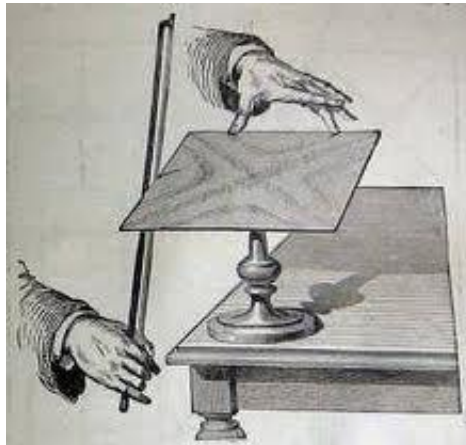Hugues Favrelière   Serge Samper   Gaëtan Le Goïc   Pierre Antoine Adragna

Modal parameters of surfaces for numeric models
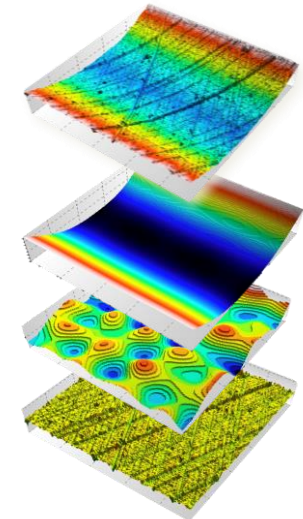## The DMD : DISCRETE MODAL DECOMPOSITION

Form

Undulation

Roughness

Hugues.favreliere@univ-smb.fr,   Serge.samper@univ-smb.fr,
Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
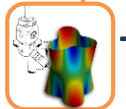
Outline

A « small » digression: What is the height of Mt Blanc?

Sounds and complexity sorting, you already know!

From the quality of the sound of a bell to a new idea.
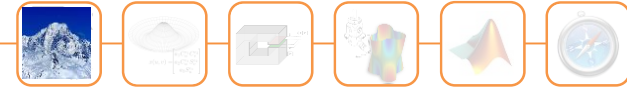
The modal filtering method

Solutions (Metrology, Assembly, Multiscale, Calibration)

Synthesis

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

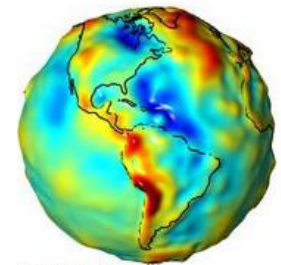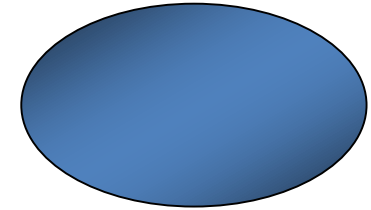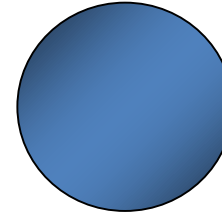# A « small » digression

4810 Level

0 Level

The height of Mont Blanc is given by?

- Two data … because each length has two boundaries.

- The top of the mountain is « known »

- Where is the bottom?

- At the sea level… under the Mont Blanc?

- There is a strange surface under the Mont Blanc… a virtual sea that gives the Mont Blanc it's height!

- Is this virtual sea a sphere at the sea level?

Hugues.favreliere@univ-smb.fr, Serge.samper@univ-smb.fr,
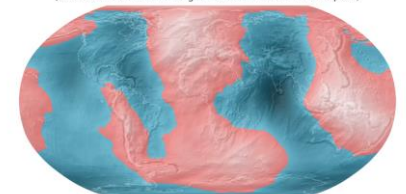Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

A « small » digression?

- The sea level is given by?
  - A single scalar value given by a radius of a sphere?
    - Too simple and not realistic.
  - Several scalars of an equation (ellipsoid)?
  - The mediteranean sea? Too far?
  - The Annecy Lake? Too small to be a sea…
  - **A set of points that defines the geoïd. This strange surface is parameterized… and Numeric & Symbolic.**

Deviation of the Geoid from the idealized figure of the Earth
(difference between the EGM96 geoid and the WGS84 reference ellipsoid)

Red areas are above the idealized ellipsoid; blue areas are below.

-107.0 m   0 m   +85.4 m

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

A small digression?
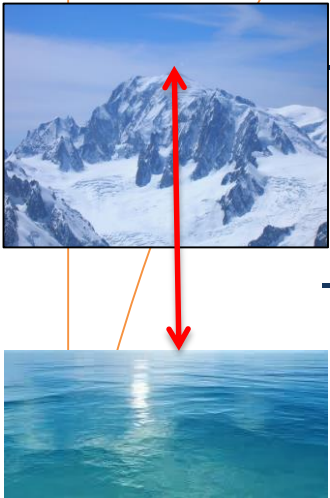
– The height of the Mont Blanc can move from the bottom and the top… and our knowledge of the calibration of the earth.

– We need flexible geometric parameters to describe measurements and model.

– Ther other observation: Numeric/Symbolic worlds:

Symbolic (Sphere/ellipse)
    Simple/Poor
    Reable
    Exacts / models
    Rigid

Numeric (measurements)
    Rich/Complex
    Not readable (data)
    Not exact

It is usefull to combine them

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

A small digression... symbolic vs numeric?

In the past « human solvers »used symbolic understanding of the world thus equations where anywhere.

Nowadays computer solvers uses numeric understanding of the world thus numbers are anywhere.

How can we understand numbers?

One number has a sense for our brain.

But what appends for Two, ten or billions?
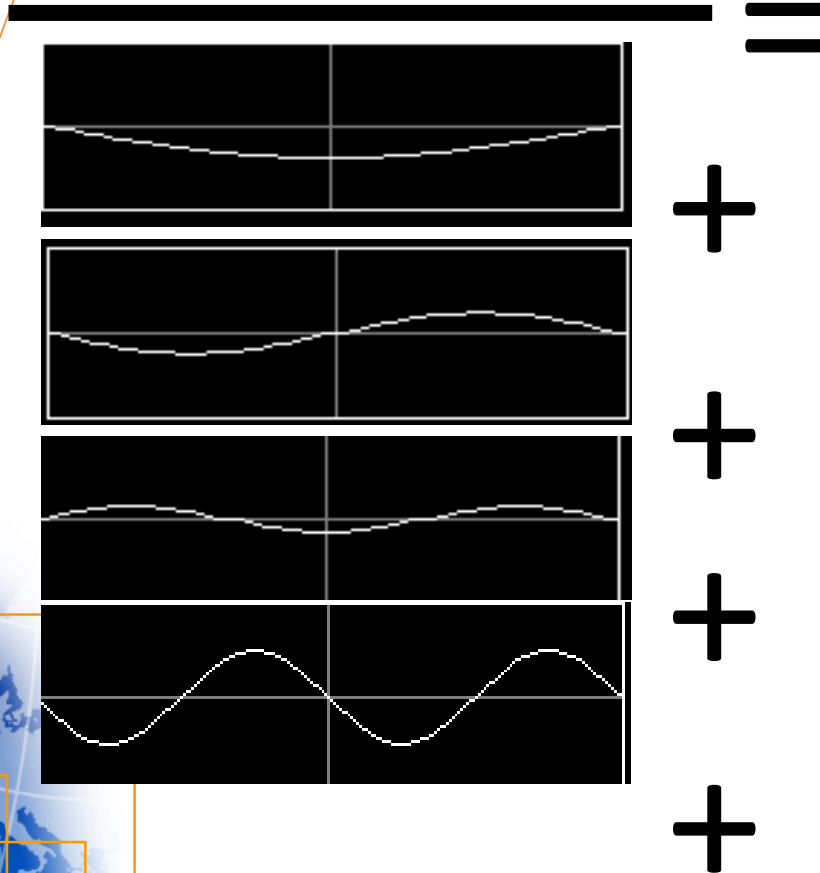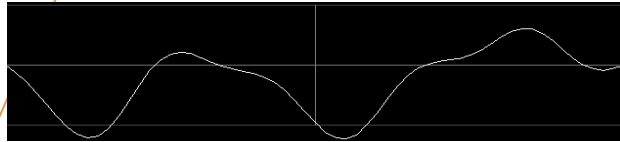
Hugues.favreliere@univ-smb.fr,   Serge.samper@univ-smb.fr,
Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

Sounds and complexity sorting

Joseph Fourier
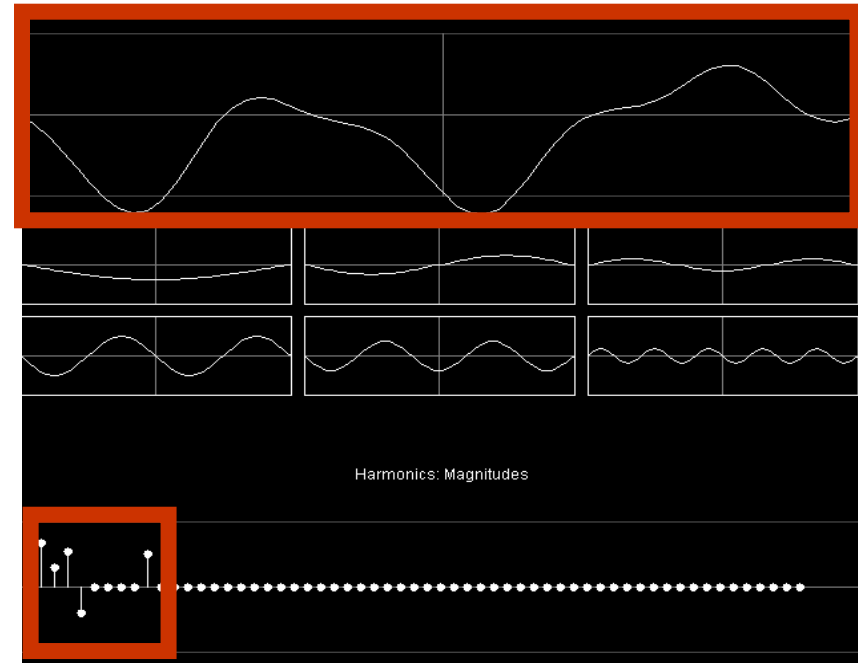
Harmonics: Magnitudes

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Sounds and complexity sorting
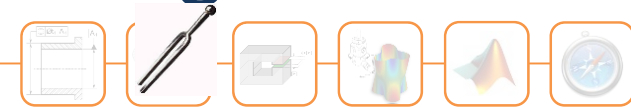
- The natural sorting of complexity
- For sounds (violin strings…)
- For images (JPEG)
- For geometry (straightness,circularity…)
- For several kind of signal:
  - Pictures
  - **Any geometry?**
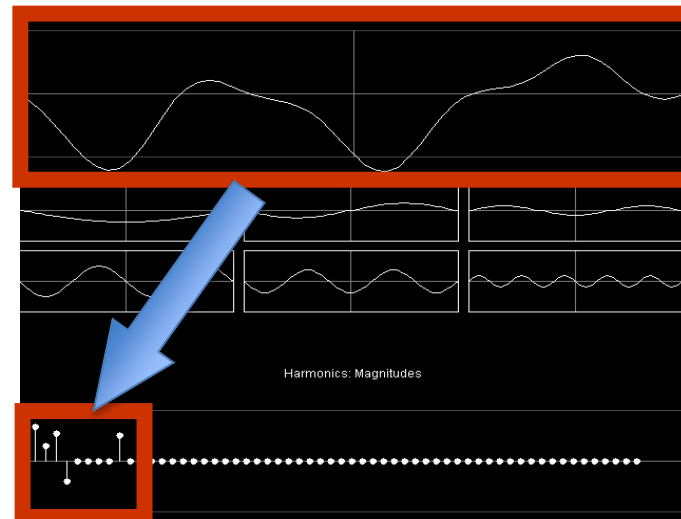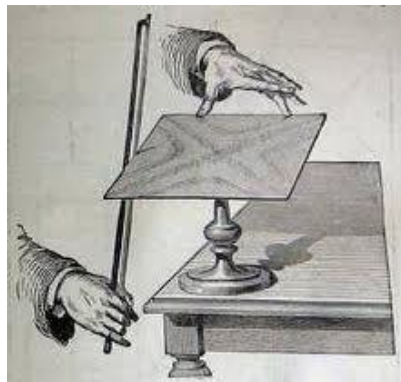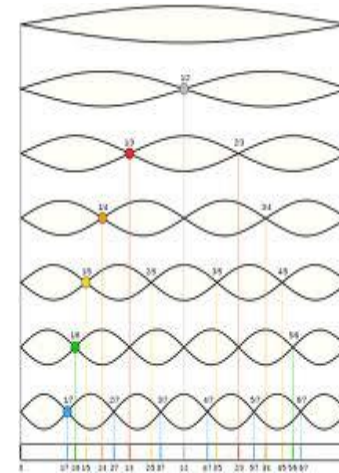
Complexity

Harmonics: Magnitudes

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

From the quality of the sound of a bell to a new idea.

