New Geometrical Filtration for Ultra-Precision and Micro/Nano Manufactured Products (EP/F032242/1)

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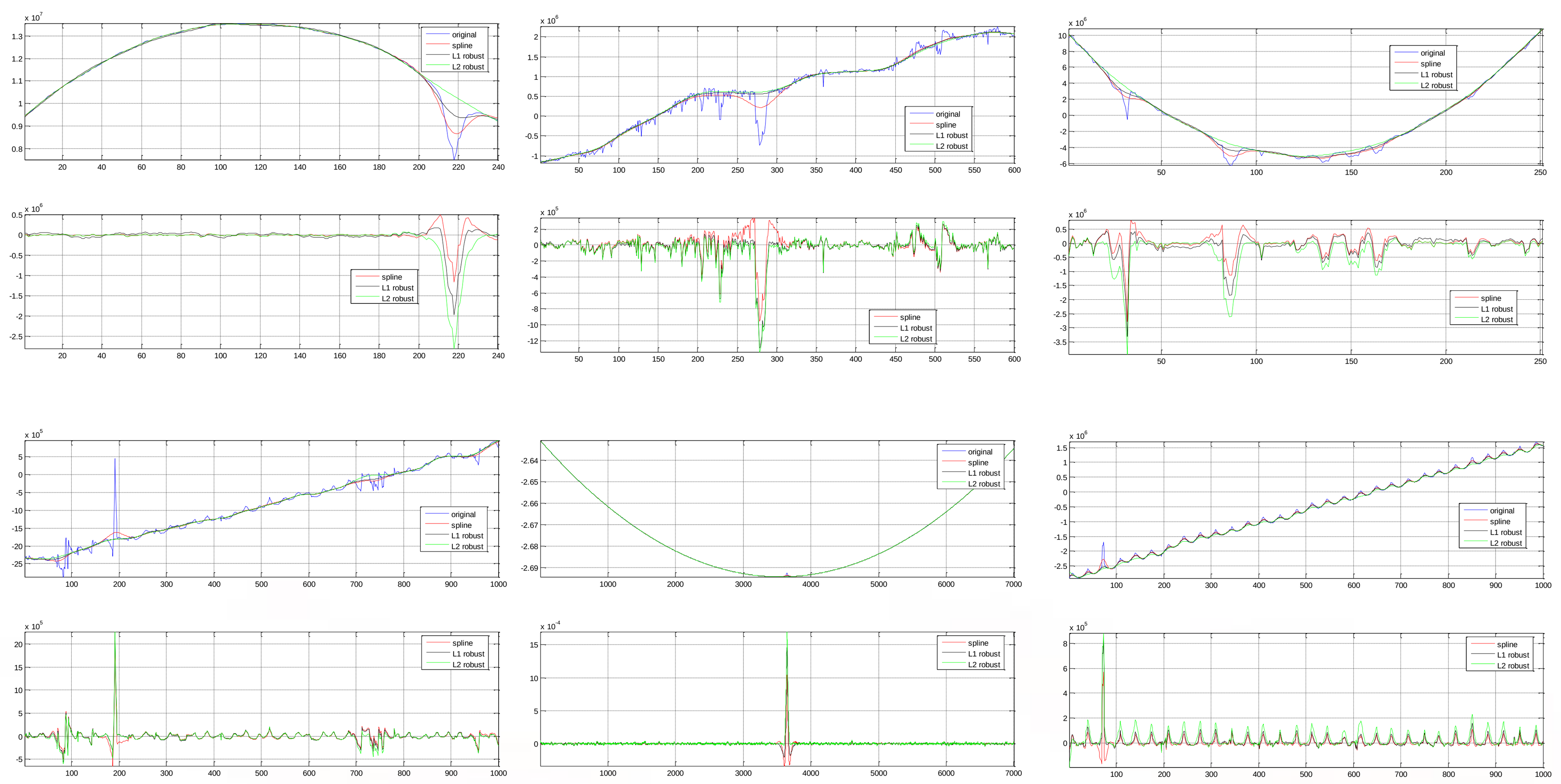
The aim of this project is to explore and develop fast and stable algorithms, standard reference algorithms, and measurement procedures for non-linear geometrical Gaussian and spline filtration. Focusing on:

- Exploration of suitable numeric models for robustness and stability of non-linear filters.
- Creation of fast algorithms for the efficient implementation of non-linear Gaussian and spline filters.
- Development of standard reference algorithms implementing the definitions according to the ISO 16610 series of standards.

