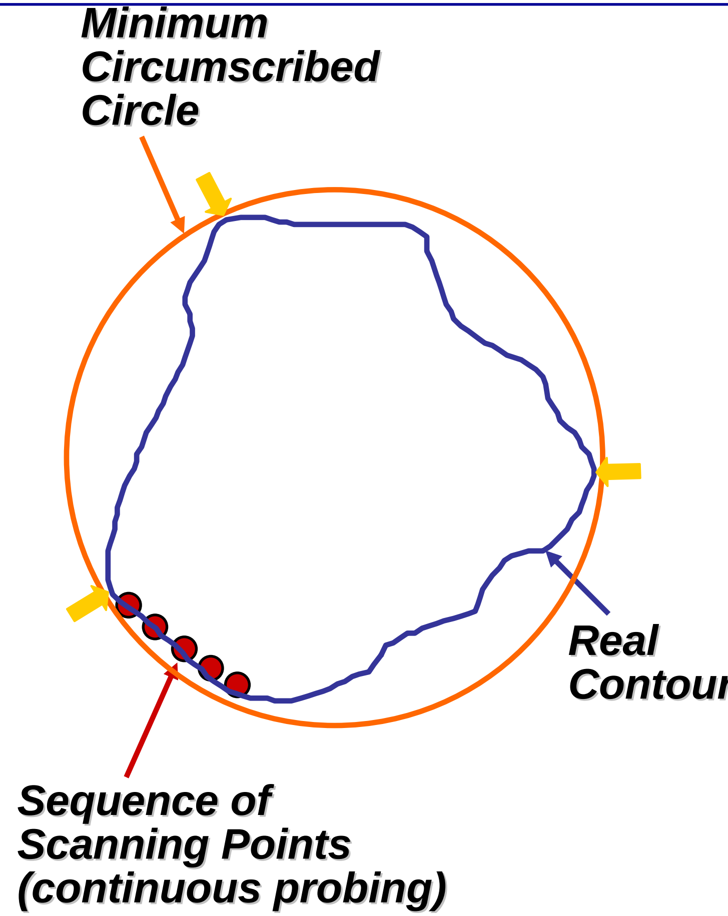
Why Maximum Inscribed ?

- **Provides the correct result for**
  - **Size**
  - **Location**
- **On *internal* diameters**
- **When used with enough data density**
- **However it is not as stable as Least Squares because..**
  - **It fits on extreme points**



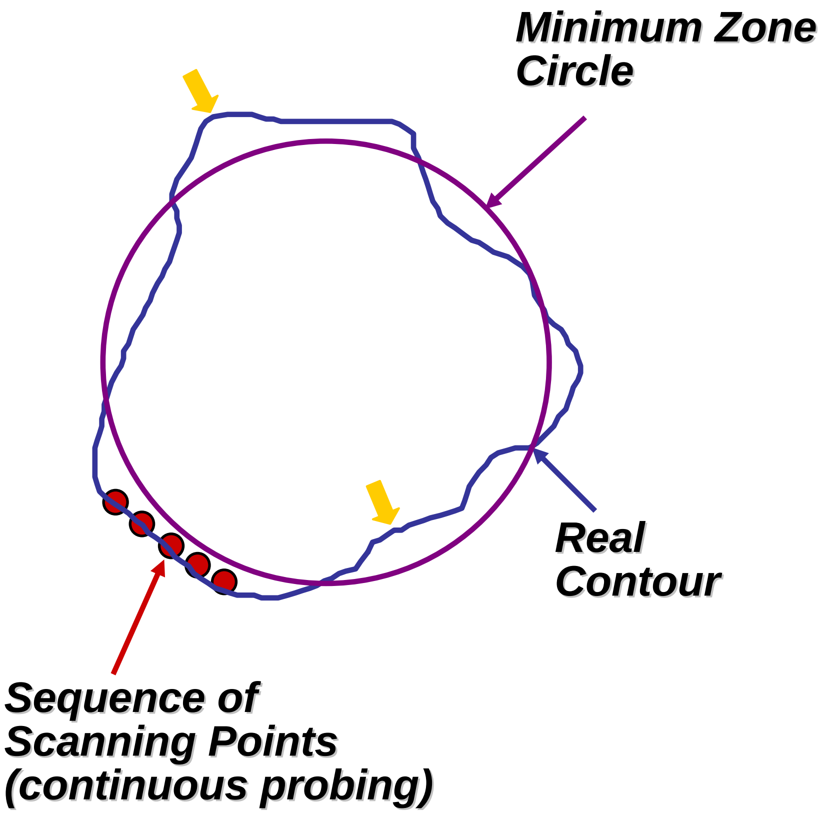
Why Minimum Circumscribed ?

- Provides the correct result for
  - Size
  - Location
- On *external* diameters
- When used with enough data density
- However it is not as stable as Least Squares because..
  - It fits on extreme points