- We were asked to analyse the quality of sounds of bells…
  - ~~Material~~
  - ~~Boundary conditions~~
  - **Geometry**
- Thus, how can we link the two following set of parameters?

Tolerancing from drawings | Sounds from natural modes

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
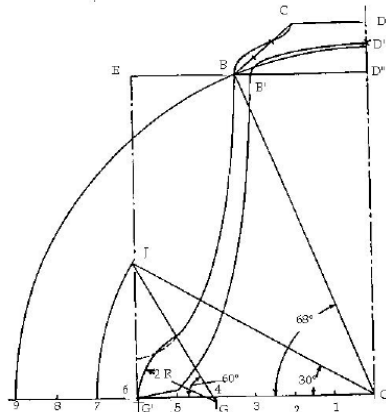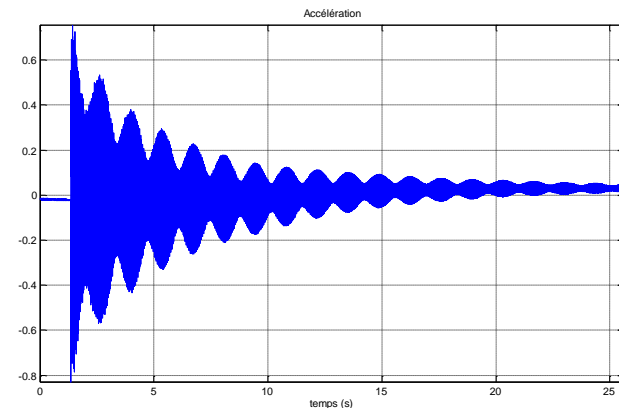
From the quality of the sound of a bell to a new idea.

At first is the customer need.
-> Sounds from natural modes
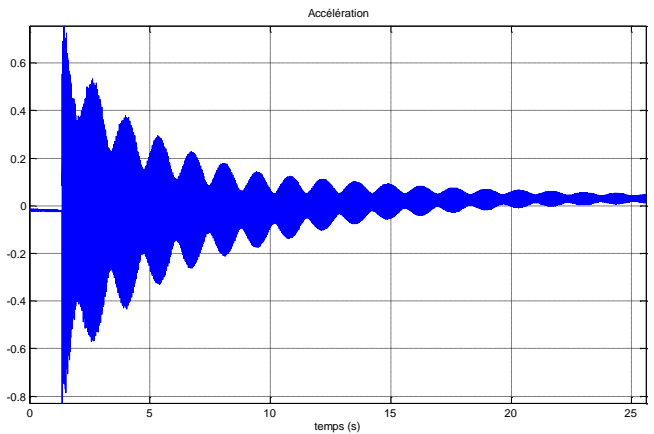
Fourier for sounds...
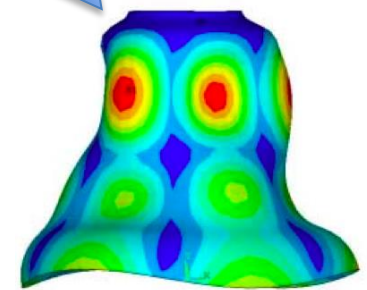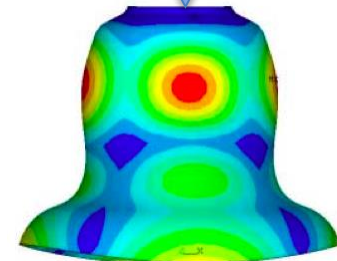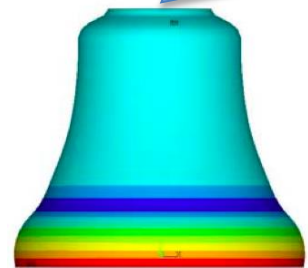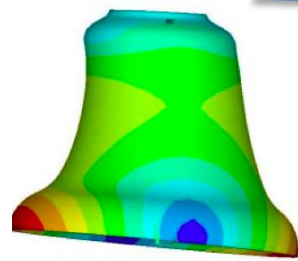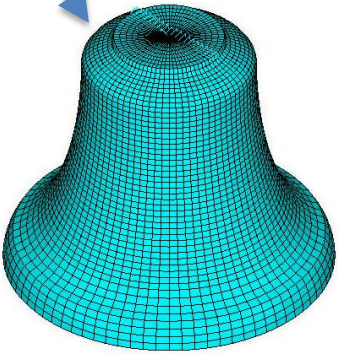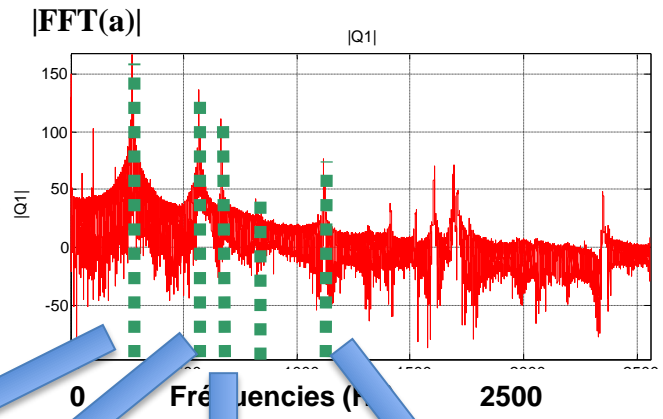
firsts natural modes shapes

Hugues.favreliere@univ-smb.fr, Serge.samper@univ-smb.fr, Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

From the quality of the sound of a bell to a new idea.

The idea was to compare the function (need) of the bell (the sound) to the undependant parameters that drives the function... and control them instead of an other undapted parameter...

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
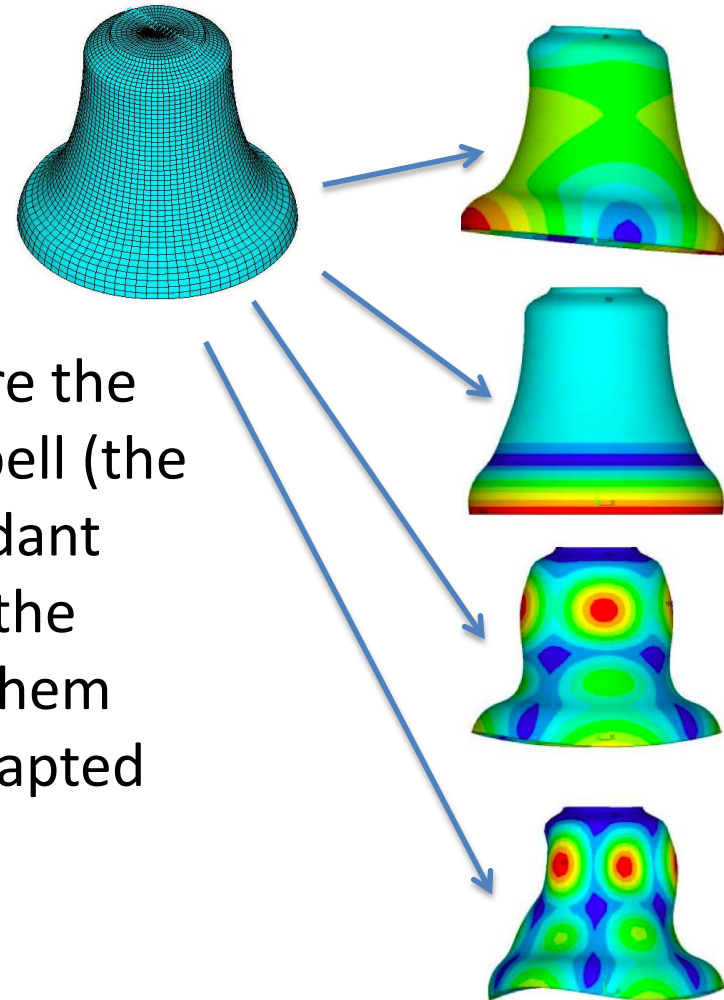
Example: the firsts mode shapes of a free square
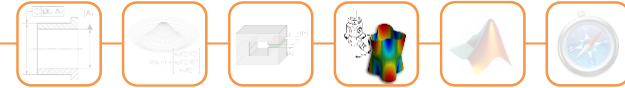
Properties

- Unicity
- Inversibility
- Stability
- Efficiency
- **Complexity sorting**
- **Exhaustivity**
- **Metric**

Position

Form

Size

Undulation

Complexity

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

Building a mountain?

The Fischerhorn
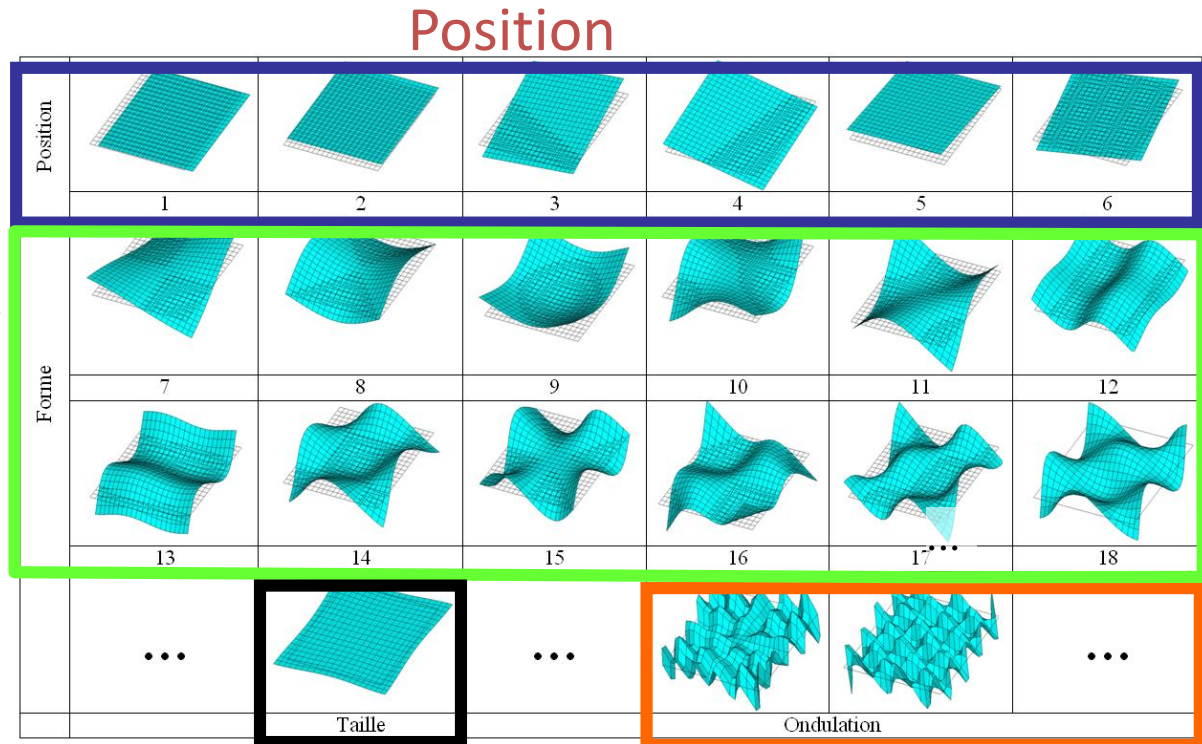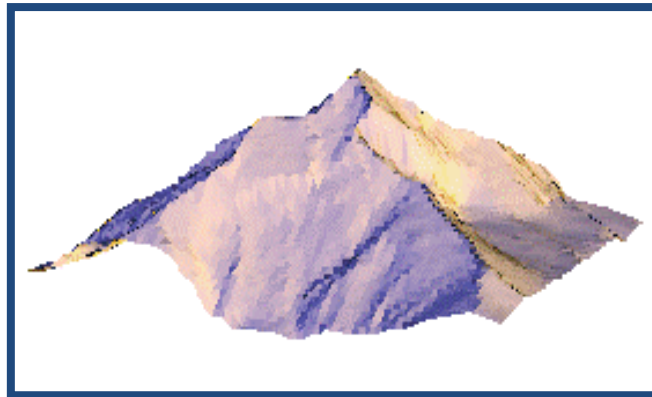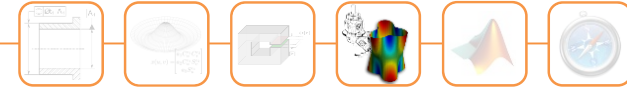
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3602.4, 3497.38, 3374.49, 3350.02, 3315.01, 3281.01, 3274.5, 3154.79, 3141.11, 3289.62, 3446.38, 3642.39,
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3733.82, 3630.81, 3602.49, 3692.61, 3748.81, 3625.48, 3371.39, 3103.88, 3345.52, 3600., 3868.38, 3970.78,
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3682.12, 3705.5, 3463.6, 3236.39, 3590.39, 3817.21, 3864.41, 3936.52, 3905.01, 3713.02, 3588.99, 3427.2,
3   3513.82, 3627.49, 3692.61, 3602.1, 3485.58, 3376.98, 3249.41, 3196.79,
3   3449.4, 3511.59, 3354.61, 3232.02, 3183.81, 3113.8, 3105.19, 3172.8,
3296.61, 3257.72, 3211.78, 3258.2, 3271.09, 3095.88, 3101.91, 3049.99, 3048.29, 3039.81, 3070.18, 3156.11