Generalised Spline filter

$$\sum_{k=0}^{n-1}\rho\left(z_k - s(x_k)\right) + \lambda\int_{x_0}^{x_{n-1}}\left\{\frac{d^2 s(x)}{dx^2}\right\}^2 dx \rightarrow \underset{s(x_k)}{Min}$$

	$\rho(x)$	$\psi(x)$	$w(x)$	
L2	$\rho(x)=x^2/2$	$\psi(x)=x$	$w(x)=1$	linear
L1	$\rho(x)=\lvert x\rvert$	$\psi(x)=\operatorname{sgn}(x)$	$w(x)=\frac{1}{\lvert x\rvert}$	Nonlinear Robust
Huber	$\rho(x)=\begin{cases} x^2/2, if\ \lvert x\rvert\le k \\ k\left(\lvert x\rvert-k/2\right), if\ \lvert x\rvert>k\end{cases}$	$\psi(x)=\begin{cases} x, if\ \lvert x\rvert\le k \\ k\operatorname{sgn}(x), if\ \lvert x\rvert>k\end{cases}$	$w(x)=\begin{cases} 1, if\ \lvert x\rvert\le k \\ k/\lvert x\rvert, if\ \lvert x\rvert>k\end{cases}$	
Cauchy	$\rho(x)=\frac{c^2}{2}\log\left(1+\left(x/c\right)^2\right)$	$\psi(x)=\frac{x}{1+(x/c)^2}$	$w(x)=\frac{1}{1+(x/c)^2}$	
Tukey	$\rho(x)=\begin{cases}\frac{c^2}{6}\left(1-\left[1-(x/c)^2\right]\sqrt{3}\right), if\ \lvert x\rvert\le c \\ \frac{c^2}{6}, if\ \lvert x\rvert>c\end{cases}$	$\psi(x)=\begin{cases} x\left[1-(x/c)^2\right]^2, if\ \lvert x\rvert\le c \\ 0, if\ \lvert x\rvert>c\end{cases}$	$w(x)=\begin{cases}\left[1-(x/c)^2\right]^2, if\ \lvert x\rvert\le c \\ 0, if\ \lvert x\rvert>c\end{cases}$	



Generalised higher order gaussian regression filter for 2D Profile

$$\int_0^l \rho\left(z(\xi)-w(x)-\beta_1(x)(\xi-x)-\beta_2(x)(\xi-x)^2\right)s(\xi-x)d\xi \rightarrow \underset{w(x),\beta_1(x),\beta_2(x)}{Min}$$

