Last edition: 2013-06-12

SPECIMeN Group

Sensing strategies, Perception and Characterization at Micro- and Nano-scales

AS2M Dep[t] – Automatic Control and Micro-Mechatronic Systems

Last edition: 2013-06-15

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Outline for AS2M scientific meeting (2014/6/24)

Part 1: annual activity report of the SPECIMeN group
Part 2: a focus on the SEMSAW project (Richard de Pauw)

Last edition: 2013-06-15

Part 1: annual activity report of the SPECIMeN group

http://www.femto-st.fr/fr/Departements-de-recherche/AS2M/Accueil/

AS2M dep^t multi-disciplinary research fields:

- **Automatic control,**
- **Robotics,**
- **Mechatronics,**
- **Industrial engineering.**

AS2M dep^t research axes:

- **Micro-robotics** (micro-manipulation & assembly, characterization and biomedical appl.),
- **Control of systems at the micro-scale** (micro-robots, micro-actuators, micro-systems),
- **Prognostics & Health Management** (industrial and biological systems).

AS2M dep^t research groups: **SPECIMeN, CODE, MiNaRoB, PHM.**

SPECIMeN group framework: **Study, development and use of specific sensing devices and information processing methods to optimize the implementation and the performances of “perception – decision – action” loops operating at micro- and nano-scales.**

http://www.femto-st.fr/fr/Departements-de-recherche/AS2M/Accueil/

SPECIMeN staff

Permanents

- Nadine Piat (PR)
- Sounkalo Dembelé (MCF HDR)
- Emmanuel Piat (MCF HDR)
- Patrick Rougeot (IR)
- Joël Abadie (IR)
- Joël Agnus (IR)

Shared manpower resources

m = 48.6 years, σ = 5.6 years

Invited researcher

- Liu Wei (8 months position, Heifei univ.)

		Supervisors
PostDoc	Antonio Escareno	MR, EP, JAb
	Naresh Marturi	SD, NP
PhDs	Margot Billot (A2)	EP, JAg + P. Stempflé (MN2S)
	Le Cui (A2)	E. Marchand (IRISA), NP, SD
	Racha Gana (A1)	EP, JAb + C. Pieralli + B. Wacogne (Optique)
	Andrey Kudryavtsev	SD, NP
	Valérian Guelpa	GL (CODE), NP
Internships	Richard de Pauw (6 months)	SD, NP + AK, PV (MN2S)
	Mickaël Ohruh (3 months)	EP, JAb
	Laurent Rivière (6 months)	EP, JAb, MR + David Heriban (Percipio Robotics)

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Small group ➪ focused issues (mandatory !)

Sensing strategies, perception and characterization at micro- and nano-scales mainly using force sensors and SEM imaging.

Scientific issues divided into two research topics:

- **Development of sensors operating at micro- and nano-scales**
- **Exploitation of sensors providing information from micro- and nano-scales**

http://www.femto-st.fr/fr/Departements-de-recherche/AS2M/Accueil/

UFC UNIVERSITÉ DE FRANCHE-COMTÉ · cnrs · ensmm · utbm université de technologie Belfort-Montbéliard

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Sensors design

Sensors modeling and calibration, sensing quality estimation

Defects and disturbances characterization and correction

Development of sensors for micro-nano scales

http://www.femto-st.fr/fr/Departements-de-recherche/AS2M/Accueil/

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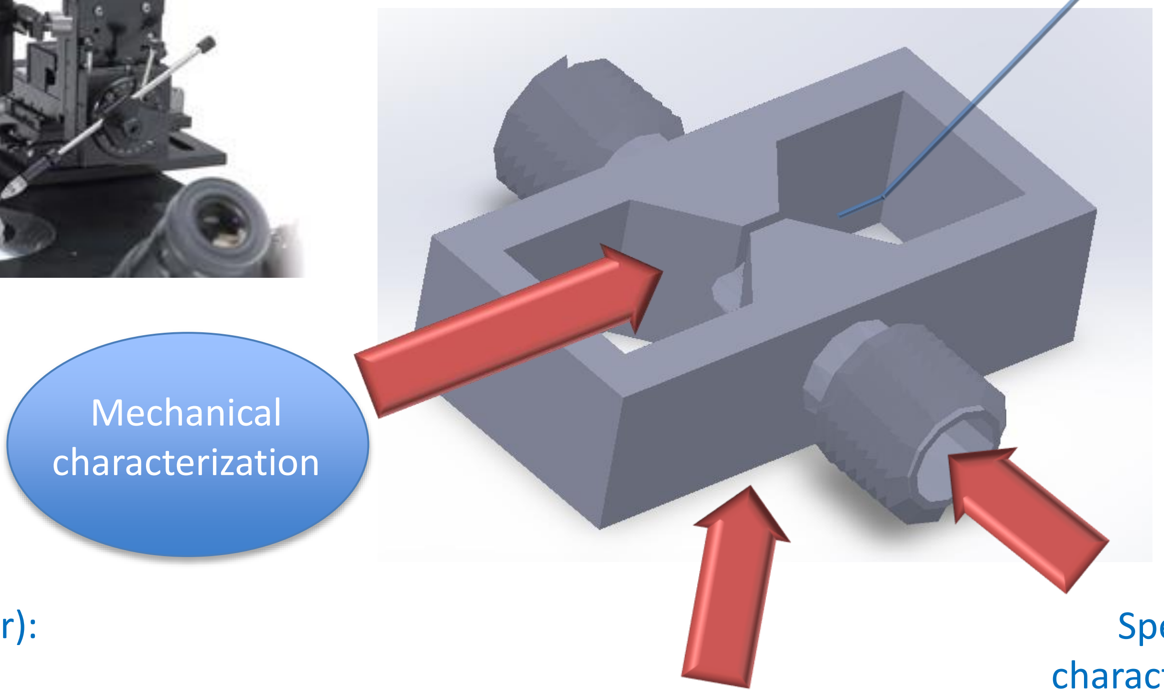
Smart sensing platform for oocyte multimodal characterization

Integration of oocyte multimodal characterization in a disposable device.