A huge set of data

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
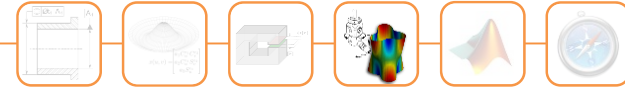
Modal method: basis

- Measurement
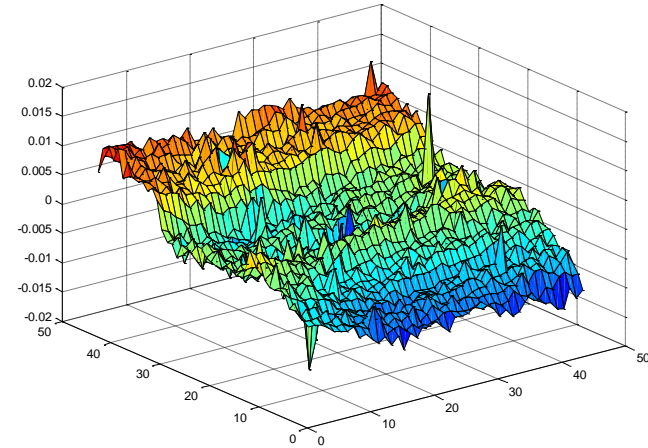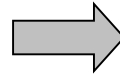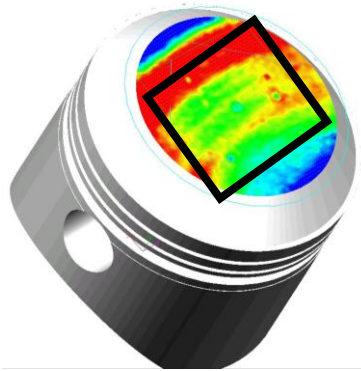
Piston

Finite Element Model of the ideal surface
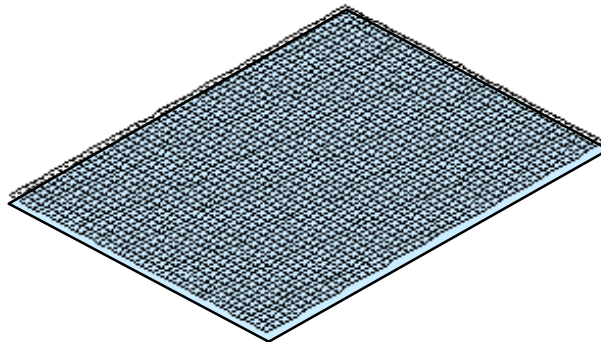
- Shell elements

-Free Boundary Conditions

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Modal method: basis

® Adragna-Favreliere
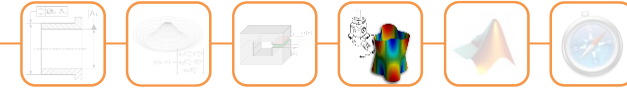
Modal basis of the surface

Basis of the mode shape : Q_i

Mode 74   Mode 3   Mode 11   Mode 19   Mode 8
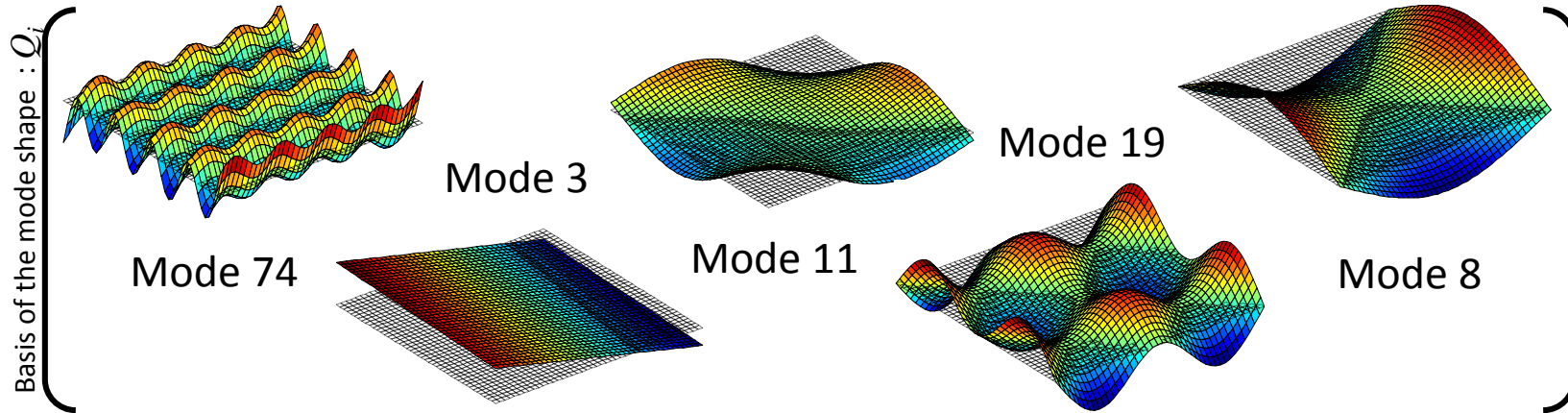
Decomposition of the modal basis

$$\lambda_i = <V.Q_i>$$

Reconstruction

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
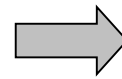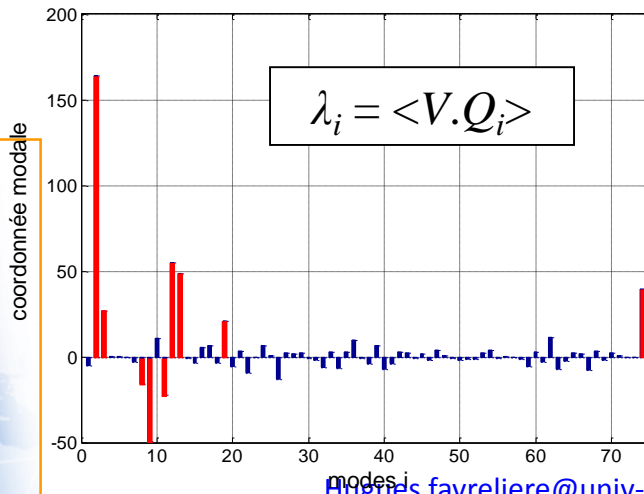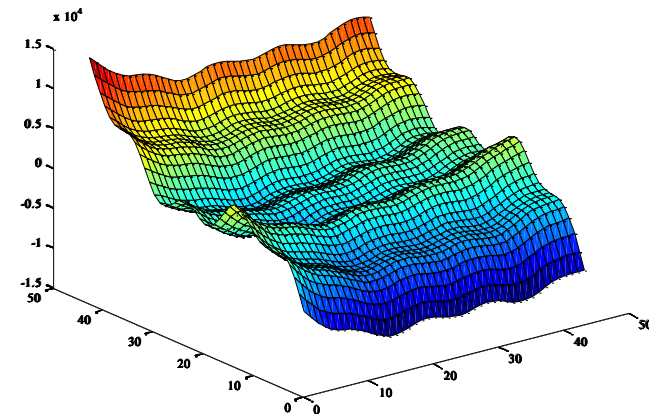
Building a mountain from a plane?
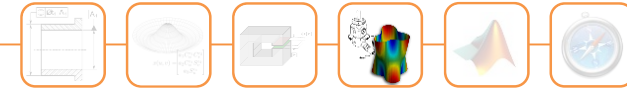
Fisherhorn

Surfaces

(modes # 30 à 60)

3D Reconstruction

Cervin

(meters)

3D Residue

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
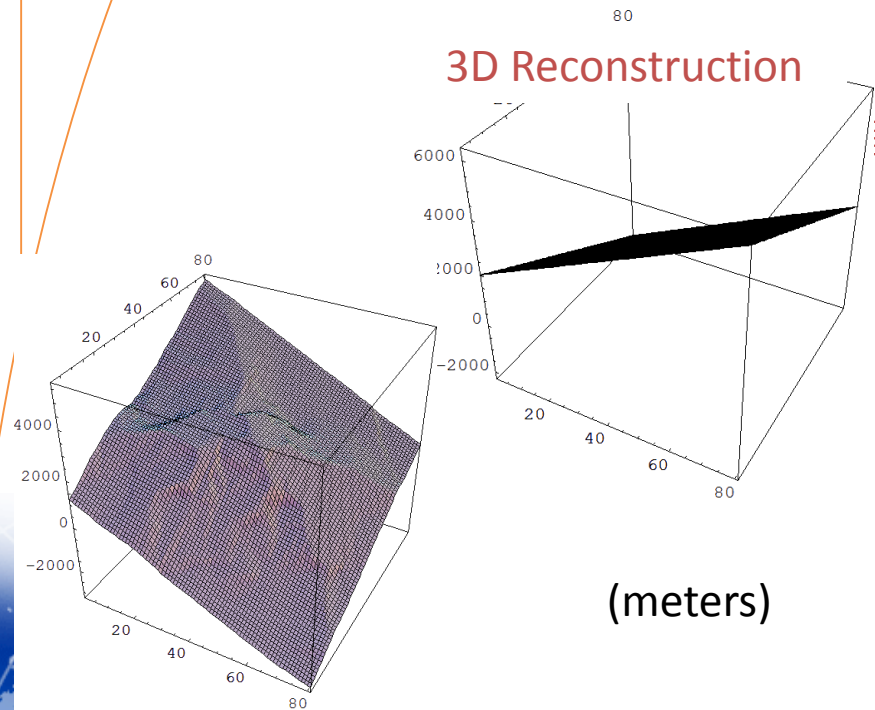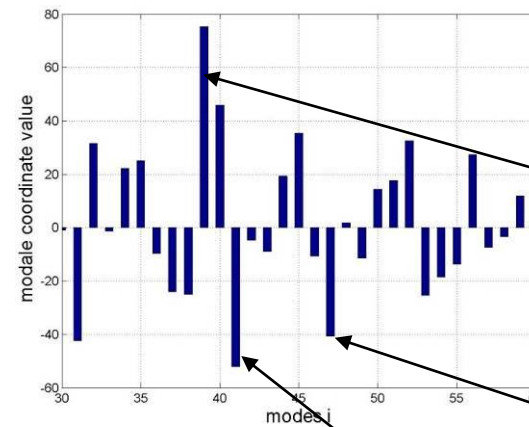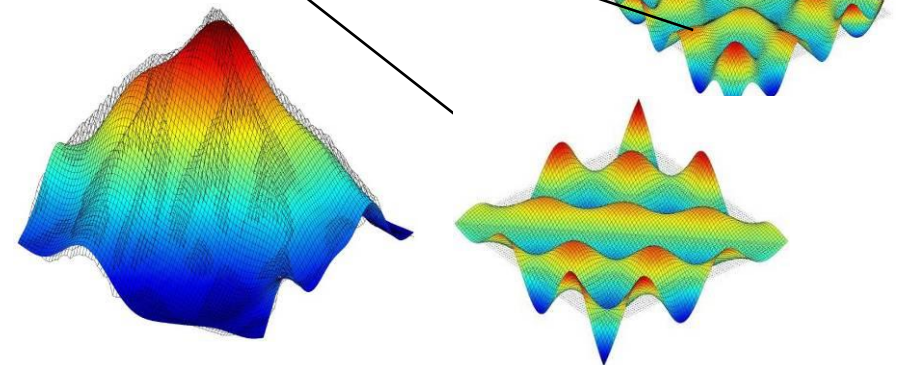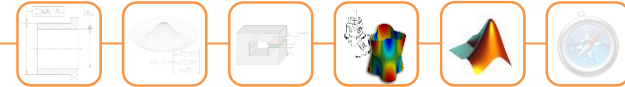
Form errors Statistics

