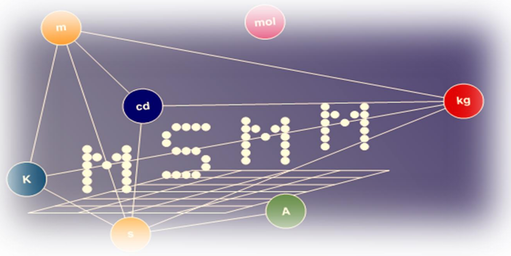


Quantitative analysis and processing of surfaces and profiles from profilometry images

A. Giura[1], M. Zucco[1], A. Balsamo[1], L. Ribotta[1]

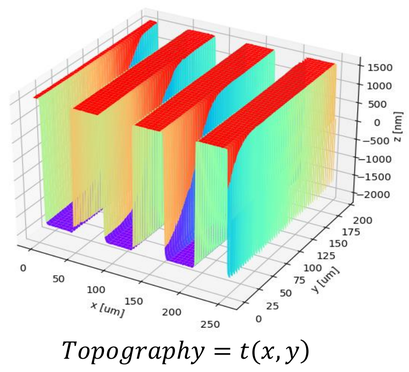
[1] Nanometrology Group, Istituto Nazionale di Ricerca Metrologica (INRIM), Strada delle Cacce 91, 10135, Turin, Italy

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

ABSTRACT

Surface metrology measures morphological parameters of surfaces or profiles, by using contact or non-contact profilometers.
The following poster describes the development of a software in Python environment that implements various processing methods on images from optical and stylus profilometers. In particular, the package focusses on image pre-processing and determination of dimensional parameters.
It is worth mentioning that many open and closed source programs are already distributed, but they do not provide a sufficient automatization in the image processing, often requiring the user to repeat the same steps for each image to obtain the expected results.
The program has been initially developed within the framework of the EMPIR 20IND07 TracOptic project for the processing of a batch of topographies on RS-M and RS-N linear step samples, in order to compensate for the lack of automation for the calculation of height parameters. The developed program is designed to be modular and scalable for expanding the processing capabilities.

SURFACE PROCESSING



$Topography = t(x, y)$

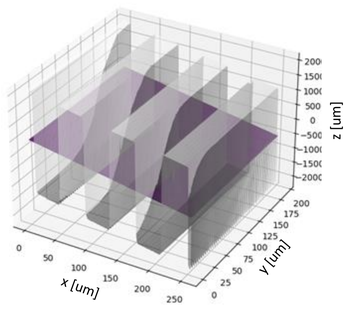
3D metrological characterization of surfaces is done by means of traceable and reliable instruments, such as stylus or optical profilometers. The output of these instruments are profiles or images that must be processed to extract the measurands of interest.

PROFILE PROCESSING

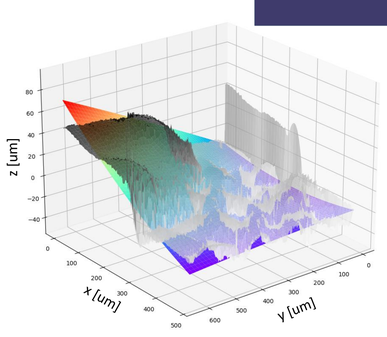
$Profile = p(x)$

Profile measurement systems measure and record the profile of a sample by tracing its surface using a stylus. In recent years, newer profilometer models have been developed that use an interferometric or a confocal probe instead of a stylus to measure complex shapes by tracing the profile in a non-contact manner.

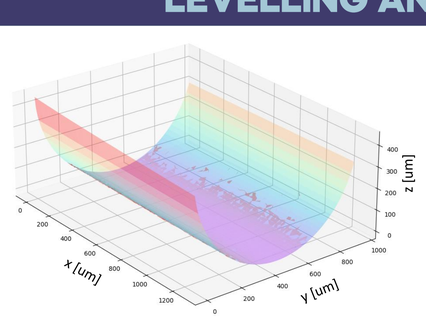
LEVELLING AND FORM REMOVAL



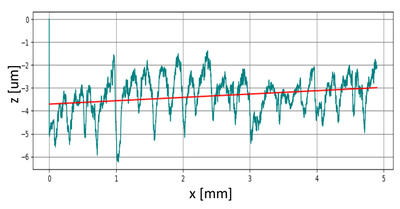
BOUNDED LS PLANE



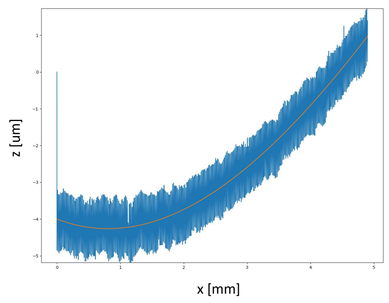
BOUNDED LS POLYNOMIAL



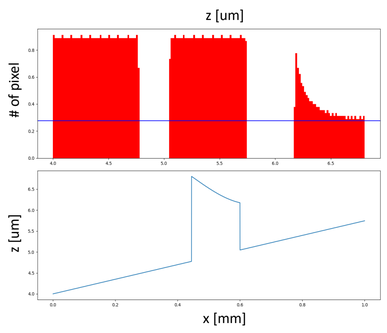
LS CYLINDER AND SPHERE



BOUNDED LS PLANE



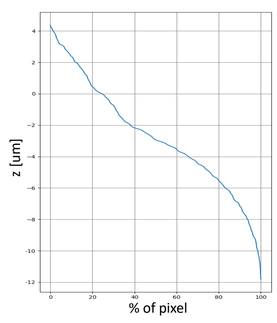
BOUNDED LS POLYNOMIAL



HISTOGRAM METHOD

The ISO 3274:1996 standard specifies that, in order to extract roughness parameters, the primary profile or topography should not contain the nominal form of the workpiece. The form component must be removed prior to any other metrological operation. When the form is just a line segment or a plane, this operation is called levelling, when the form is non planar, it is called form removal.
The package implements various methods to take into account the most common morphologies of standards.