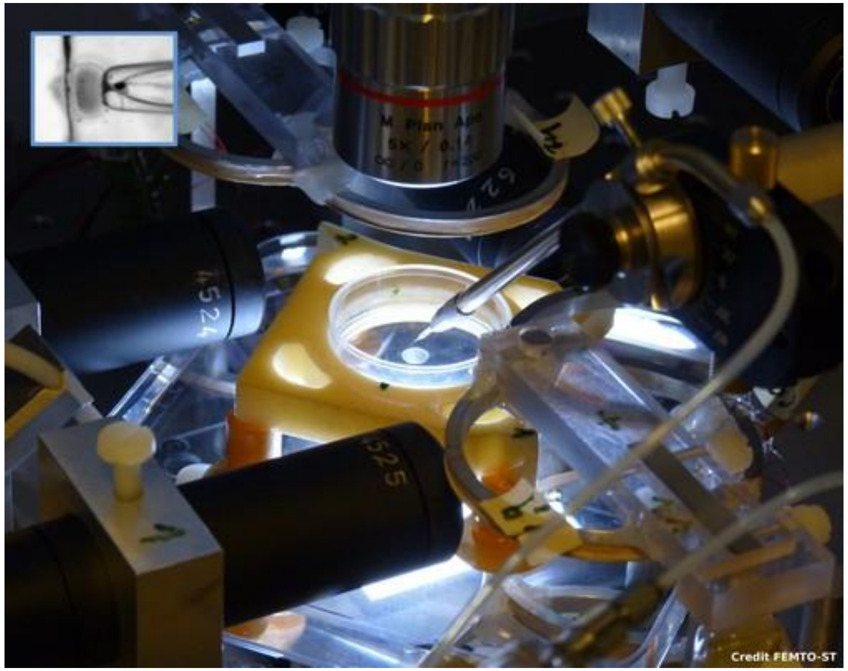
Compliant with current ART constraints (validation by the Biomédecine agency).

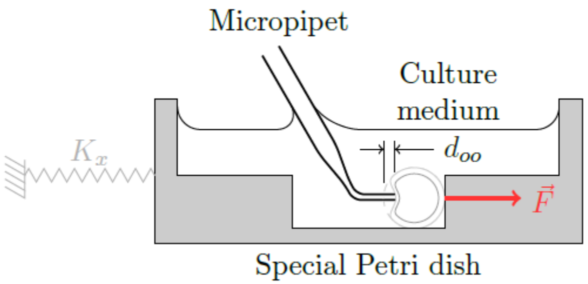
All components in contact with oocytes must be disposable, low cost and with non toxicity.

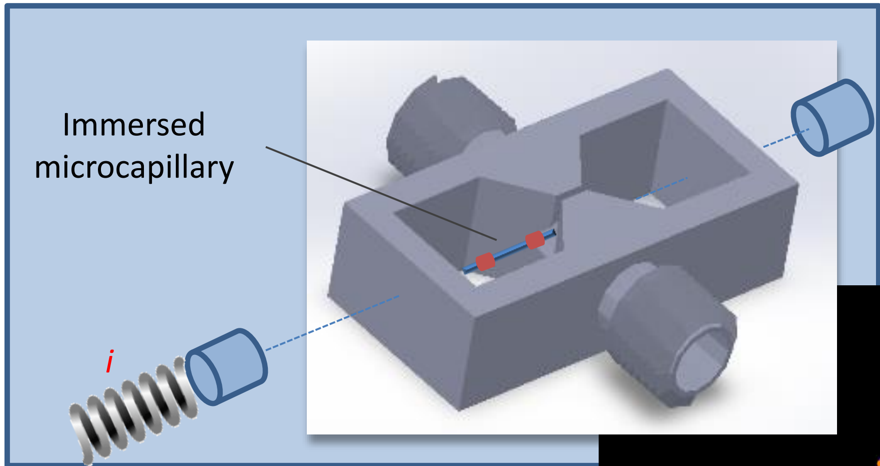


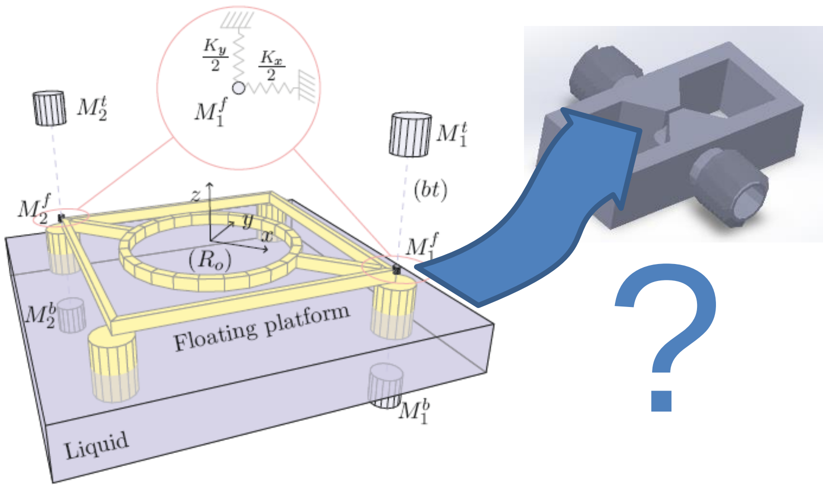
Addressed topics (1st year):
- Bibliography
- Magnetic nanoforce sensor modeling and design.
- Oocyte mechanical behavior modeling.

Dev. of a force sensor for oocyte mechanical characterization (RG, JAb, EP)

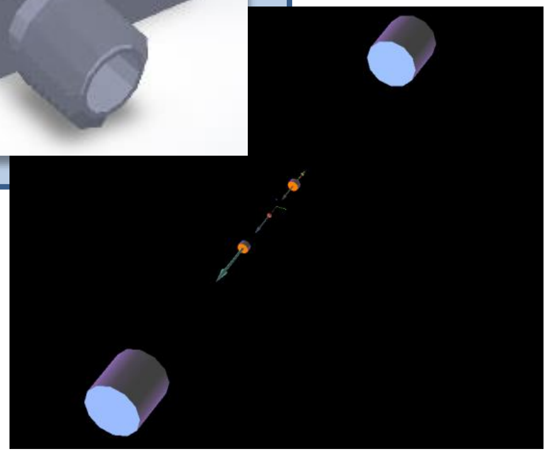








Non stable magnetic configuration
on measurement axis that is stabilised
by the repulsive force induced by the oocyte.