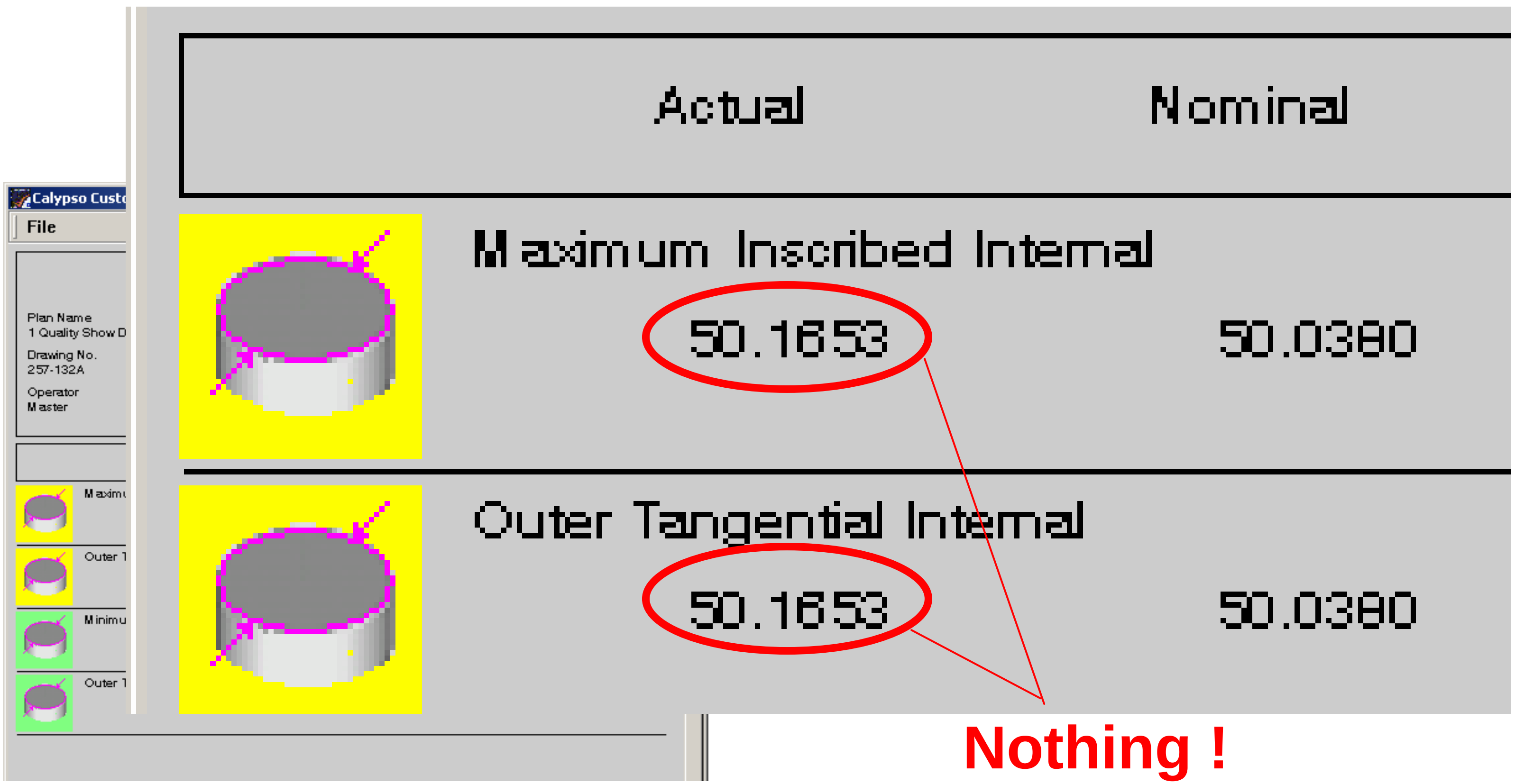
Why Minimum Zone ?

- **Provides the correct result for**
  - **Form**
- **When used with enough data density**
- **However it is not as stable as Least Squares because..**
  - **It fits on extreme points**



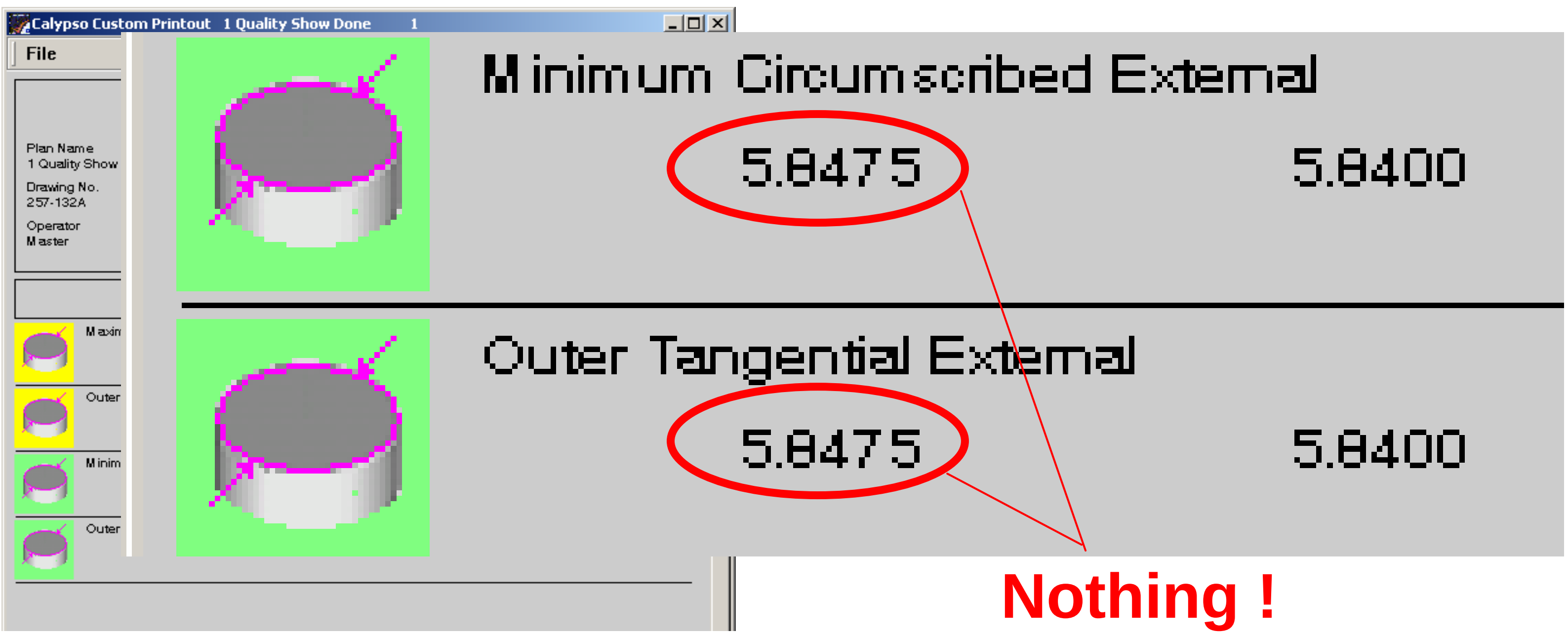
What about Inner and Outer Tangential ?