Geometry

FEM Mode

Mode 12

Mode 45

Mode 67

Mode 77

Gap
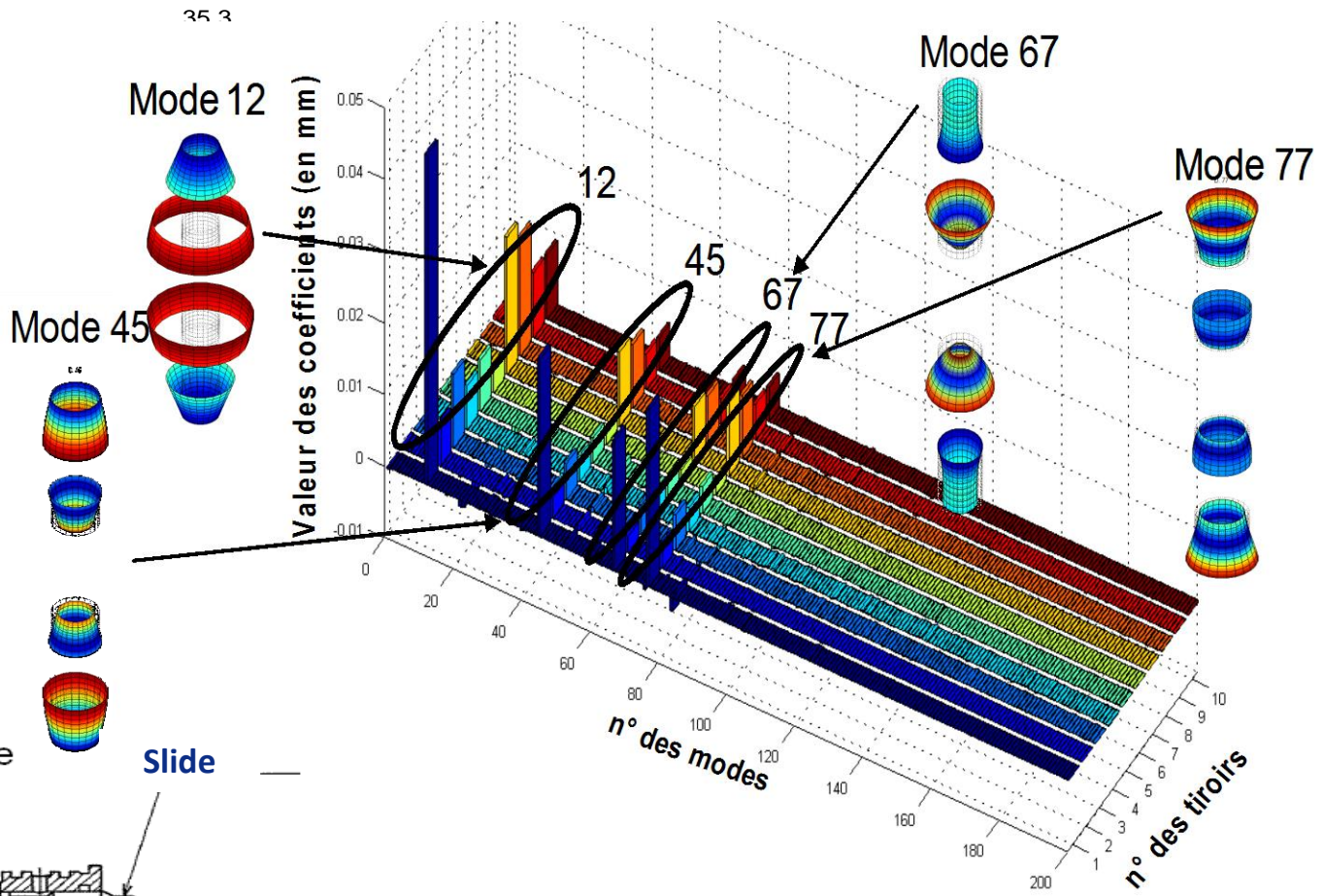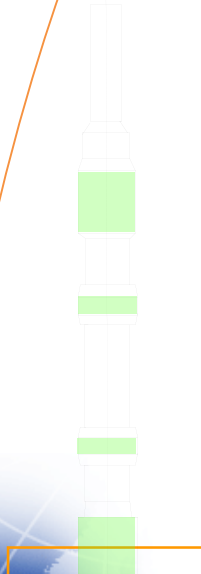
Sleeve

Slide

Hugues.favreliere@univ-smb.fr, Serge.samper@univ-smb.fr,
Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
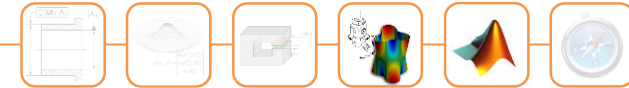
- ## Simulation of a familly of shapes based on a model of combination of parameters

Generate a random modal signature

Compute the associated form deviation
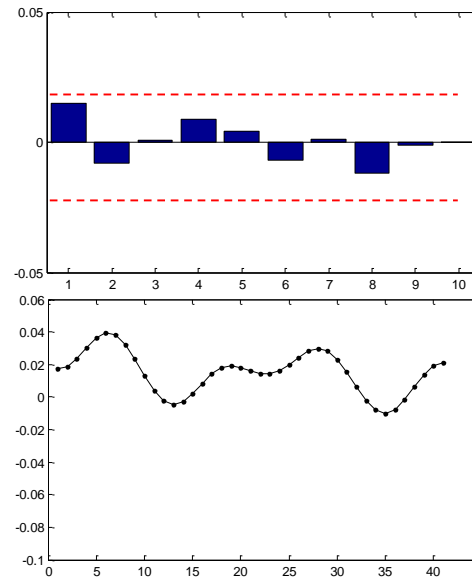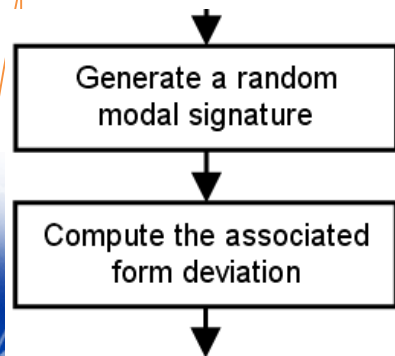
Example 1: uniform
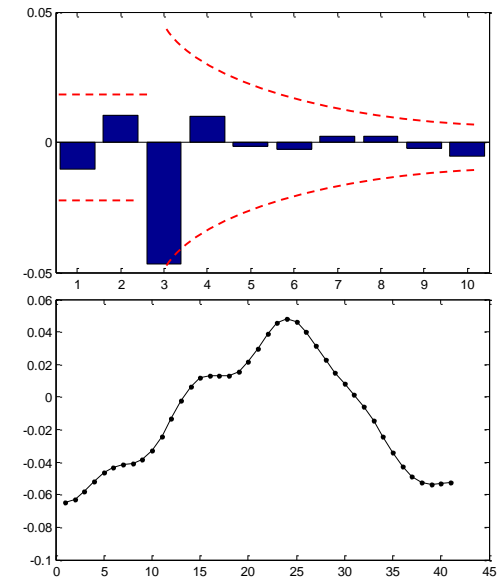
Example 2: repartition law

Hugues.favreliere@univ-smb.fr, Serge.samper@univ-smb.fr,

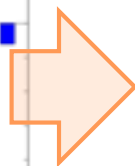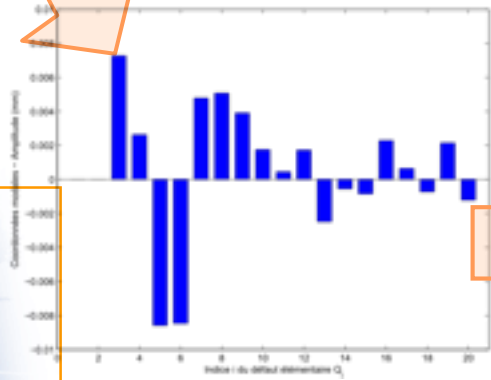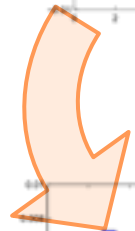Serge Samper – LURPA – ENS Cachan pierre.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr Mardi 18 octobre 2011   Transparent 18
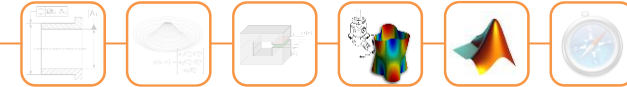
– Statistical data of points: means & covariances

Measure : 10 parts

**mean
Covariance**

Generation : 100 parts

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
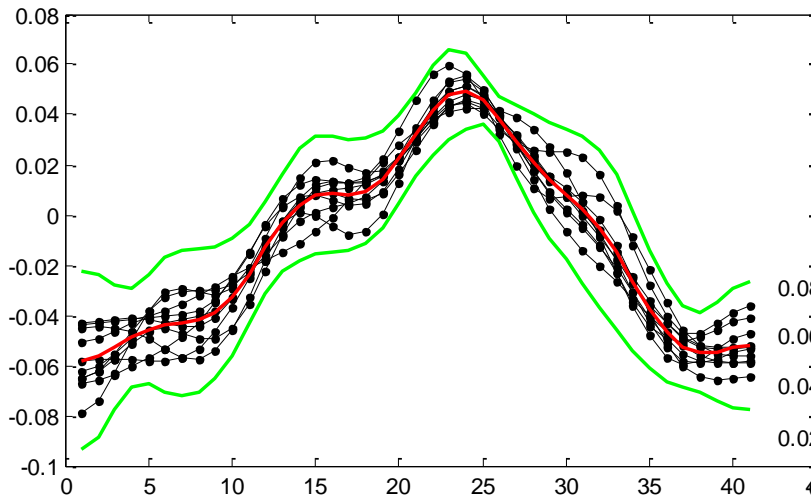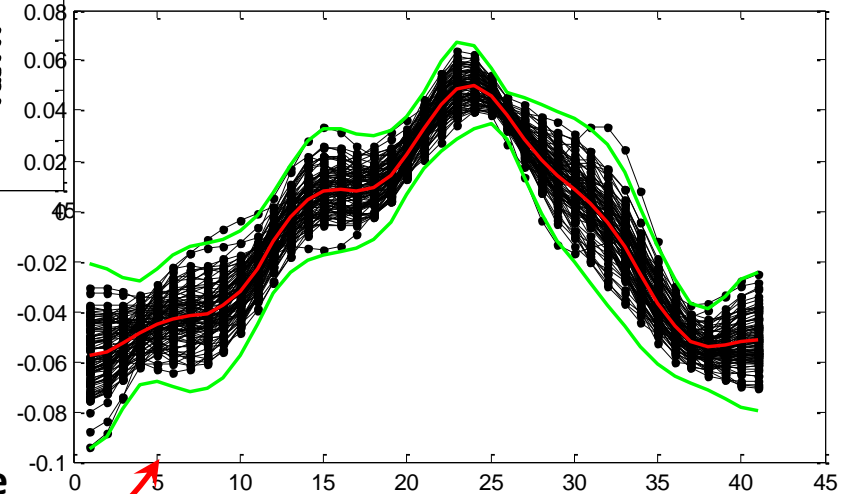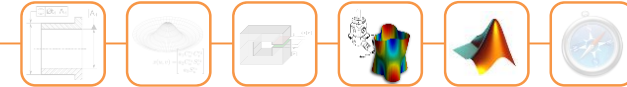
- ## Statistical data
    - – Means & covariances,
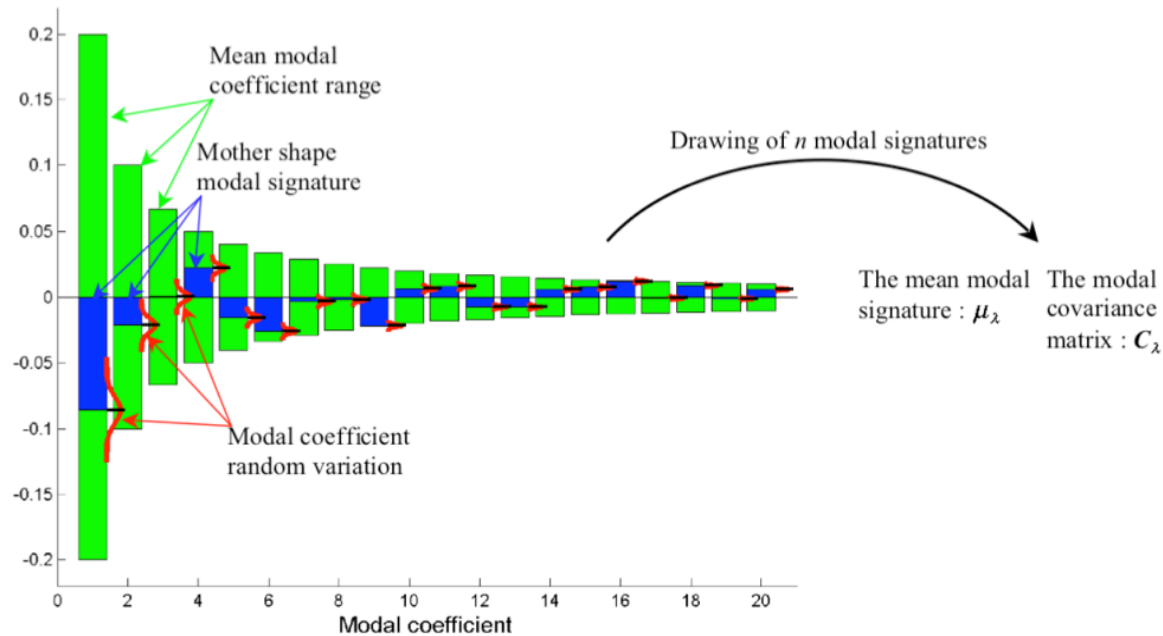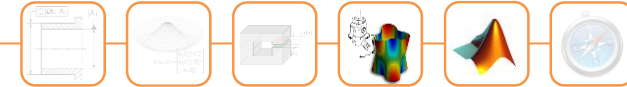
• ISO geometrical constrains on parameters