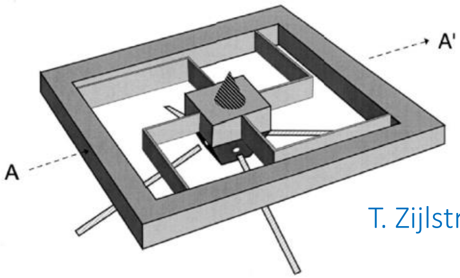


Dev. of new devices for multi-asperity nanofriction characterization (MB, EP, JAg + PS)

Application to analysis of controlled triboactive surfaces

Addressed topics (2nd year):

- Bibliography
- 6DOF sensor modeling / optimization.
- Theoretical performance evaluation (coupling).
- Publication writing (Tribology international).
- Platform development (with the help of PR and OL)
- Calibration brainstorming.

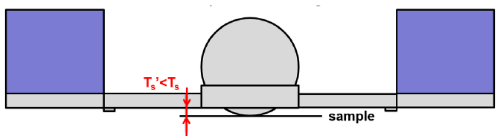


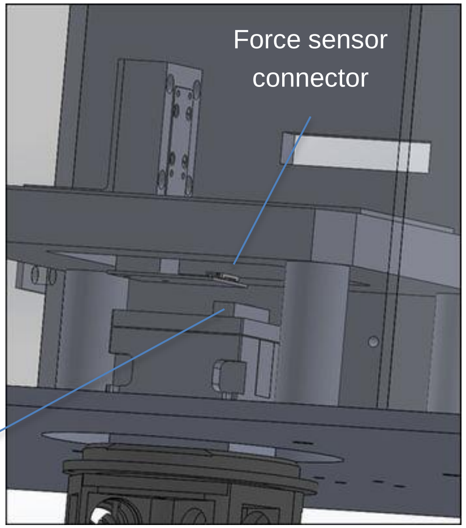
T. Zijlstra and all, S&A A: Physical, 2000

Met problem:

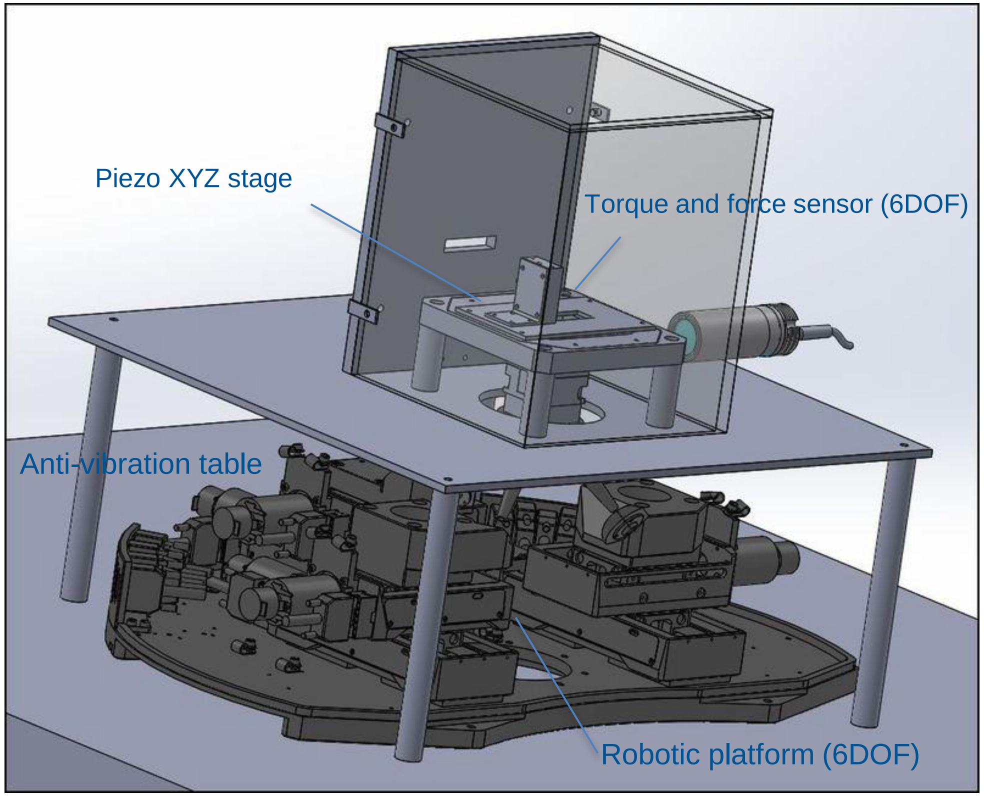
Order of SOI wafers with the LABEX ACTION.

4 months of intense negotiations to have the order accepted…





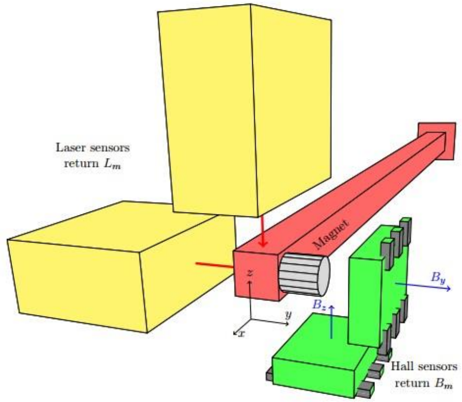
In-air version of the nanotribometer

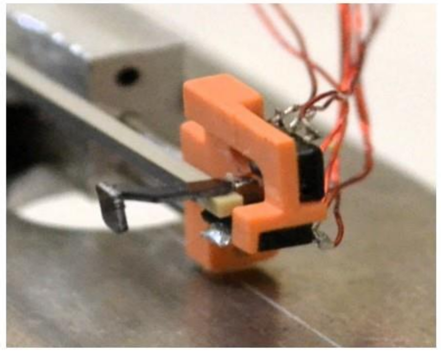


Unknown input disturbances compensation using a deconvolution scheme based on Kalman filtering (AE, JAb, EP)