- **What's the difference between Outer Tangential and Maximum Inscribed on an *internal* diameter ?**



What about Inner and Outer Tangential ?

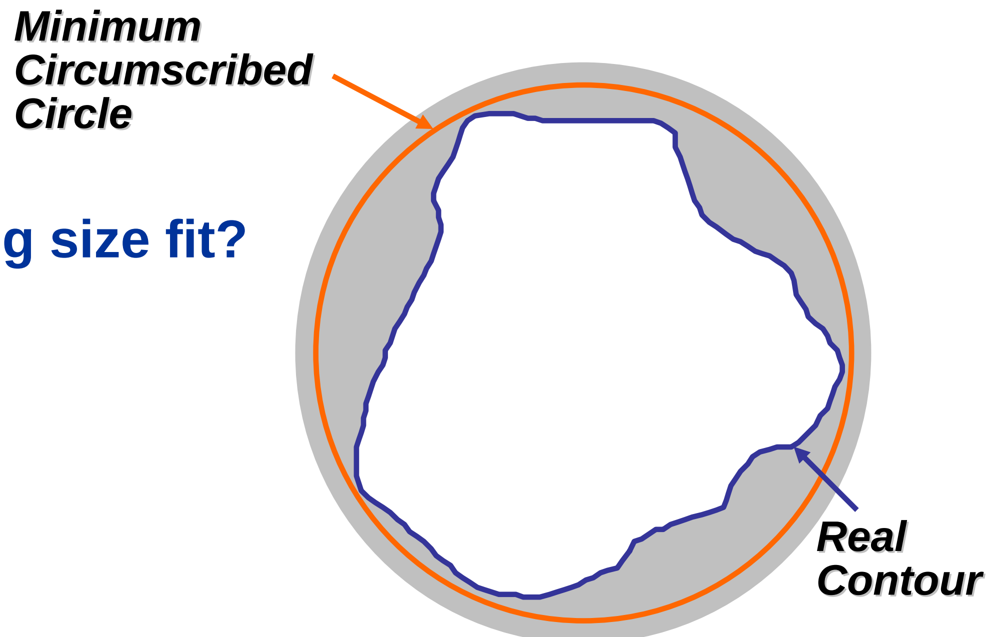
- **What's the difference between Outer Tangential and Minimum Circumscribed on an *external* diameter ?**



Nothing !

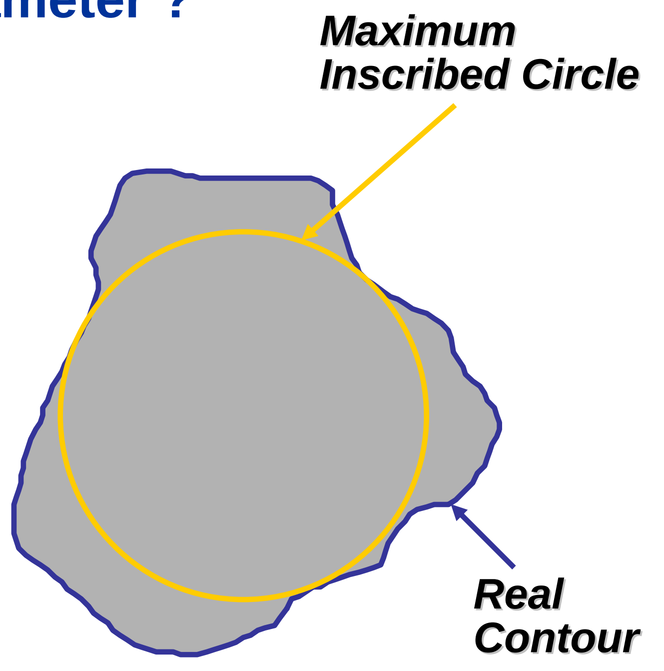
What about Inner and Outer Tangential ?

- **What's the difference between Inner Tangential and Minimum Circumscribed on an *internal* diameter ?**
- **Nothing !**
- **Is this a functional mating size fit?**
- **No !**
- **When might you use it ?**
- **To determine if there is enough material on a casting so that it will cleanup during machining, to evaluate the maximum size, or to evaluate wall thickness**



What about Inner and Outer Tangential ?