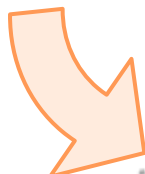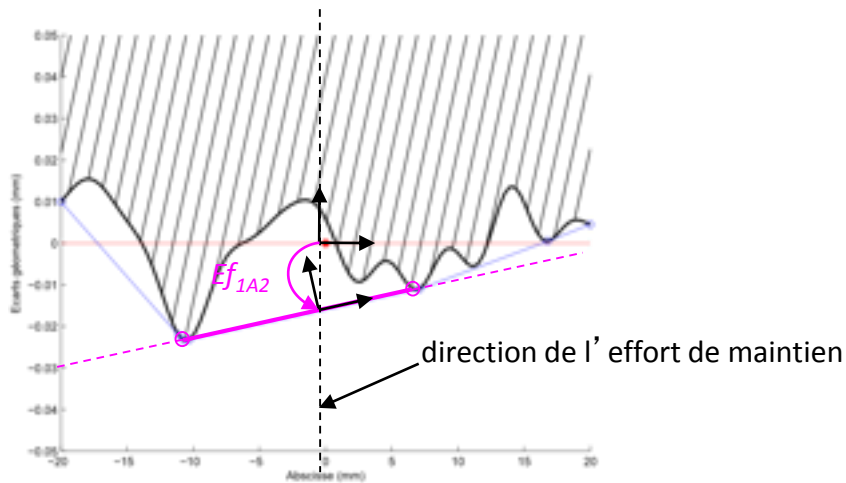Hugues.favreliere@univ-smb.fr,   Serge.samper@univ-smb.fr,
Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
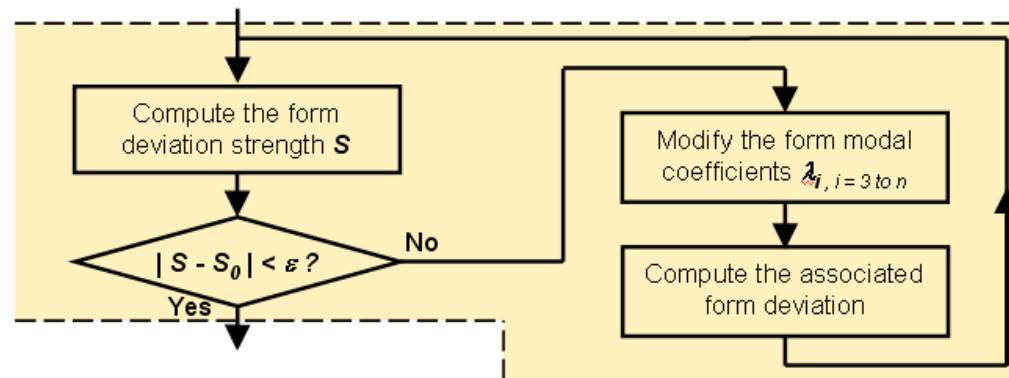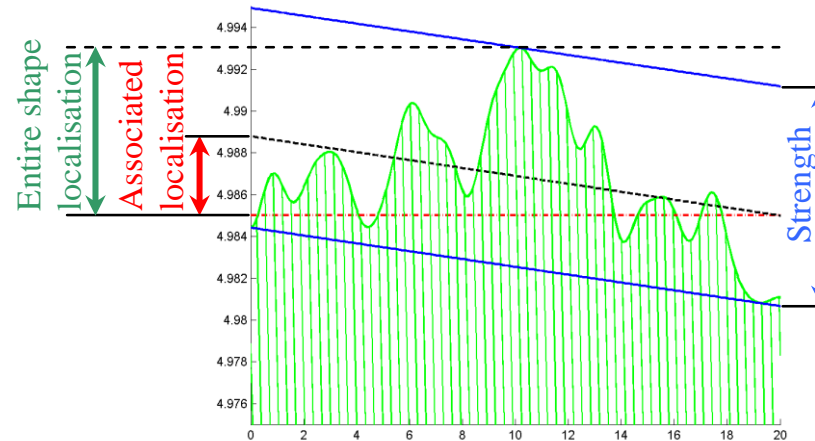
2D Assemblies / Form errors

® Adragna-Favreliere

Assumptions
- Rigid parts
- No clearance
- Positionning force

→ Considering the form deviations

L_{Ax} = 40 mm
L_{Bx} = 20 mm
L_z = 40 mm

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® Adragna-Favreliere

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Serge Samper – LURPA – ENS Cachan

2D Assemblies / Form errors

$$\lambda_{1A2_i} = \lambda_{A2_i} - \lambda_{A1_i}$$

convexe associé

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2D Assemblies / Form errors

Ef_{1A2}

direction de l'effort de maintien

MIP sur la facette

E_{1A2}

r_z

E_{1A2}

Er_{1A2}

Ef_{1A2}

t_y

r_z

Ef_{1A2}

E_{1A2}

Er_{1A2}

t_y

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
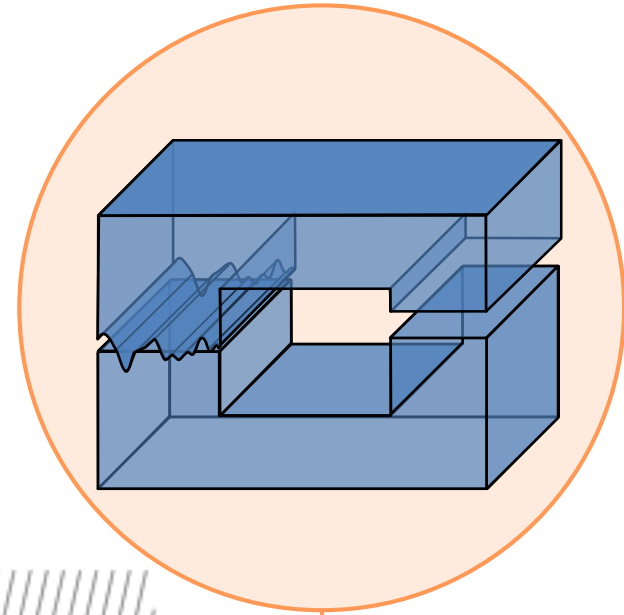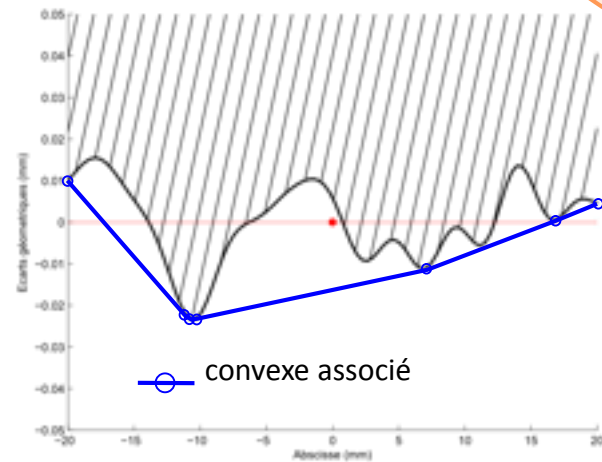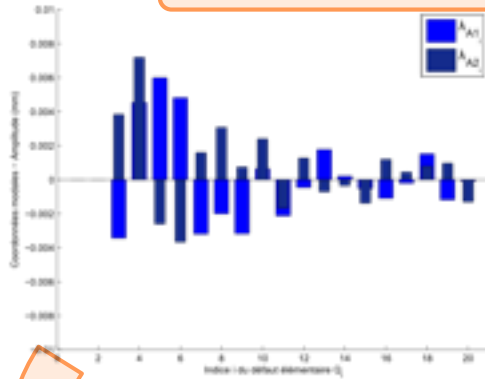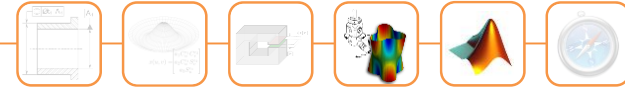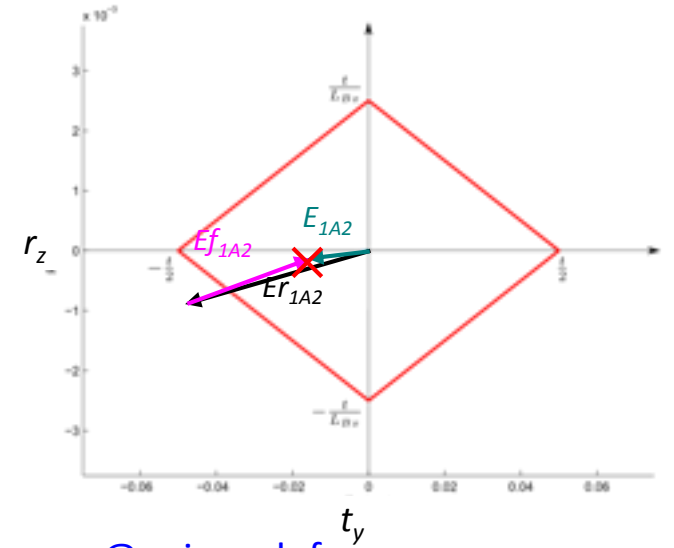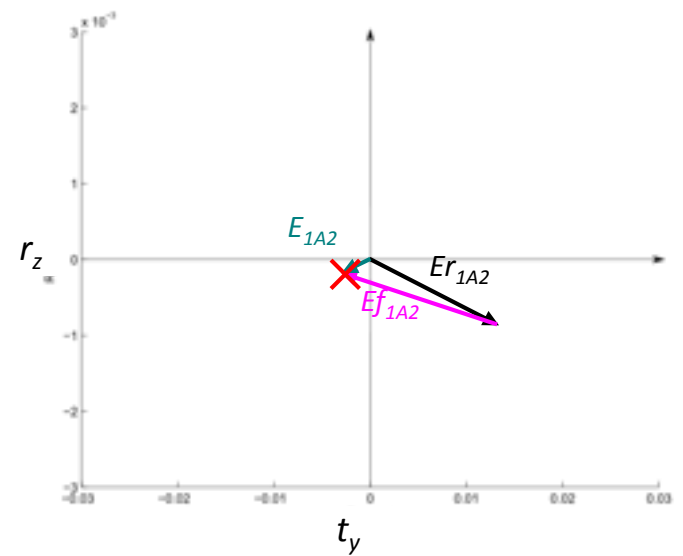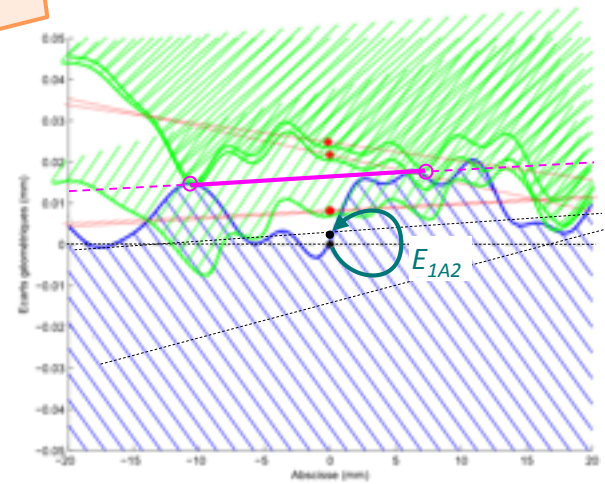
→ Paramétrage des défauts