Generalised higher order gaussian regression filter for 3D surface

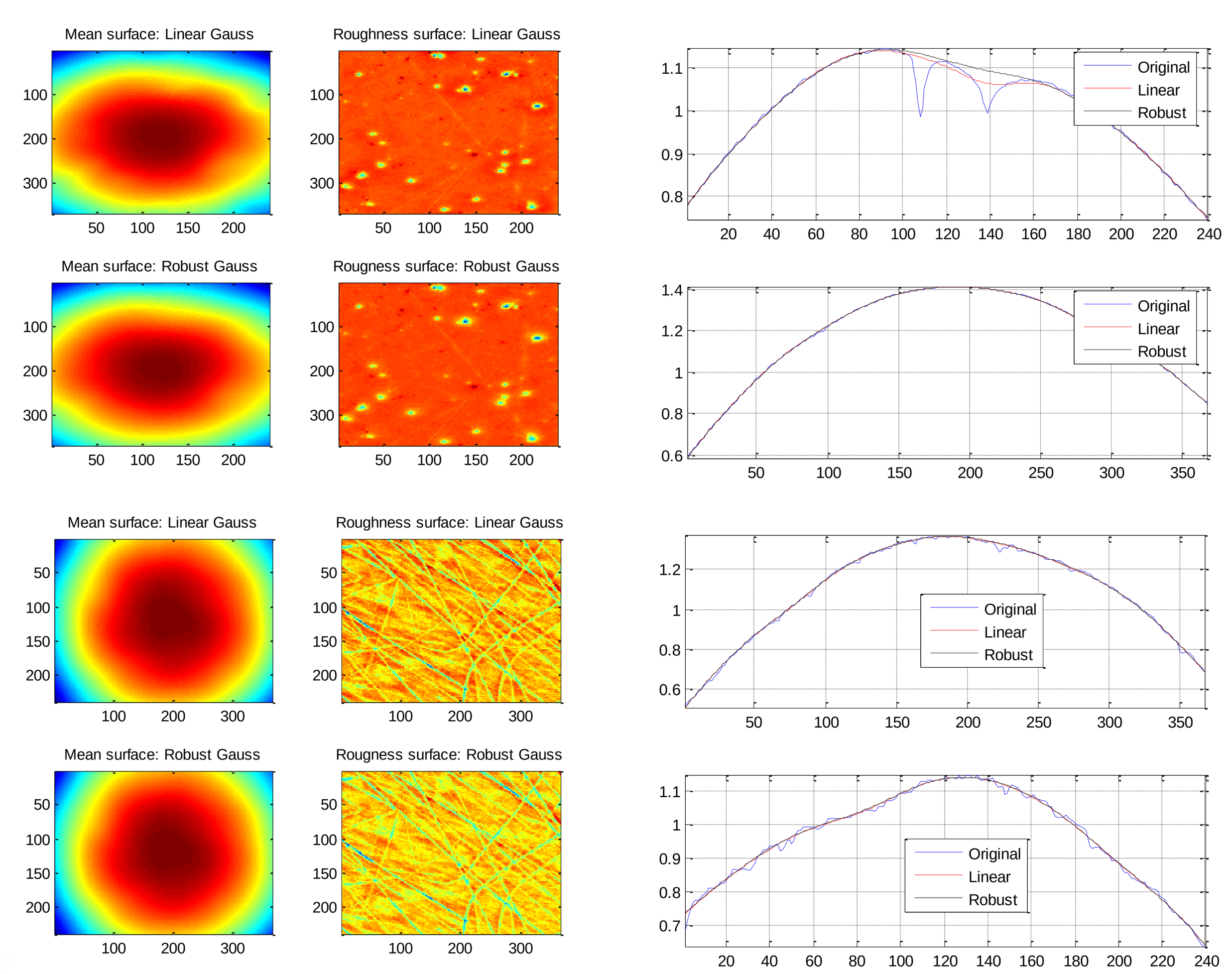
$$\int_0^{ly}\int_0^{lx}\rho\begin{Bmatrix} z(\xi,\eta)-\beta_{10}(x,y)(\xi-x)-\beta_{01}(x,y)(\eta-y)-\beta_{20}(x,y)(\xi-x)^2 \\ -\beta_{11}(x,y)(\xi-x)(\eta-y)-\beta_{02}(x,y)(\eta-y)^2-w(x,y)\end{Bmatrix}\cdot s(\xi-x,\eta-y)d\xi d\eta$$