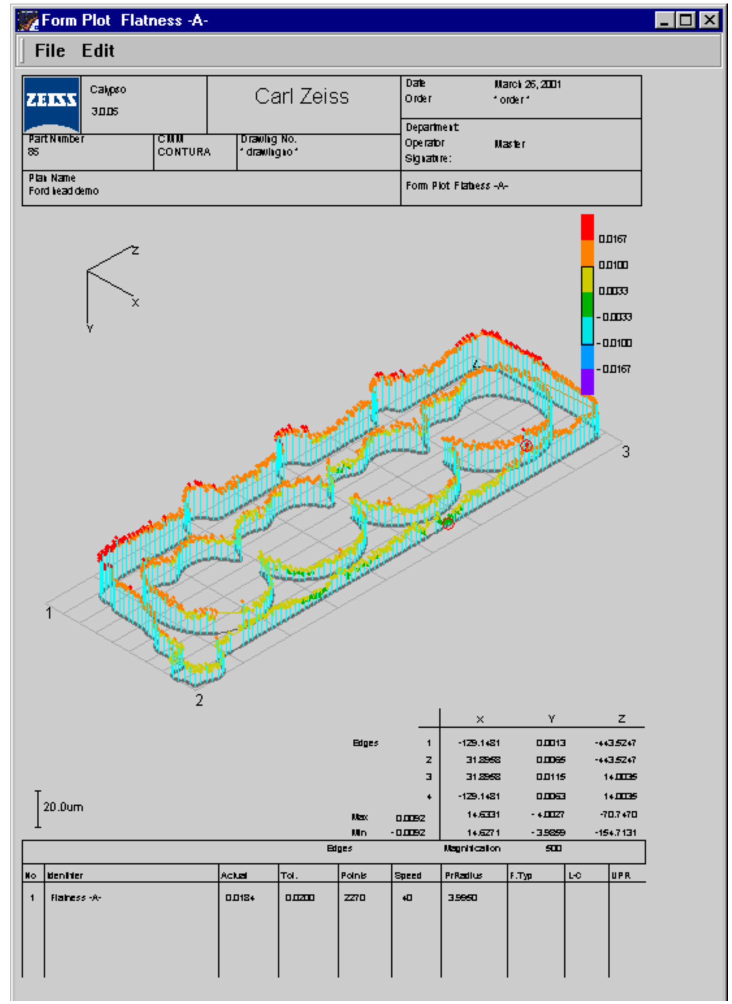
- **What's the difference between Inner Tangential and Maximum Inscribed on an *external* diameter ?**



- **Nothing !**
- **Is this functional mating size fit?**
- **No !**
- **When might you use it ?**
- **To determine if there is enough material on a casting so that it will cleanup during machining, to evaluate the minimum size, or to evaluate wall thickness**

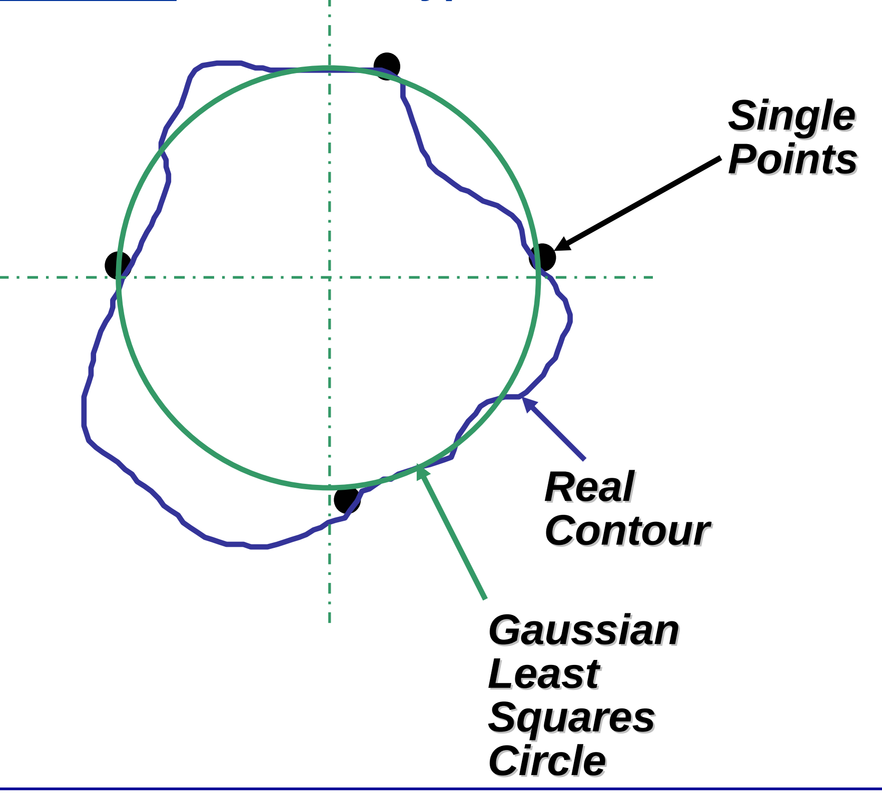
So why do we have Inner and Outer Tangential ?