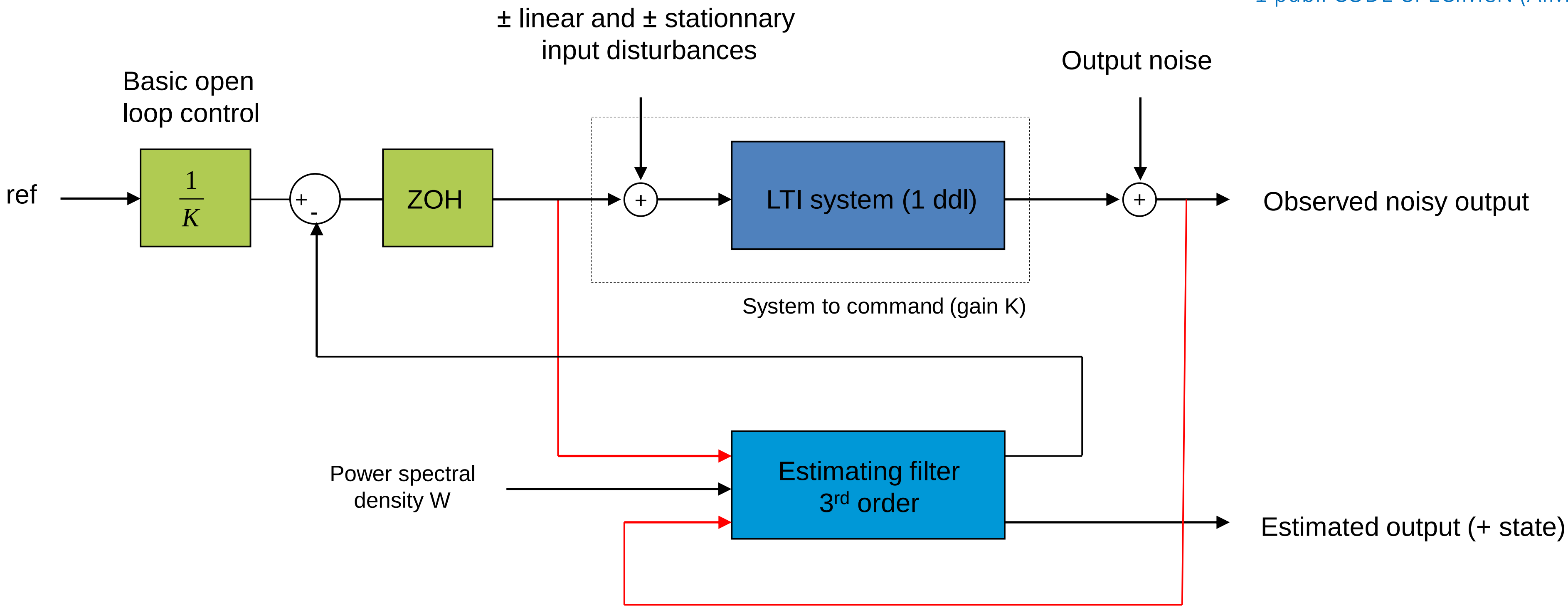
Application (MiM-HaC project):

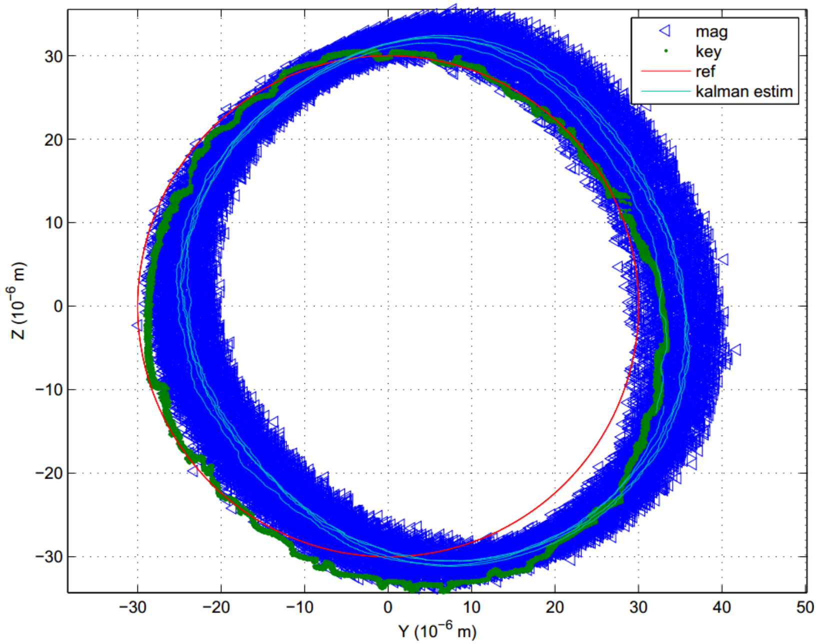
2-DOF control of a piezocantilever without any deterministic modeling of the input disturbances (hysteresis, axis coupling, drift, environmental noises).



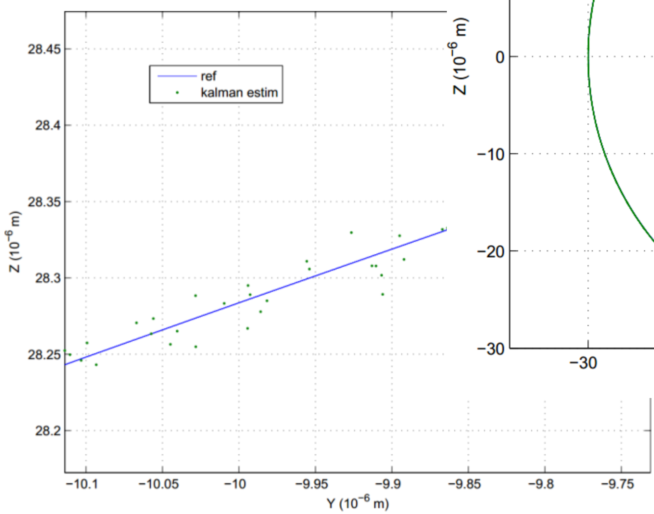


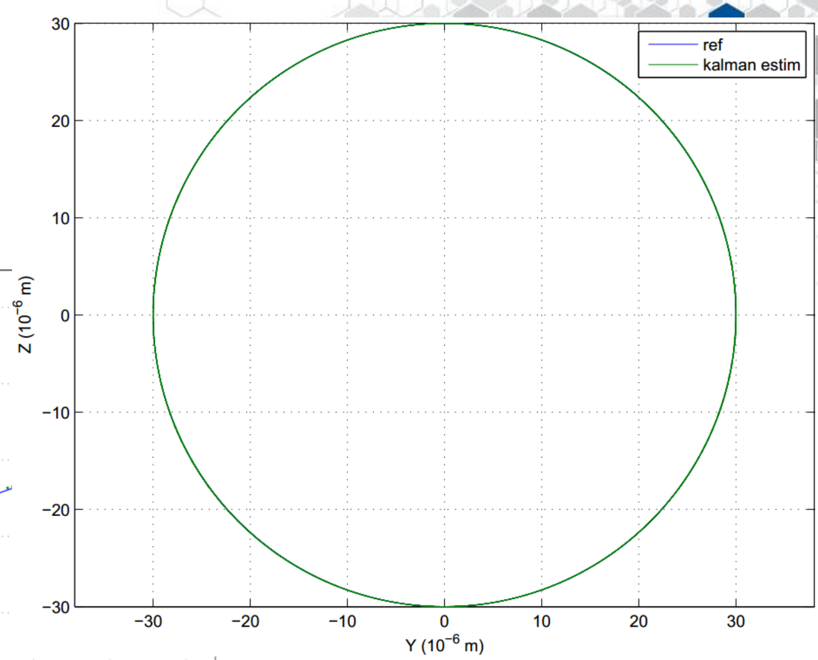
1 publi CODE-SPECIMeN (AIM 2014)