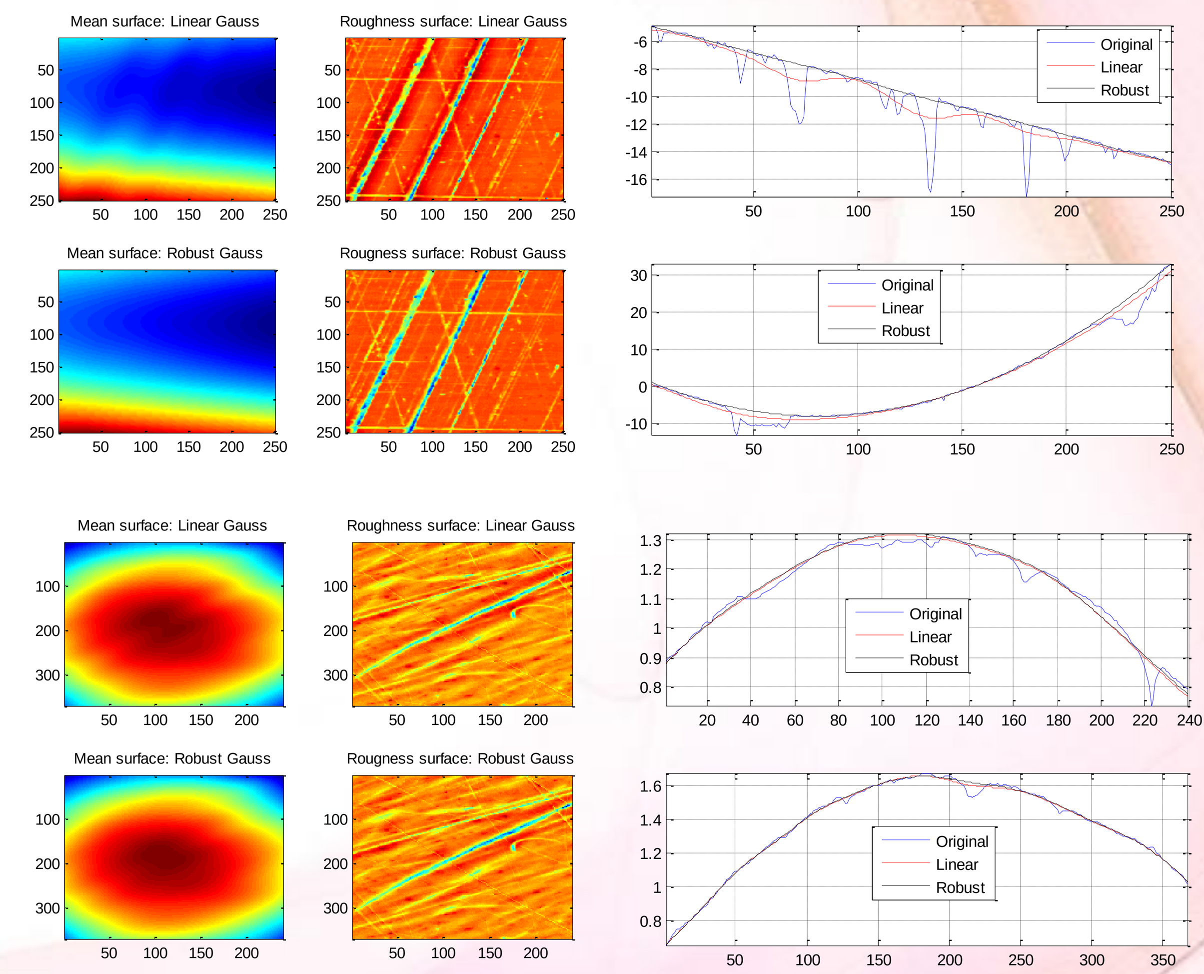
$$\Rightarrow \underset{w(x,y),\beta_{10}(x,y),\beta_{01}(x,y),\beta_{20}(x,y),\beta_{11}(x,y),\beta_{02}(x,y)}{Min}$$

Fast algorithms:

1. Convolution to FFT;
2. Pre-calculation;
3. Separable in rows and cols

Significant speed improvement:
For a typical 60,000 pts data, 100 ms is needed compared with tradition algorithms need a few hours





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