- **Because it is more descriptive for Planes and Lines**



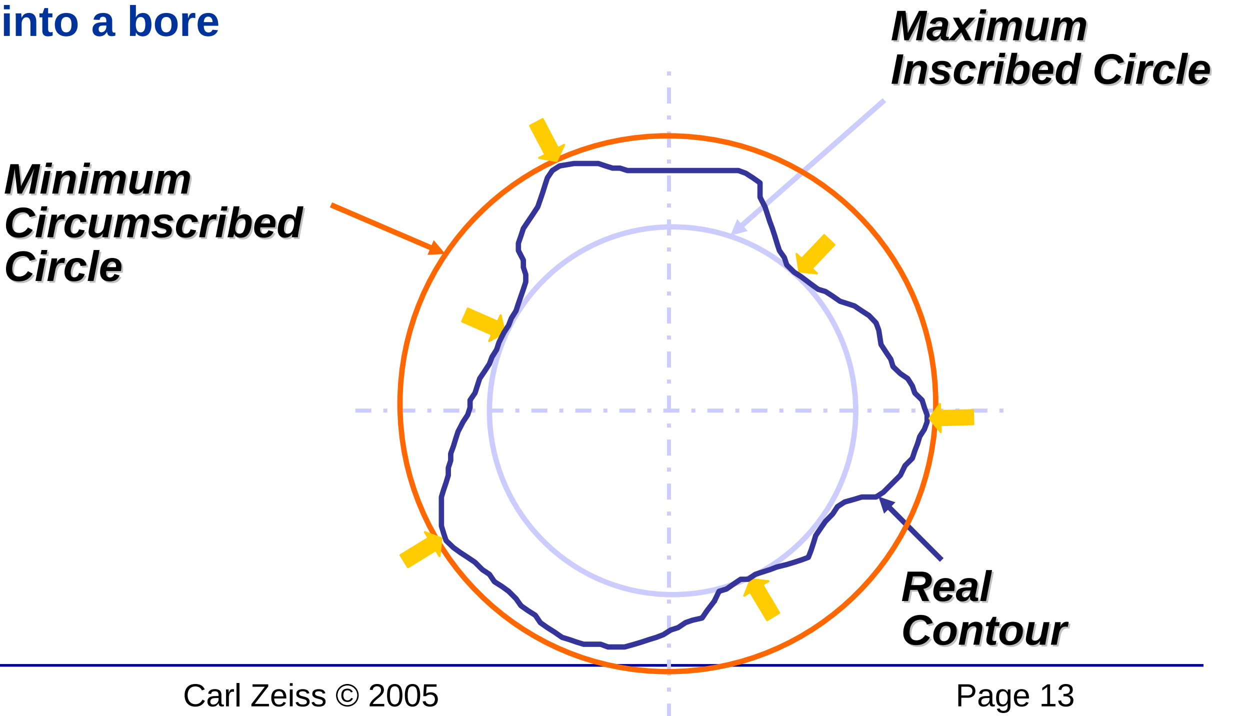
So lets generalize the math

- We have Gaussian Least Squares fits which minimize the square root of the sum of the squared errors
  - In this type of fit all data points have the same weight in determining the fit
  - There is ***absolutely nothing functional*** about this type of fit



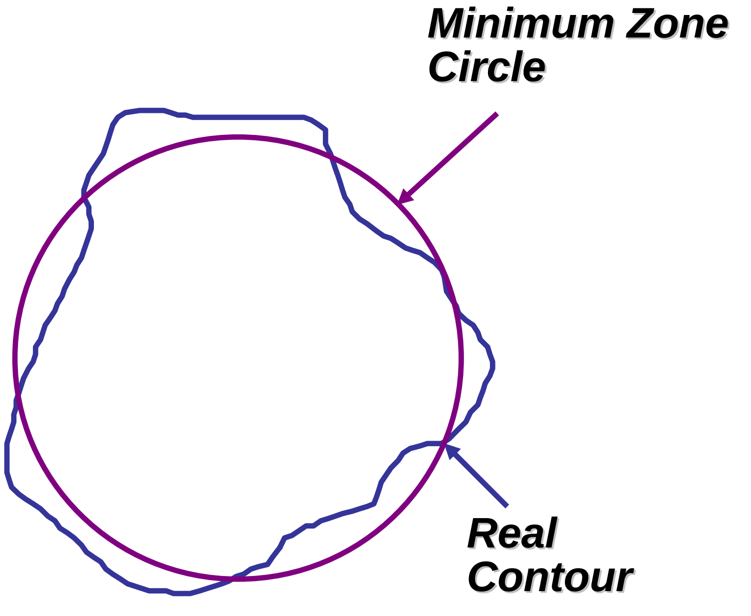
So lets generalize the math

- We have ***extrema*** fits (Inner and Outer Tangential, Max Inscribed, Min Circumscribed) which fit on the high points of the feature
  - In this type of fit only the high points have any weight in determining the fit
  - This is ***absolutely functional*** fitting for size and location like when mating a plane against a granite surface plate, or finding the slip fit pin that just fits into a bore



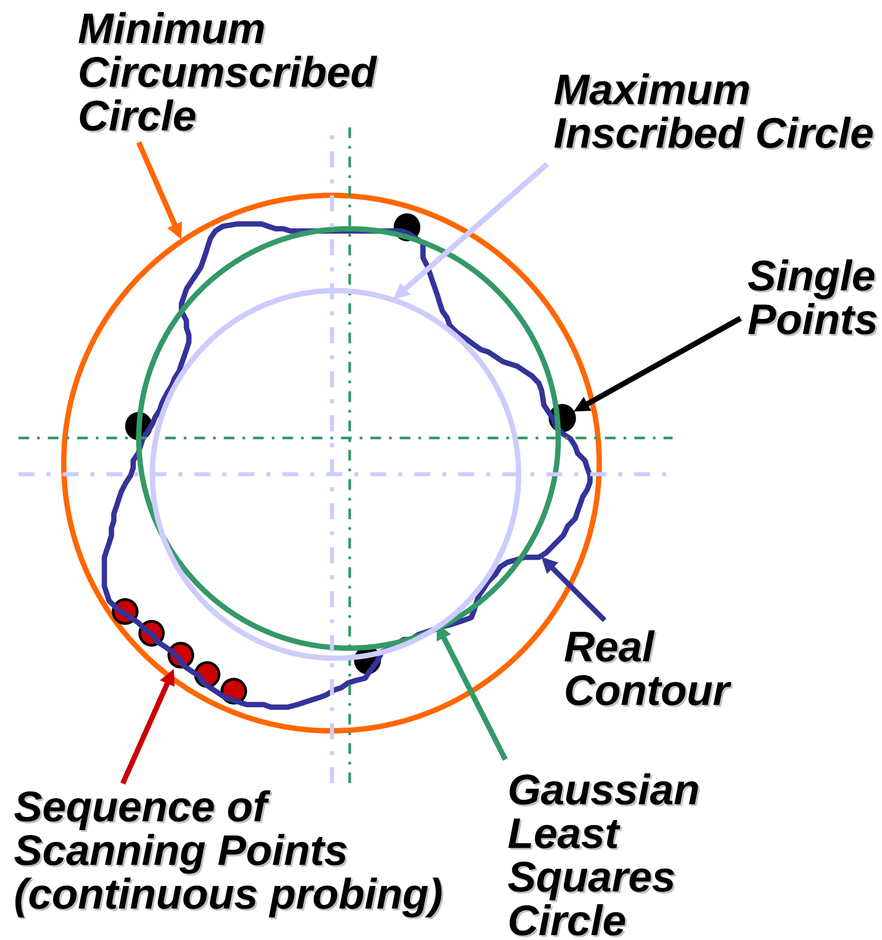
So lets generalize the math

- **We have *minimum zone* fits which equally balance the high and low point of the feature**
  - **In this type of fit only the high point and low point have any weight in determining the fit**
  - **This is *absolutely functional* fitting for form analysis**