σ ≈ 10 nm





Without input compensation

and proportional feed-forward controller

With input compensation

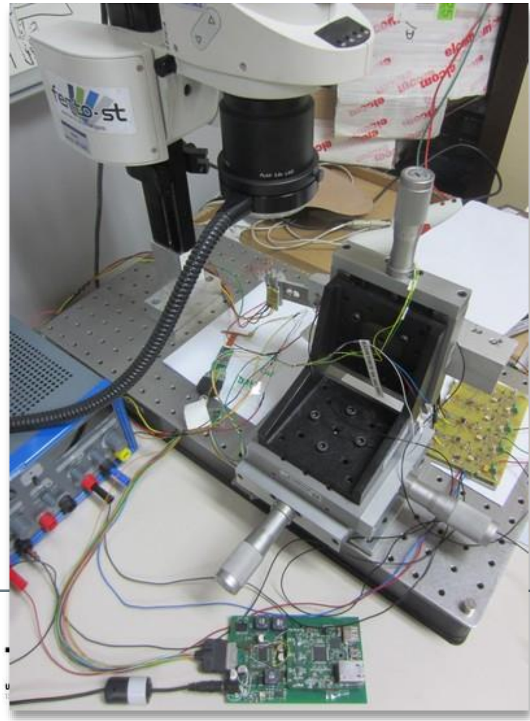
and proportional feed-forward controller

Fs = 5 kHz

0.1 Hz reference (∅ 60 µm circle)

Laurent Rivière PFE (Percipio Robotics) :

- Build a « clean » experimental setup based on a vision sensor instead of Keyence laser sensors.
- Use a low cost Microchip micro-controller instead of dSpace DSP.
- Use Percipio Robotics hardware and software (AP2M).



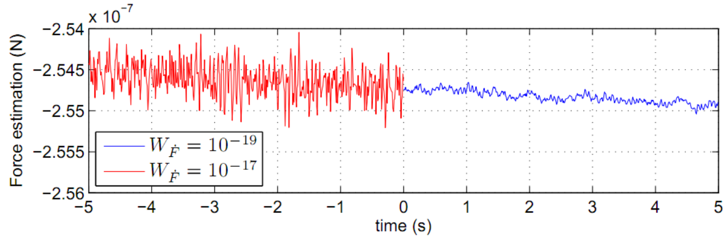
PERCIPIO ROBOTICS
Conception de systèmes robotisés de micro-assemblage

Environmental disturbances compensation for micro and nanoforce sensors based on passive magnetic springs

Two main sources of low-frequency disturbances for force sensors based on macroscopic force/displacement transducers ($f_r \approx$ Hz) :

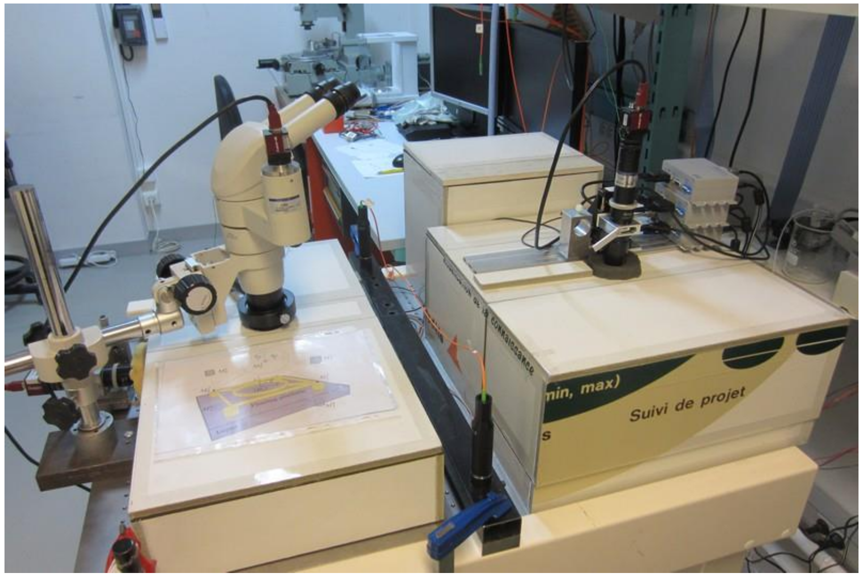
- orientation change of the working surface

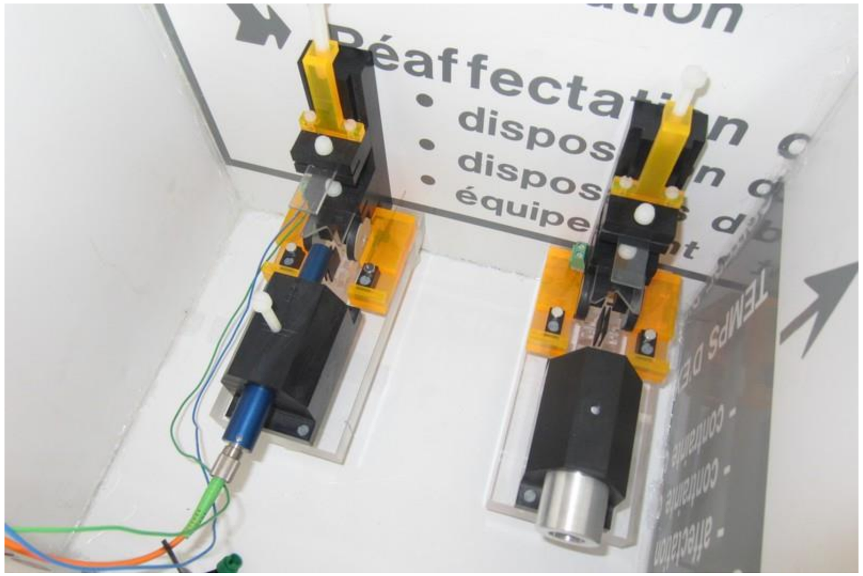
- residual seismic vibrations of the working surface