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
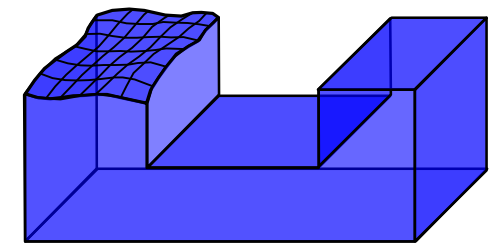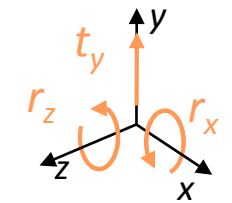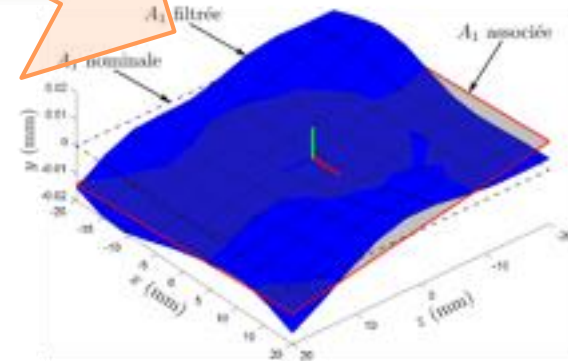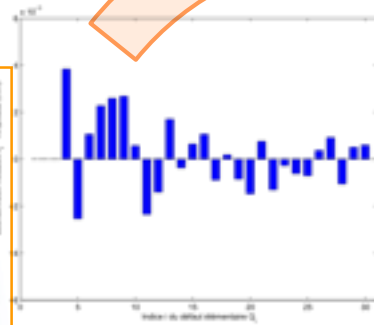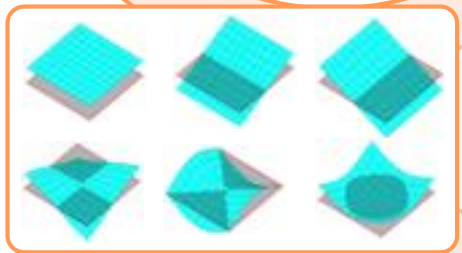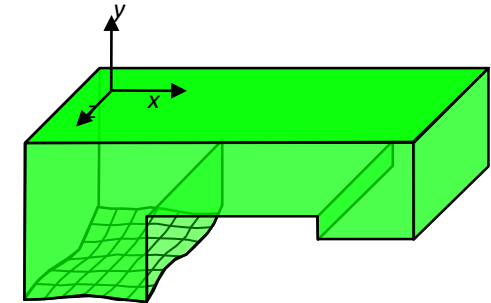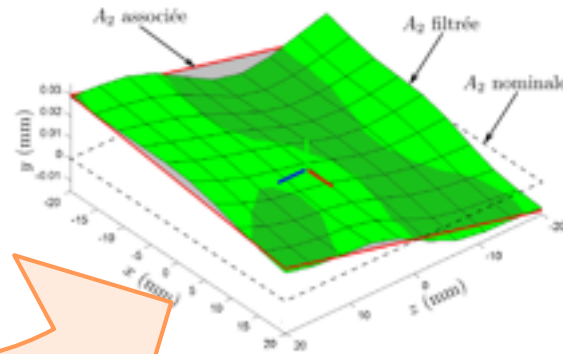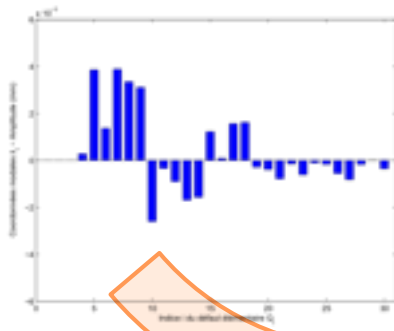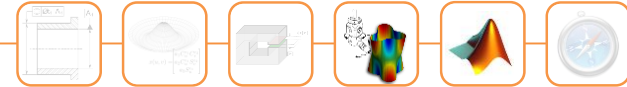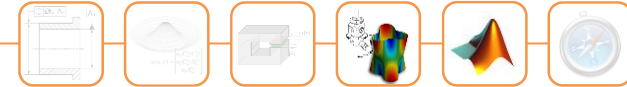
→ Mise en position sans défauts de forme
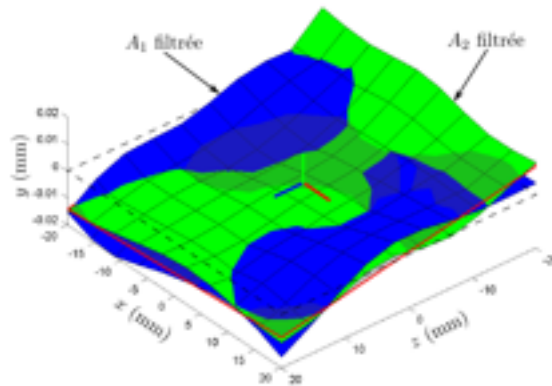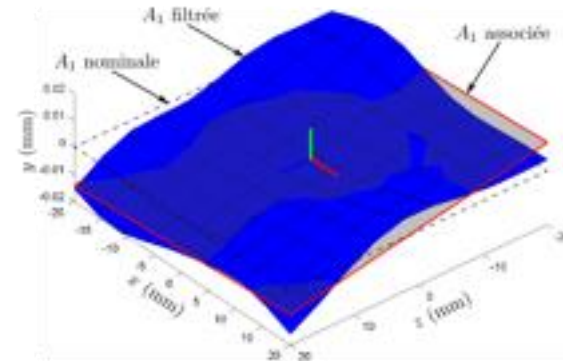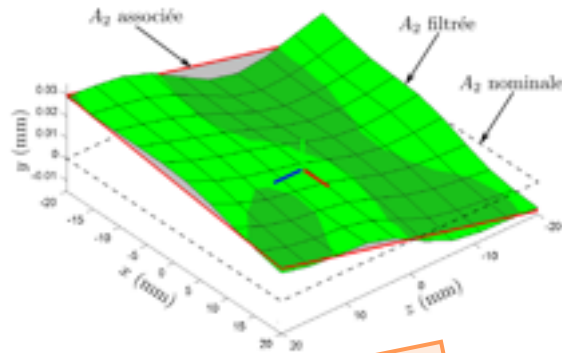
Espace des petits déplacements

Hugues.favreliere@univ-smb.fr, Serge.samper@univ-smb.fr,
Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
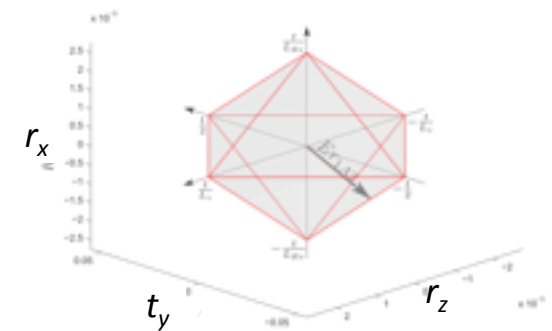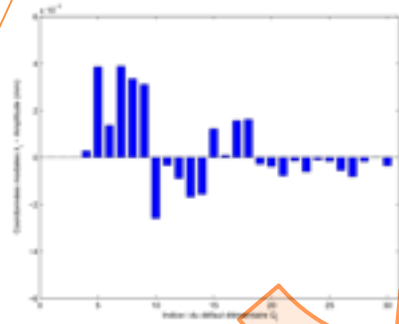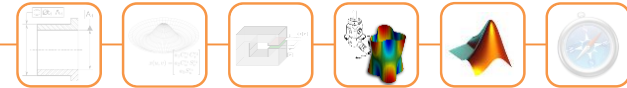
Topographie de la surface écart et convexe associé

$$\lambda_{1A2_i} = \lambda_{A2_i} - \lambda_{A1_i}$$

F

(mm)

A_1 filtrée

A_2 filtrée

x (mm)

y (mm)

z (mm)

z (mm)

○ points de contact
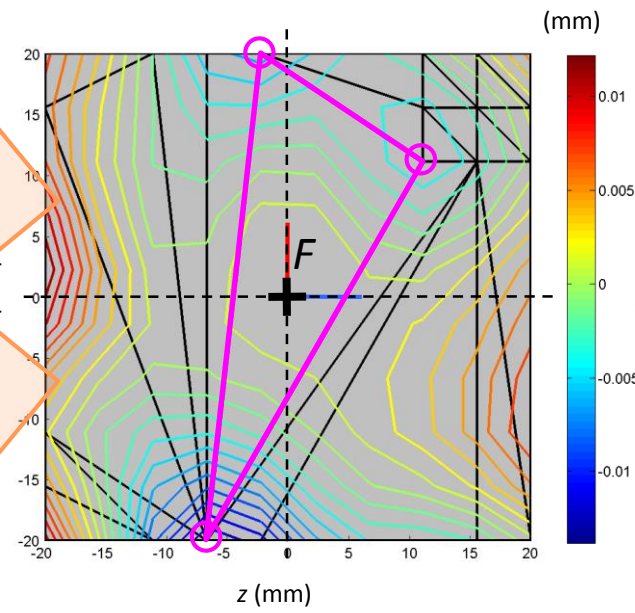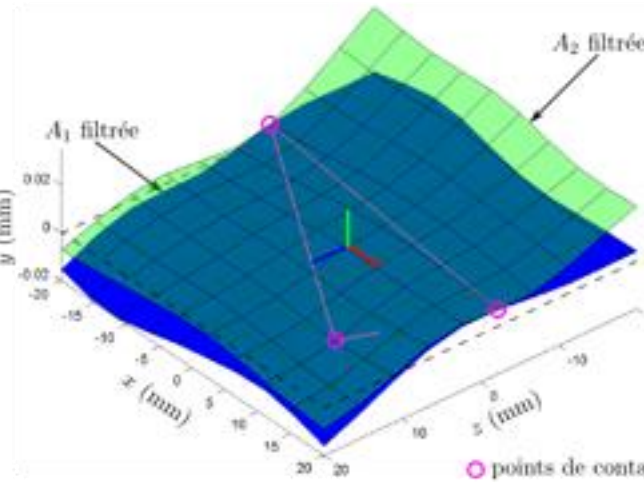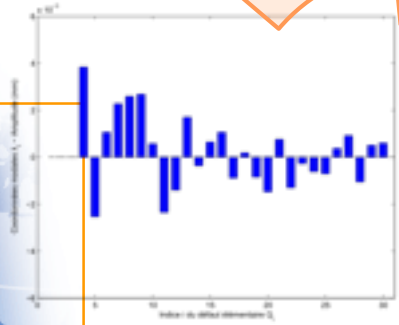
Détection de la facette de contact

Mise en position

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

→ Mise en position 3D avec défauts de forme
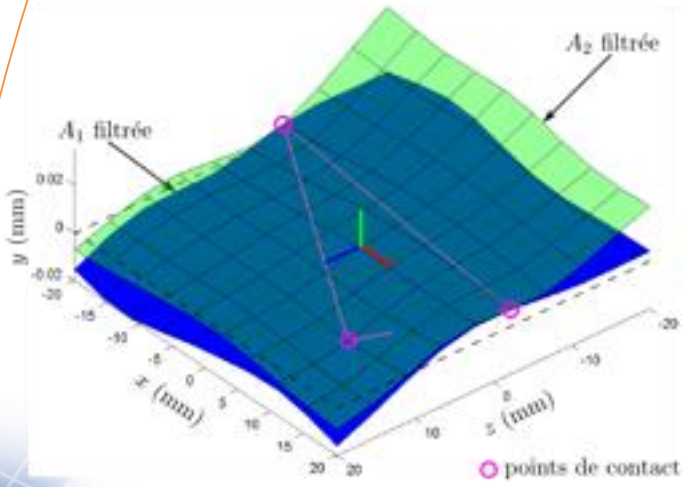
Mise en position