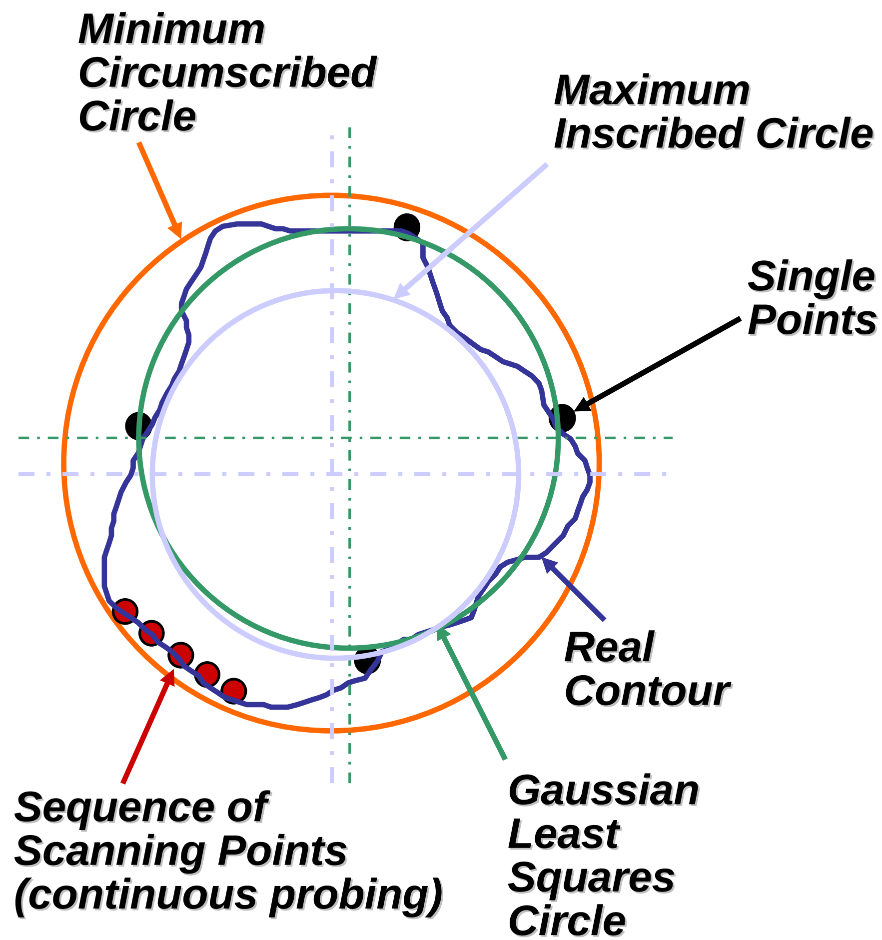
Summary

- Know the basic best math of each algorithm
- Understand the potential difference (pros and cons) each algorithm can provide
- Apply the algorithm that meets the needs of the application accordingly
- There is no one simple rule that can define what to use and when, as a CMM programmer, you must help decide what is best on a case-by-case basis