Addressed approach:

compensation using differential force sensors and based on stochastic black box input modeling coupled with optimal deconvolution





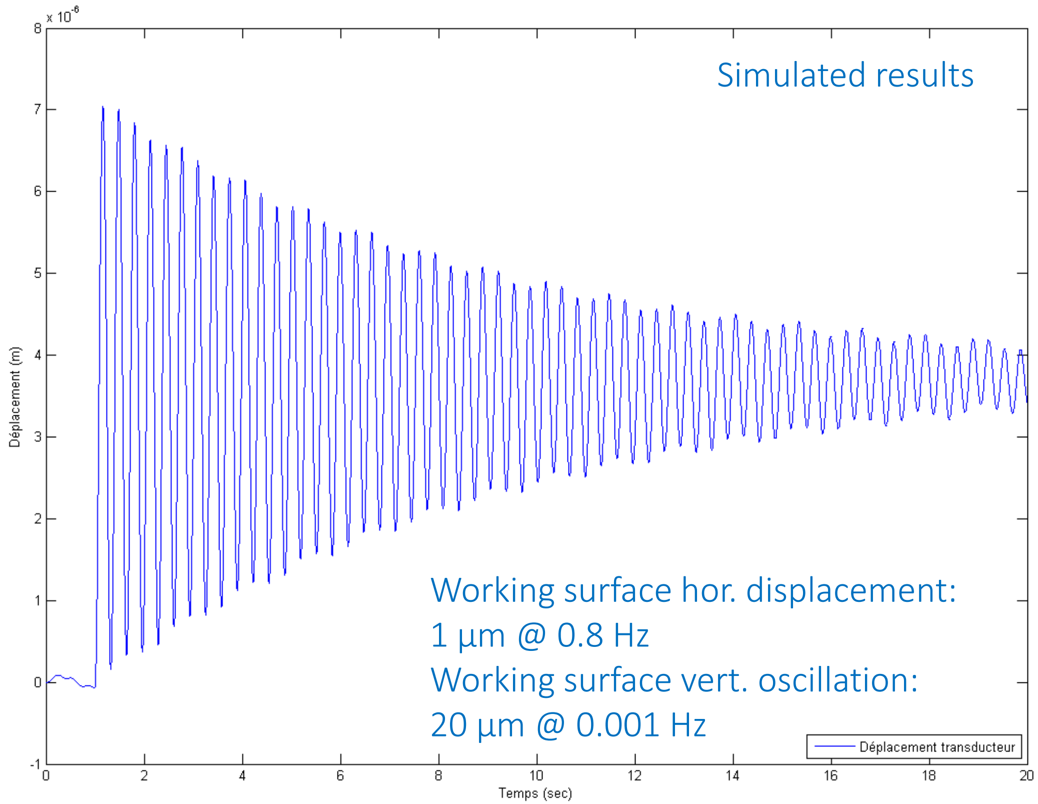
Environmental disturbances compensation for micro and nanoforce sensors based on passive magnetic springs (EP, MO, JAb)

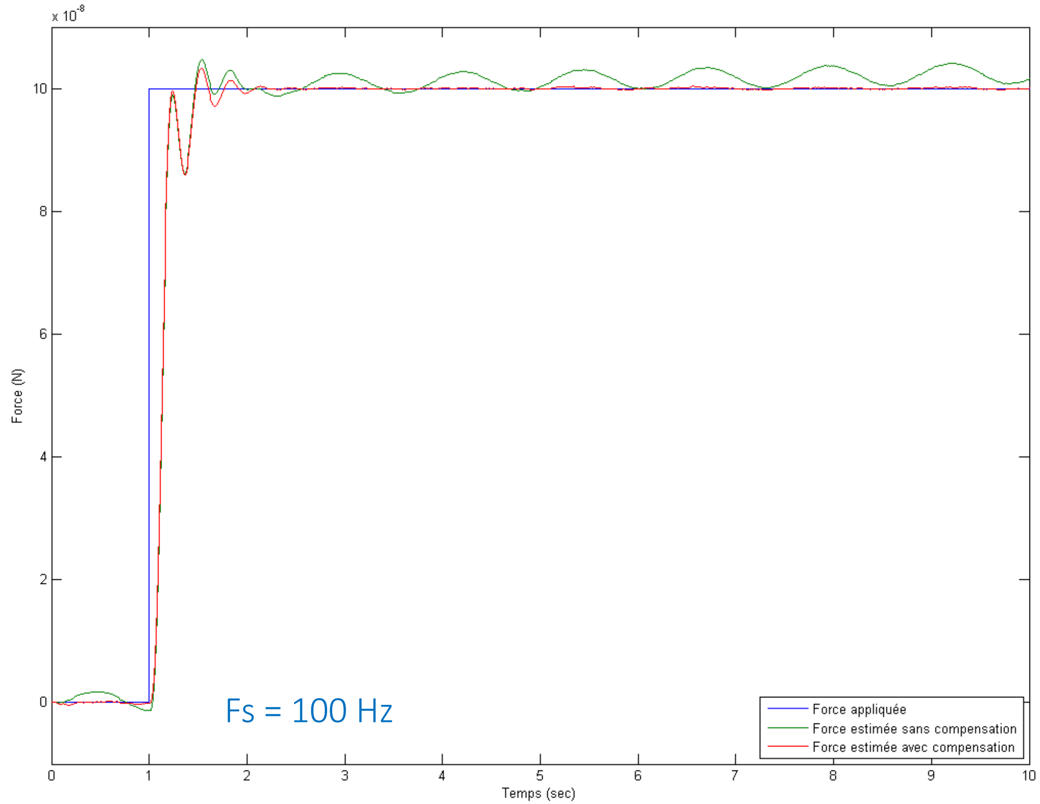
Actions addressed:

1. Modeling of the nanoforce sensors based on diamagnetic levitation in a non Galilean reference frame.

$$f(\ddot{x}, \dot{x}, x) = g(F_{ext} + CNL\ var\ env.\ et\ leurs\ dérivées)$$

2. Compensation scheme studied in simulation with differential force sensors based on diamagnetic levitation.



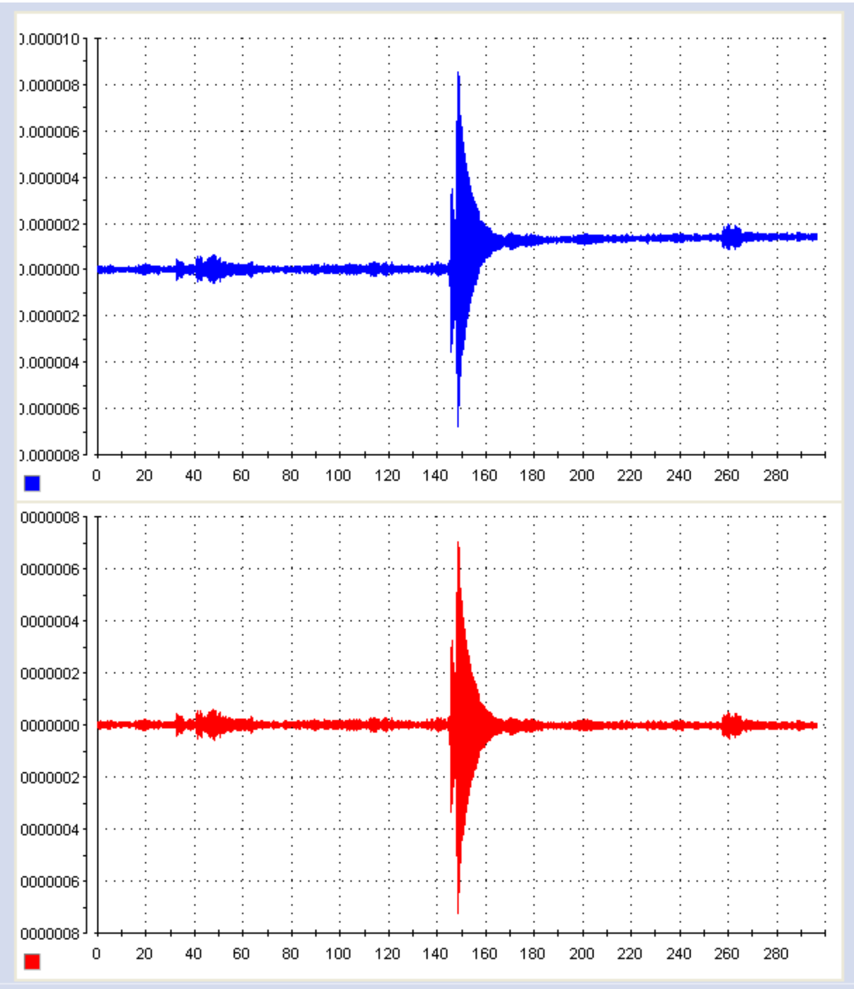


Environmental disturbances compensation for micro and nanoforce sensors based on passive magnetic springs (MO, JAb, EP)

Actions addressed:

3. Modeling of the new pendulum nanoforce sensor in a non Galilean reference frame.

$$f(CNL\ \ddot{x},\dot{x},x\ et\ var.env.et\ leur\ dérivée) = g(F_{ext} + CNL\ var\ env.\ et\ leurs\ dérivées)$$



Action 3 led to a nonlinear and nonstationary modeling that induces new problematics in identification and deconvolution to correctly compensate the disturbances and estimate the force.

4. Experimental drift compensation using a differential pendulum nanoforce sensor.

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Exploitation of sensors at micro-nano scales

Multi-scale sensing strategies

Interactions and micro-objects characterization at micro-nanoscales

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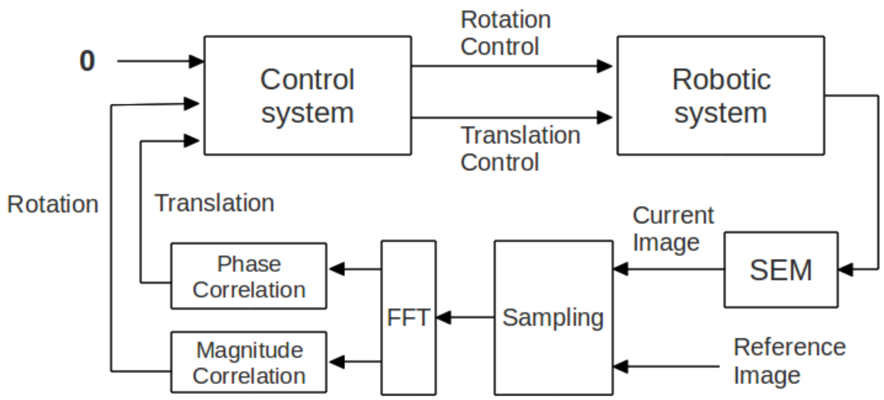
Fourier based visual servoing with sub-pixel accuracy for nanopositioning (NM, SD, NP)



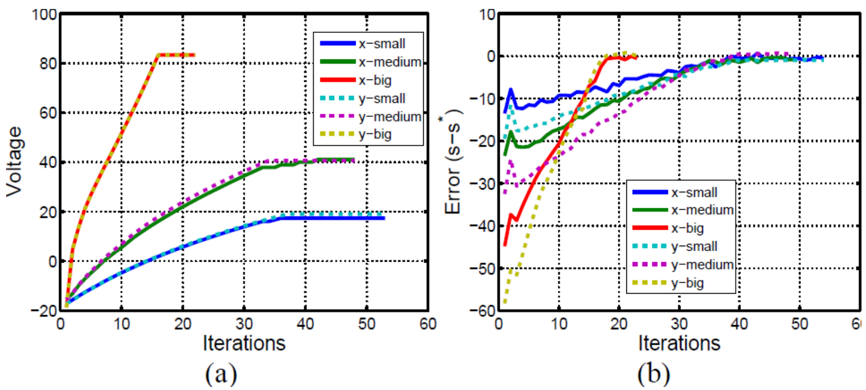
Naresh rated 3rd in the contest « meilleure thèse 2013 de l'Université de Franche Comté ».
1 Scanning, 2014
1 CASE août 2013 – 1 IROS nov 2013 – 1 CARE déc 2013 – 1 ICRA 2014

Sub-pixel accuracy (σ = 10 nm) is achieved by oversampling images before computing translation and rotation.