Espace des petits déplacements
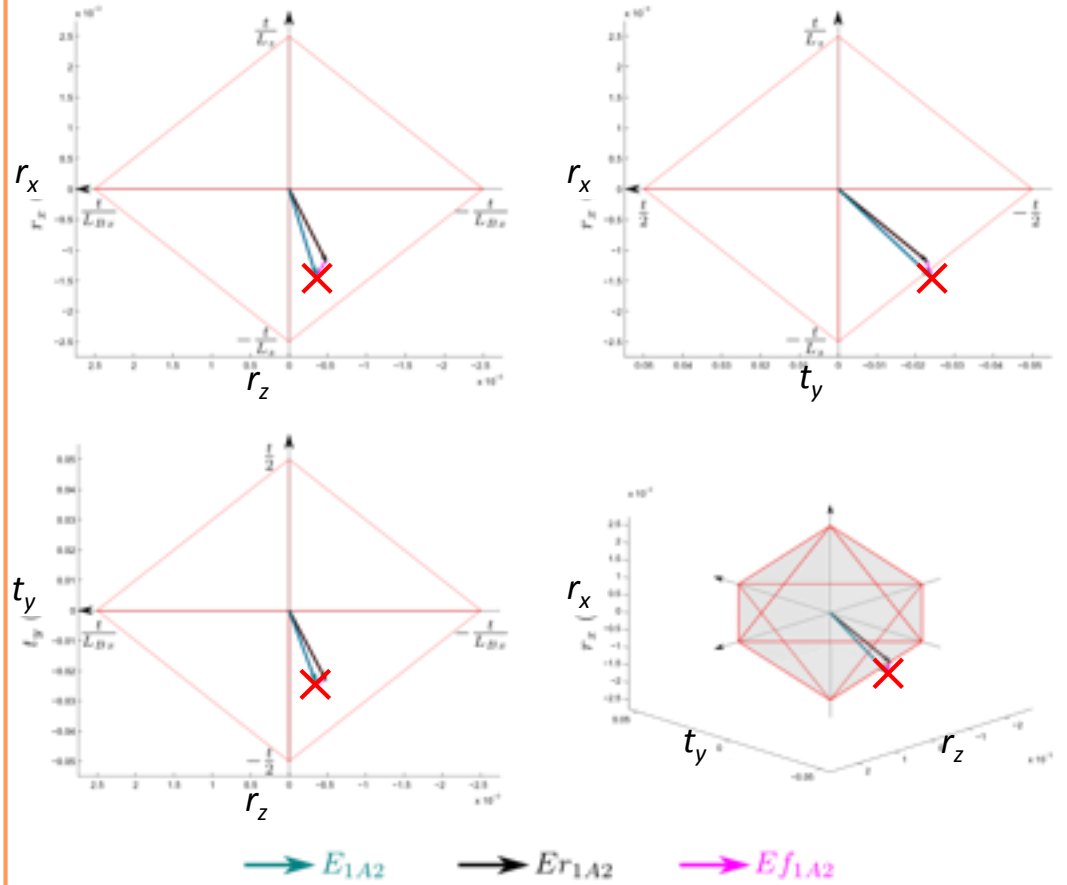
Hugues.favreliere@univ-smb.fr, Serge.samper@univ-smb.fr,
Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
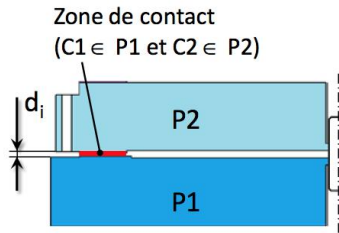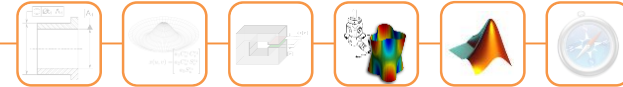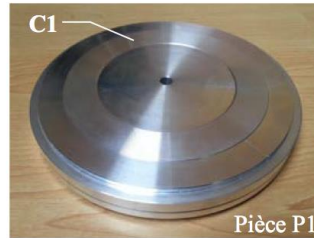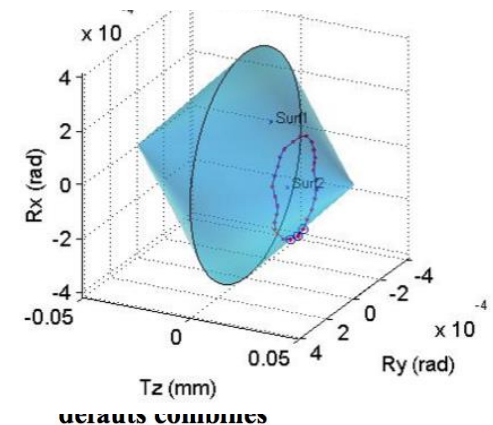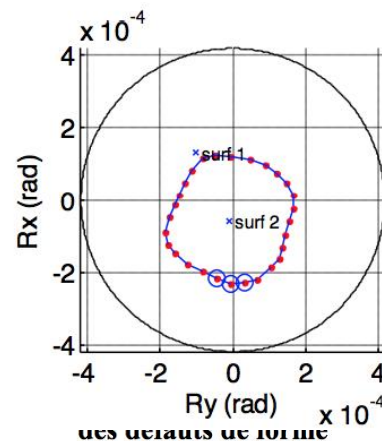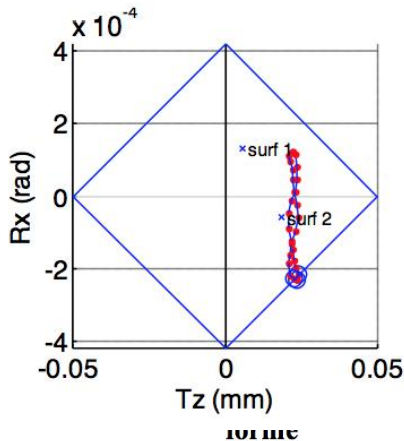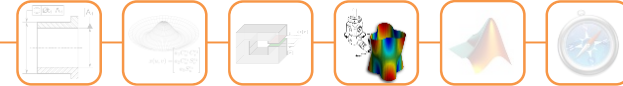
Multi-scale: How?

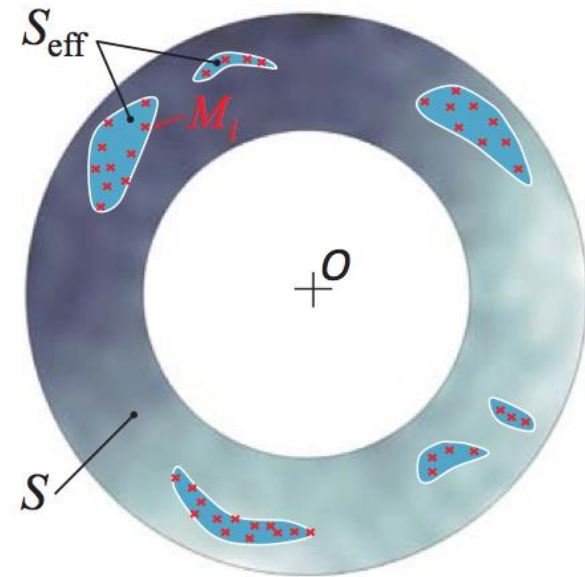**Measure**

Data (x, y, z)
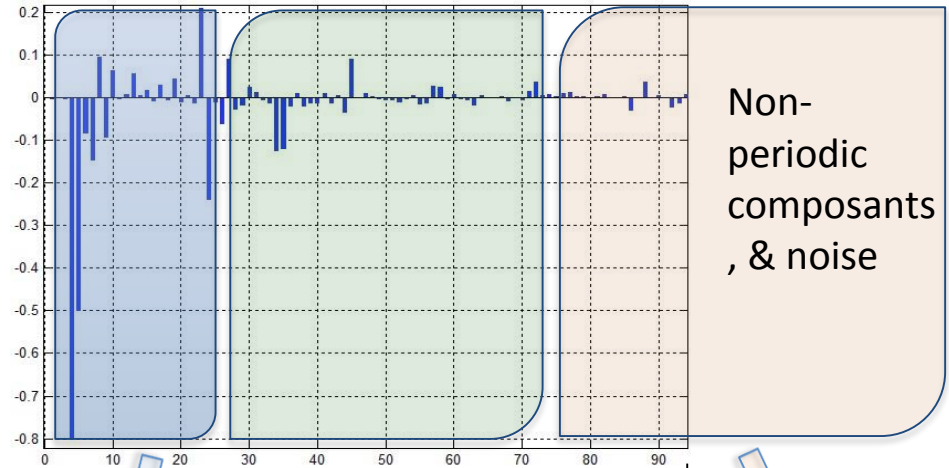
Modal Discrete Decomposition (MDD)

Modal Basis Q
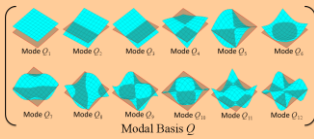
Spectral sorting & representation

Modal Filtering

Modal spectrum of amplitudes

Non-periodic composants, & noise
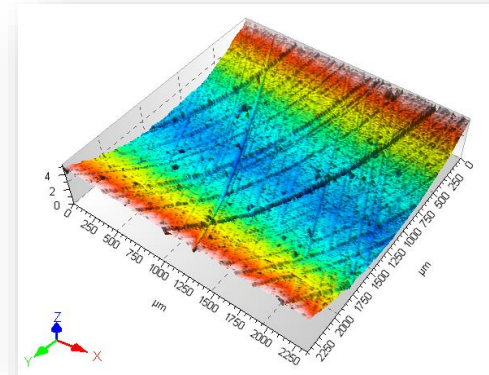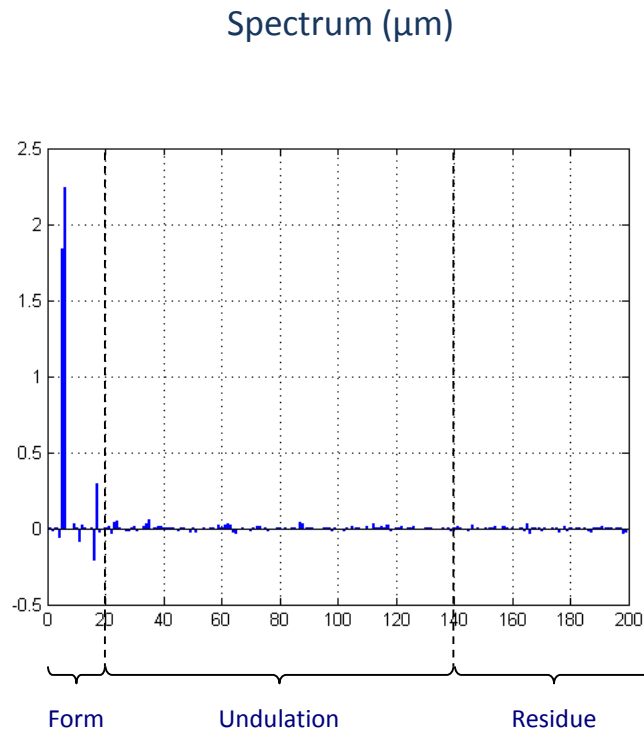
$$v_j = \sum_{i=1}^{N_f} \lambda_i \cdot q_{ji} + \sum_{i=N_f+1}^{N_o} \lambda_i \cdot q_{ji} + \varepsilon(N_o)$$

Source $=$ Form $+$ Undulation $+$ Residue

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

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- **Multi scale analysis of a cylinder**