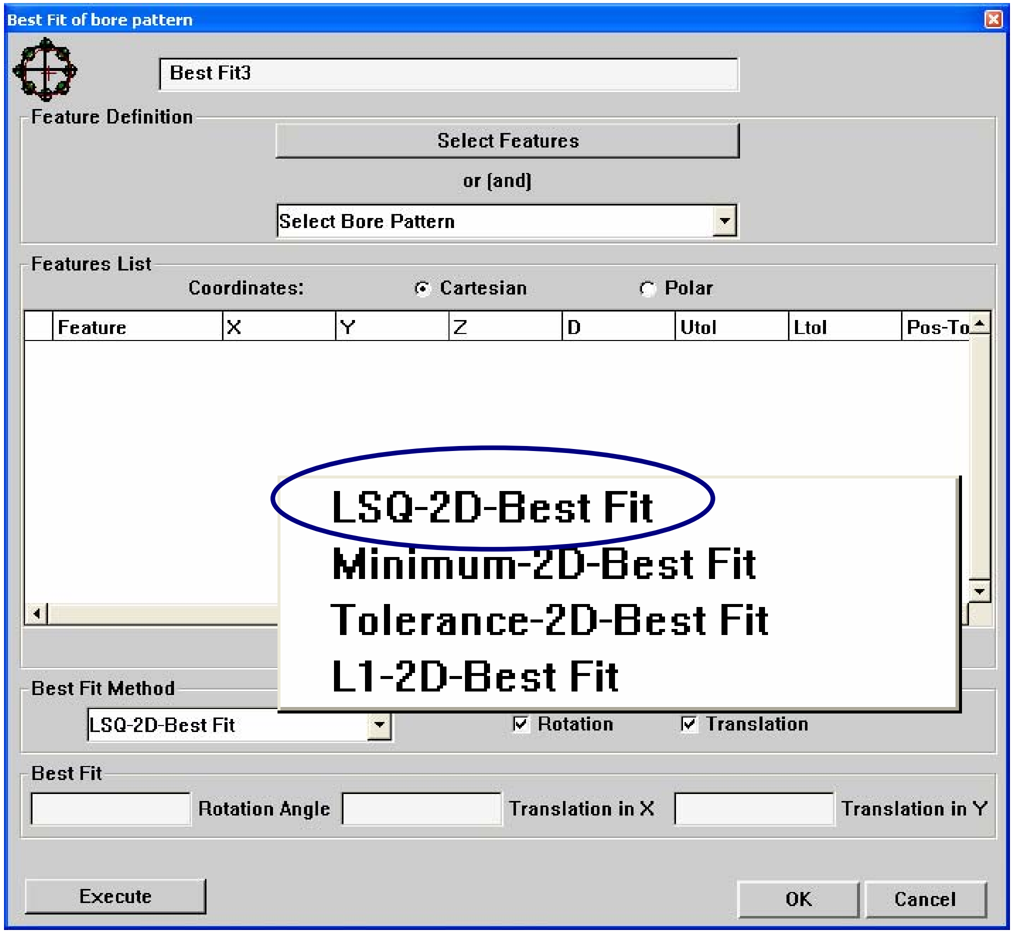
Summary

- **You need to consider**
  - **Data density**
  - **Purpose of the measurement**
    - Accept / Reject
    - Process control
  - **Correlation concerns**



Bore Pattern Algorithms

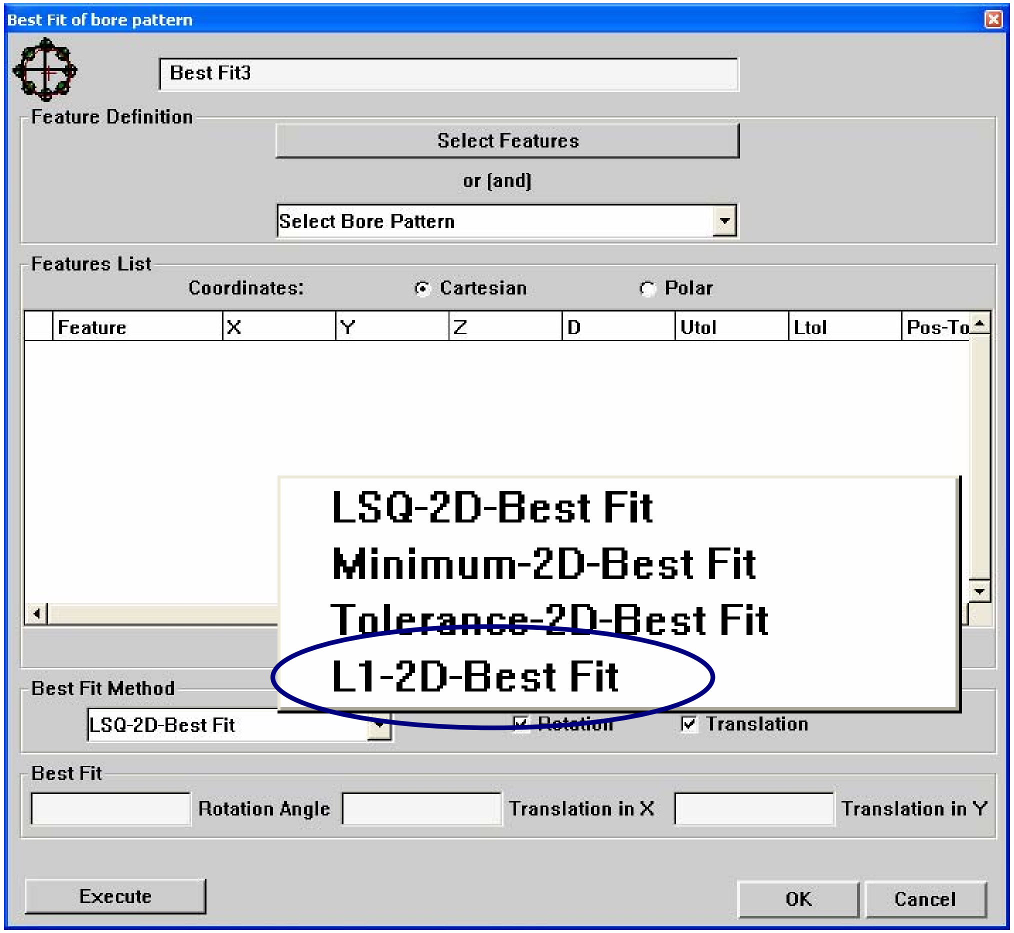
- **LSQ –2D Best Fit**
  - **Textbook math (Gauss) that minimizes the square root of the sum of the squared deviations**
  - **In certain cases it can reject a good part**
  - **Best use is for understanding the process, not for accept/reject analysis**



