Fitting, Filtering and Analysis:

Feature Extraction in Dimensional Metrology Applications

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• A "cloud" of data points.



• Fitting



• Filtering



• Analysis



Thinking "Outside the Box"

- Do the current analysis methods provide the information that you are looking for?
 - Modeling of performance
 - Correlation with process controls
 - Failure analysis
 - -????
- Why measure in the first place?

Why measure?

Information!!!

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Fitting, Filtering & Analysis

 There are many tools at our disposal for the "better" analysis of data!



Fitting, Filtering & Analysis

- An overview of some of the tools
- Applications
- Getting the tools into my "box"

Goal:

Make you think differently about what you are measuring.

Fitting

- Not much has changed!
 - Depending on the geometry there are a few options:



Fitting

 Fitting alone doesn't address all of the issues



Filtering

- Filter-phobia
 - "I don't want to corrupt my data"
 - "I don't use filters; they hide things"
 - "I want to see the real surface"
- The proper use of filtering:
 Exploit the features of interest

A Filtering Toolbox

- ISO/TC213 Advisory Group 9 "GPS Extraction Techniques"
 - Linear Filters
 - Morphological Filters
 - Spline Filters
 - Spline Wavelet Filters
 - Alternating Sequence Filters
 - Robust Filters
 - Technical Specifications are being produced

An easier view...



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Traditional Filtering

Gaussian Filter



- End regions are not valid!

Improved Gaussian Filtering

Spline-based Gaussian Filtering



– Filtered data is available all the way to the ends of the raw data set!

Mechanical Filtering (by Math)



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Powerful filtering...

• Robust Filters



These filters are insensitive to extreme points.

What makes these cool...



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Disclaimer

 It should be noted that the concept of "sampling" is closely connected to the concept of filtering (mechanical, electronic or mathematical).

– There, I said it.



• Surface texture has been suffering for many years with a condition known as:

"The Parameter Rash"

 However, many other fields could benefit from some additional numerical descriptions.

Analysis

- A single "number" doesn't always describe the functionality of a surface or interface.
 - Examples:
 - Peak to valley distance, RMS
 - Rates of change, slope
 - Bearing Ratio, volumetric analysis
 - Harmonic Content

Application Example #1

- The Cam Lobe
 - The underlying, load carrying geometry is of interest.
 - The orientation and "shape" of this underlying surface is to be characterized.



Sampling the Cam Lobe



Analyzing the Cam Lobe

- Simple fitting does not yield functional information.
 - The outlier influences the form and orientation.
- Simple filtering corrupts the underlying "shape"



Simple filtering isn't enough...



Combined Fitting/Filtering

• Suppress the nominal geometry via Least Squares fitting.



Combined Fitting/Filtering

• Remove outliers or apply robust filtering on the residuals.



Combined Fitting/Filtering

• Re-apply the suppressed geometry and analyze the resulting data.



Application Example #2

- A gasket interface.
 - A solid surface in contact with a conformable component.

Conformable Surface (e.g. gasket)



Conformable Interfaces...

• There is a strong sensitivity to localized surface variations (curvatures).

- Typically these are "middle wavelengths".



Traditional Filtering

 Bandpass waviness analysis is somewhat useful.



Bandpass Waviness

• Traditional filtering is used to separate the data into 3 domains.



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Bandpass Waviness

• The bandpass waviness approach does not adequately model the interface.

- It's good, but not great.



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• A better approach is to combine robust filtering with morphological filtering.



• First a robust filter is applied.



• Next a morphological closing filter is applied to the waviness profile.



• The resulting profiles represent conformability and the resulting "gaps".





- The cutoff and closing radius can be tuned to simulate gasket properties.
 - The gap area (between the morphological and robust filtered profiles) can be calculated as a "functional" analysis.



 Similar peak-to-valley values, but different performance:



Gap area is key!



Old dogs, new tricks...

How can I use this stuff on my machine?

Answer: Software Add-Ins (Helpers)

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Software Add-Ins (Helpers)

 Several approaches are available for extracting data from instrumentation for further analysis.



Direct Hardware Interfacing

- Example: Analog to digital conversion of analog probe signal
 - Requires calibration and often requires other control interfacing.





Serial Interfacing

• Many instruments provide data output via a serial (RS-232 or other) port.



Software Interfacing

- Some instrument software packages provide an interface for external applications.
 - Spawning of external applications
 - Dynamic Data Exchange (DDE)
 - Object Linking and Embedding (OLE/COM)



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File Based Interfacing

- The control software simply stores a file.
 - The "add-in" package monitors the file and loads it when changed.



Fitting, Filtering & Analysis

<u>Summary:</u>

- Several analysis tools are available to better exploit the features of interest.
 – Choose wisely Grasshopper!
- These tools can be applied to many existing measurement systems.

Thank you!

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