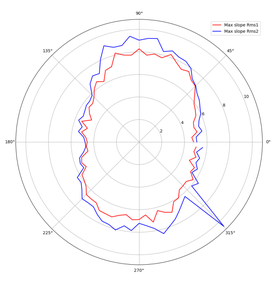
MORPHOLOGICAL FEATURES



HISTOGRAM & A-F CURVE

The program subdivides the measured points according to the height of the point, the resulting histogram is significant for step height or groove samples measurements.
By analyzing the resulting histogram it is possible to calculate the primary height of the sample.

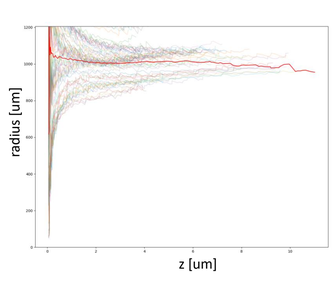
The Abbott-Firestone curve describes the surface texture of an object. Mathematically it is the cumulative probability density function of the surface profile's height and can be calculated by integrating the probability density function. The curve is useful for understanding the properties of sealing and bearing surfaces.



MAXIMUM SLOPE

The maximum measurable slope ϕ_{MS} is defined in ISO 25178-600:2019 as the greatest local slope of a surface feature that can be assessed by the measuring system.
Given a topography (a spherical cap in the example), the program calculates the maximum measured slope radially taking into account two different breakpoints for each radial profile.

The first breakpoint is taken at the first non-measured point, the second breakpoint is taken at the last measured point, the user can select the angular definition of the processing.



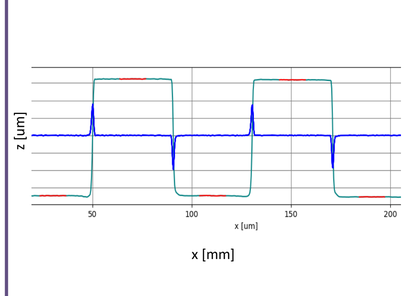
SPHERE & CYLINDER RADIUS

Given a spherical or cylindrical cap topography, the program can calculate its radius in two different ways:

- radially and at different z values of the extracted profile. The program extracts a radial profile and then calculates the radius at each point of the profile:

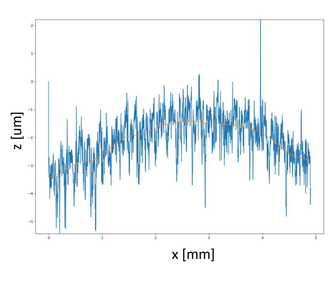
$$R\_radial_j(z_{eh}) = [R_1, \ldots, R_n] \; : \; R_i = \frac{x_i^2 + z_{eh,i}^2}{2z_{eh,i}}$$

- cylinder or sphere fit



STEP HEIGHT

The program calculates the step height according to ISO 5436-01:2000, the standard stipulates that the height measurement is made taking into consideration three zones of the profile for each step.
To automate the selection of the regions of interest (ROIs), the program calculates the derivative of the profile and a threshold value above or below which to search for peaks.
It may happen, however, that the step is not well defined due to the shape of the measurand or instrumental inaccuracy, in which case the program will fail to calculate the step height correctly and will return a warning.



FILTERS

Before calculating roughness parameters, it is necessary to filter the profile according to the filters described in ISO 16610:2011, by using three different types of filters implemented in the package:

- Gaussian filter
- Robust gaussian
- Cubic spline (with tension)

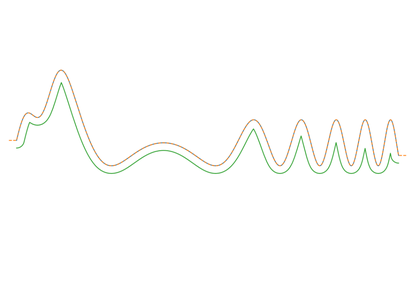
To apply a filter to a profile two methods can be used:

spatial domain:

$$p_{filtered}(x) = s(x) \otimes p(x)$$

wavelength domain:

$$p_{filtered}(x) = \mathfrak{F}^{-1}\{S(\lambda)\, P(\lambda)\}$$



MORPHOLOGICAL FILTER

The resulting profile is the locus of points traversed by the center of a circumference rolling below the profile (erosion).
This processing is used for contact profile measurements to reconstruct the primary profile from the skin model, as described in ISO 21920-2:2021.

The implemented method compares locally a semicircle and the profile itself and, using a recursive bisection method, moves the semicircle center up or down in order to have the whole profile laying above the curve.

CONCLUSIONS

At present the developed Python package provides various methods and tools for processing topographies and profiles, both single and in batch, the methods for levelling, rotating, cutting profiles and surfaces are valid and allow a high degree of flexibility for special needs of the sample geometry under analysis.
Further developments will regard the study on (i) roughness and texture parameters according to ISO 25178-02:2021, (ii) new parameters based on the functional characteristics of the sample, and (iii) uncertainty analysis according to GUM and Monte Carlo methods.

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GitHub
@andeledea

EMPIR 20IND07 TracOptic project

a.giura@inrim.it

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