Bore Pattern Algorithms

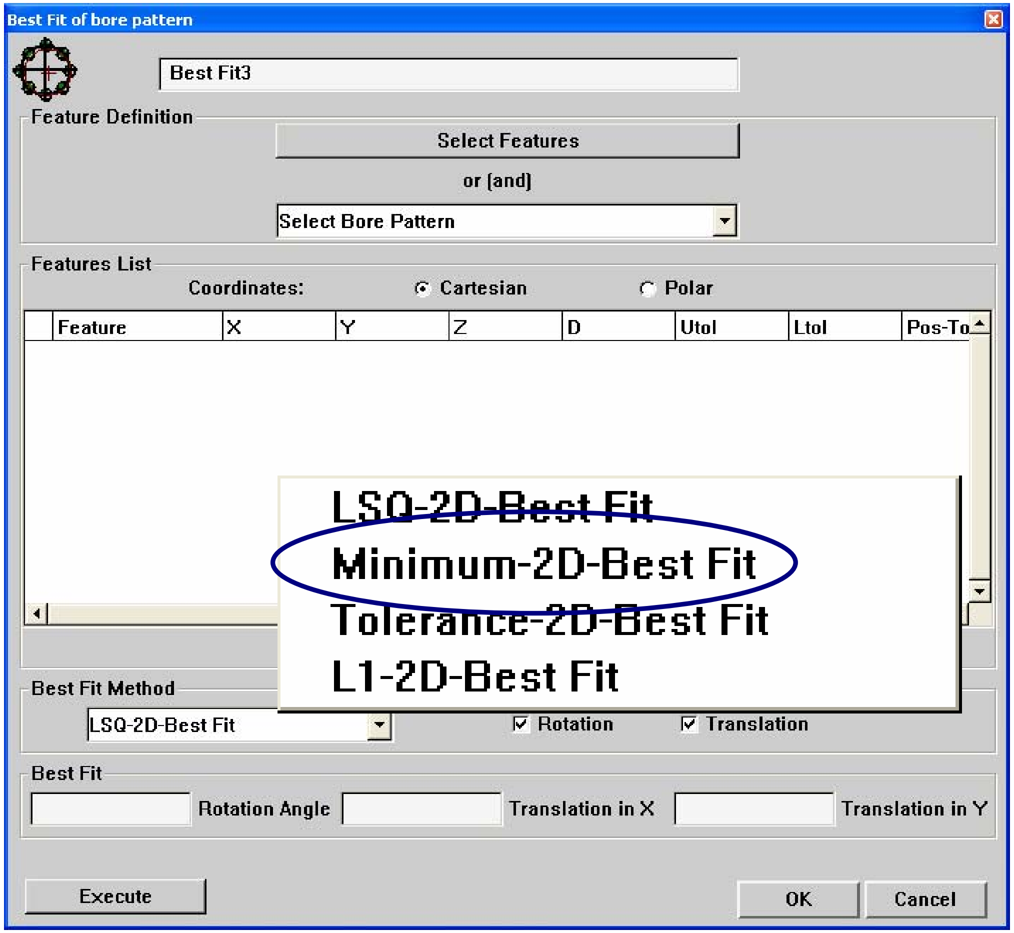
We make it visible.

- **L1 –2D Best Fit**
  - Zeiss math that tries to show the worst case error more clearly
  - In certain cases it can reject a good part, and will do so more than LSQ
  - Best use is for understanding the process, not for accept/reject analysis, and it does this better than LSQ at showing the process problem
  - The geometric element is determined in such a way to minimize the sum of the deviation values.
  - This best fit is insensitive against outliers and leads to a clear result with low computational effort.



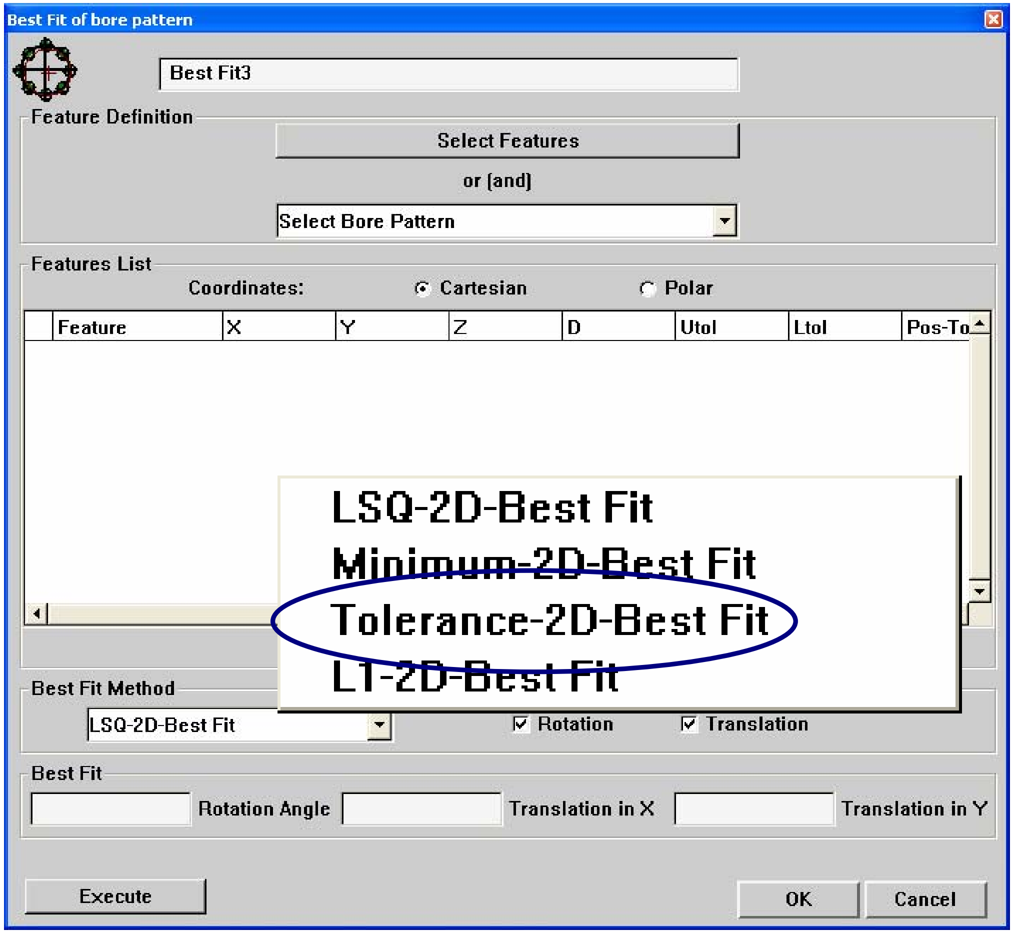
Bore Pattern Algorithms

- **Minimum –2D Best Fit**
  - **Textbook math (Tschebychev) that minimizes the maximum deviation**
  - **Will at times reject a good part, but less frequently than LSQ**
  - **Best use is for accept/reject analysis**



Bore Pattern Algorithms

- **Tolerance –2D Best Fit**
  - **Zeiss math that iteratively tries to accept the part like you would with a hard gage**
  - **Will accept the maximum number of parts**
  - **Best use is for accept/reject analysis and does a better job than Minimum**



Carl Zeiss Industrial Metrology

Questions