Spectrum (µm)
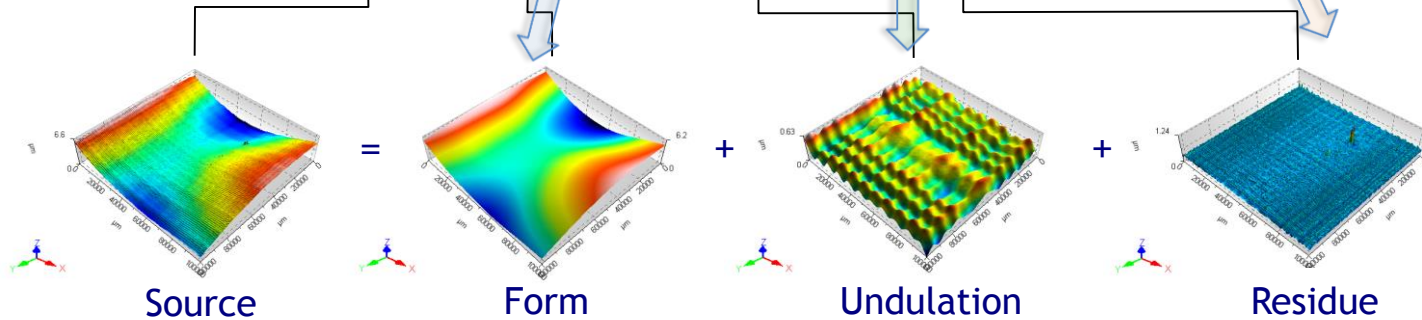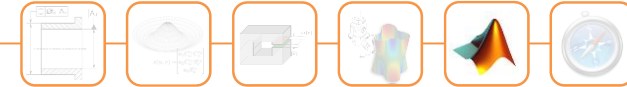
Measured surface
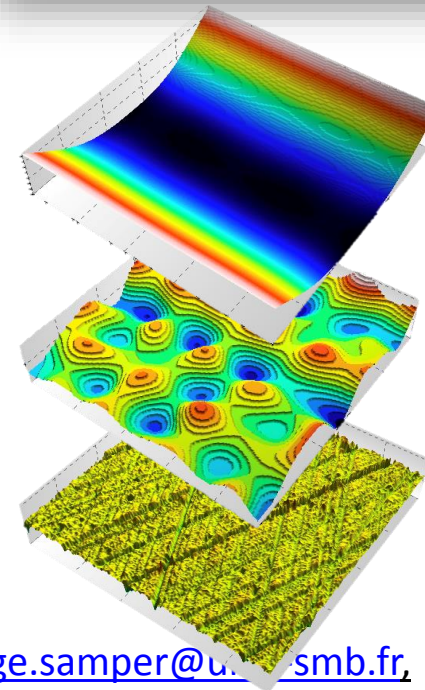
Form

Undulation

Residue/Roughness

Form   Undulation   Residue

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Modal Multi-Scale Filtering Software

® Le-Goïc

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® Le-Goïc

• **Multi scale analysis of a cylinder**

Spectrum (µm)

Measured surface

Form

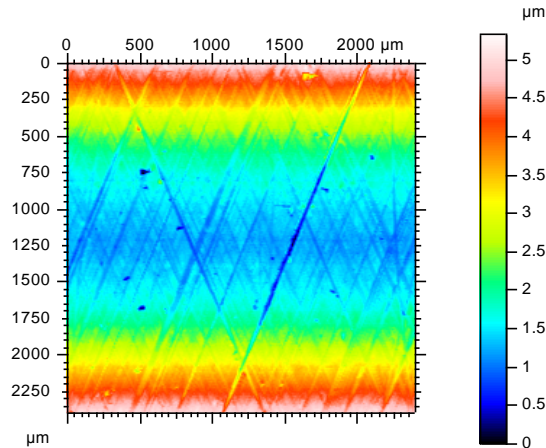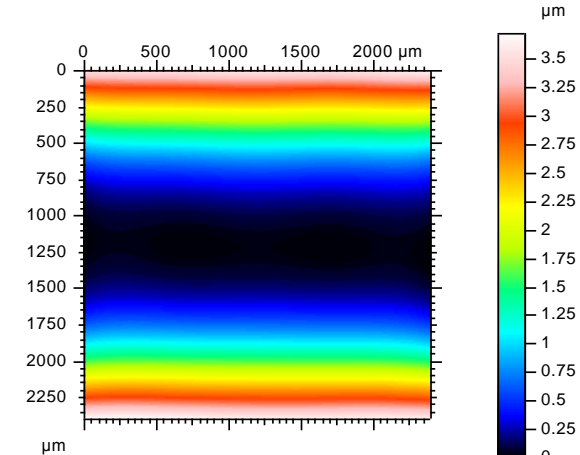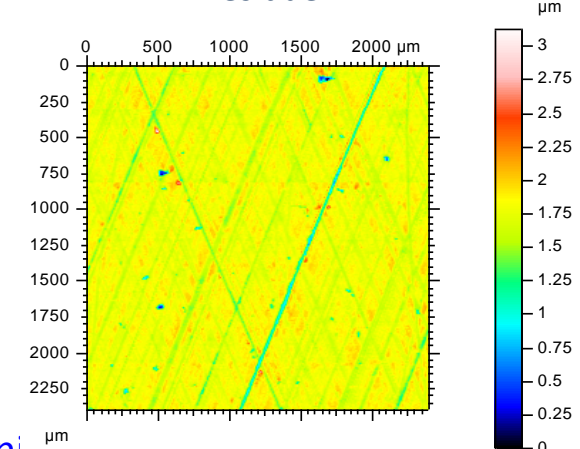Undulation

Residue

Form   Undulation   Residue
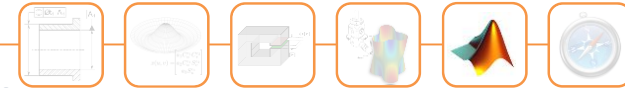
Hugues.favrel
Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
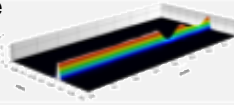
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Multiscale & Calibration

- **Solutions (software linked to hardware)**
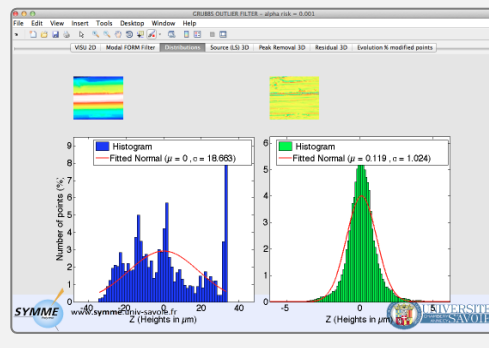
• Décomposition Modale Discrète & Filtrage
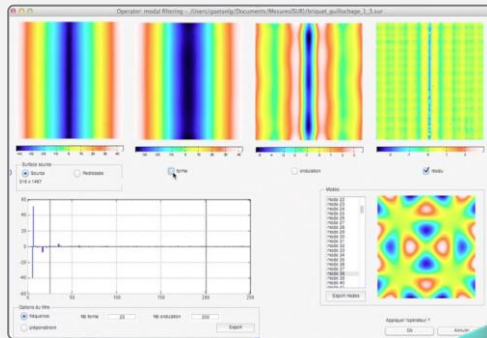
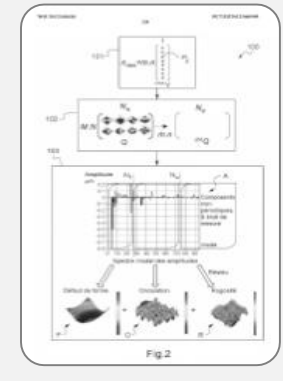•Analyse multi-échelle en pentes et courbures d'une surface

• Identification et filtrage des points aberrants

• **Patent**: « Method and device for characterizing surfaces »
Samper, S, Le Goic, G, Favrelière, H
WO Patent 2,012,168,436, 2012

• **Method :** « calibration modale d'une machine de mesure de surface »

Moyen de mesure & système de micro-positionnement

Correction en temps réel des mesures

Mesures d'un lot de surfaces de calibration (étalon)
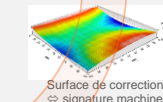
Surface de correction ⇔ signature machine

Décomposition Modale du lot
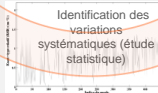
Identification des variations systématiques (étude statistique)

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr

• Analyse en courbures d'une surface issue du filtrage modal

Cartographies des courbures

Surface Source

Mini

Moyenne

Ru

Maxi

Gauss

→ courbures positives

→ courbures négatives

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr
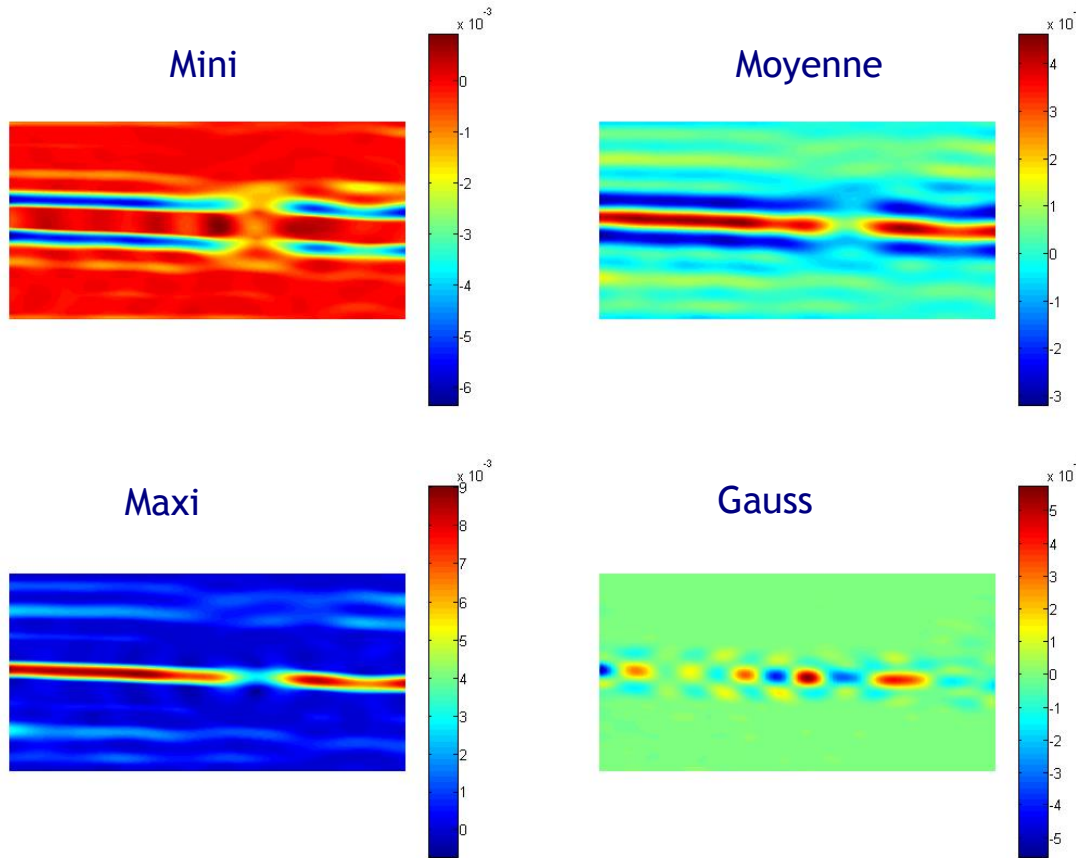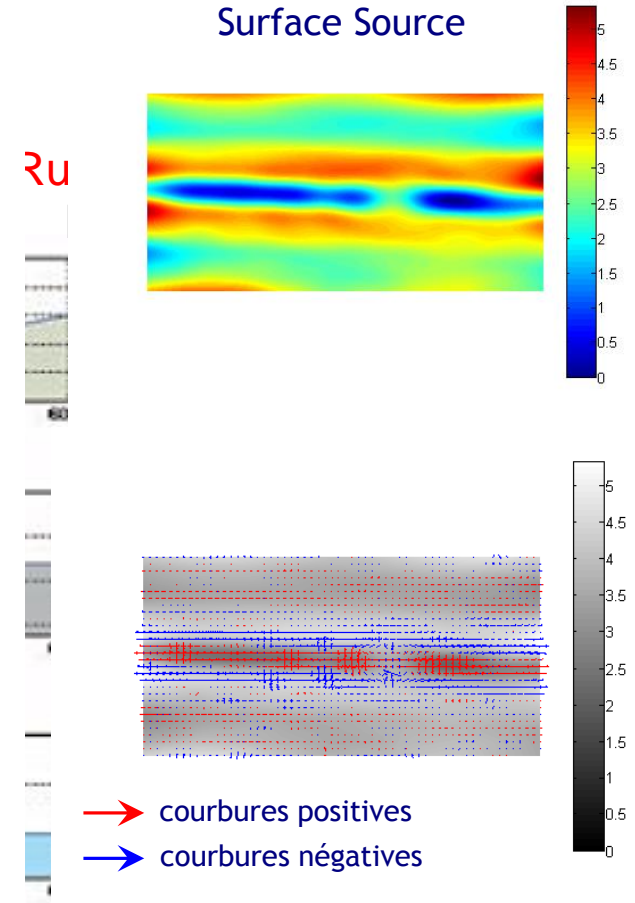
Synthesis

- Parameterization is a very important issue.

- Nature have given us beautifull tools.

- Modal method is versatile and multi-scale
  - From size to roughness
  - Helps to remove shapes/waviness/roughness
  - Useful to make calibrations
  - "Automatic" method. You do not have to define symbolic functions!
  - There are several applications.

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Pierre-Antoine.adragna@utt.fr , gaetan.le-goic@u-bourgogne.fr