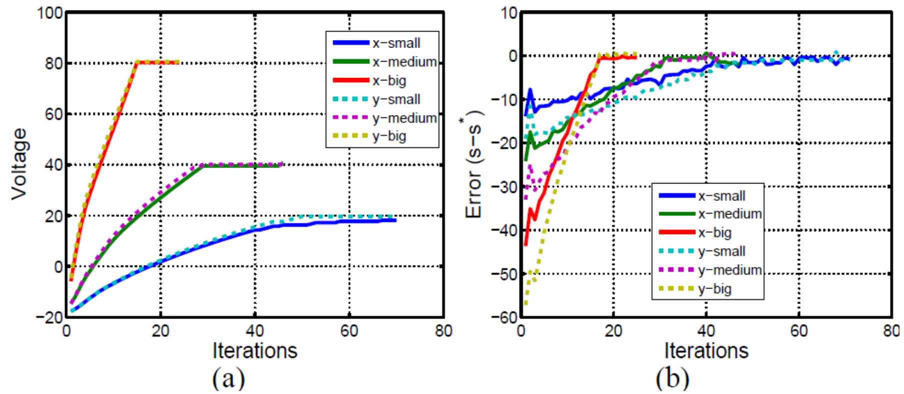
Translation is obtained from phase correlation.

Rotation is obtained from log-polar magnitude correlation.

Application to a XY nanopositiong stage inside a JSM 820



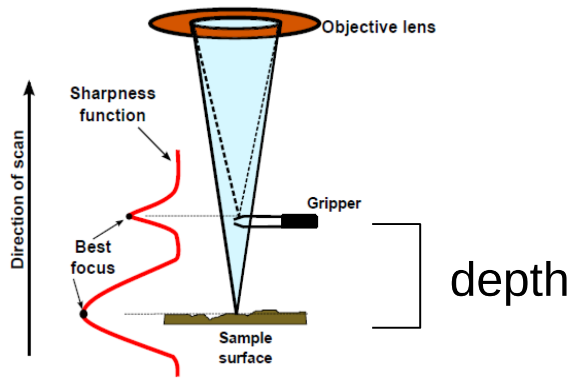
Normal conditions (low frame rate)

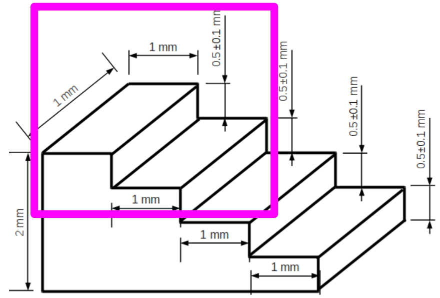


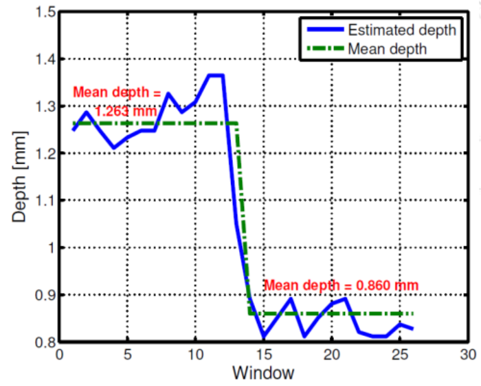
Noisy conditions (high frame rate)

In conclusion, the method is accurate and robust to image acquisition parameters.
Submitted to IEEE TRO.

Depth estimation using visual servoing based autofocusing (NM, SD, NP)





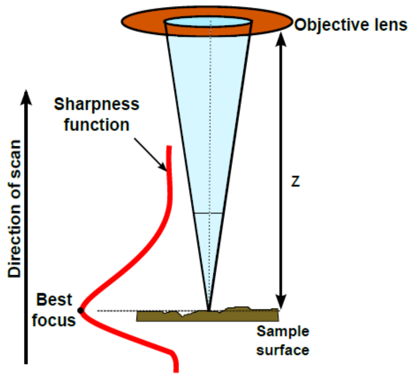


Both best focus (gripper, surface) are obtained using visual servoing

The accuracy (vs time) of sensing can be tuned by the processing window.

The result opens the way to visual servoing based z positinoning in SEM.

Learning approach based autofocusing (Liu Wei, NM, SD, NP)



1. Training of BPNN (Back-Propagation Neural Network) and LS-SVM (Least Squares – Support Vector Machines) with data obtained by Naresh (sharpness score = variance).

2. Prediction of the best focus from a set of images based on the first 20 gradients of the curve.

For a silicon part, both methods are equivalent:
Standard Error of Prediction = 0.5 mm.

Surface acoustic wave characterization with a SEM (RP, SD, NP)

See part II.

A real interest expressed by MN2S, TF and Optic departments (big help provided):

Abdelkrim Khelif (MN2S) – expertise

Sarah Benchabane (MN2S) – equipment loan / expertise

Franck Lardet – Vieudrin (MN2S) – wire bonding / advice

Mahmoud Addouche (MN2S) – equipment loan

Damien Teyssieux (MN2S) – equipment loan

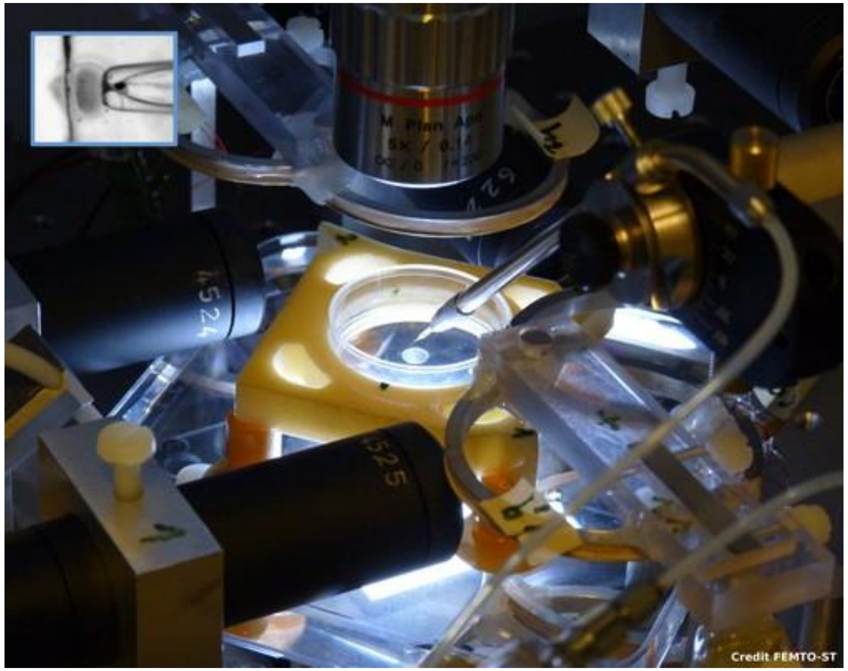
Sylwester Bargiel (OPT) – equipment loan / programming

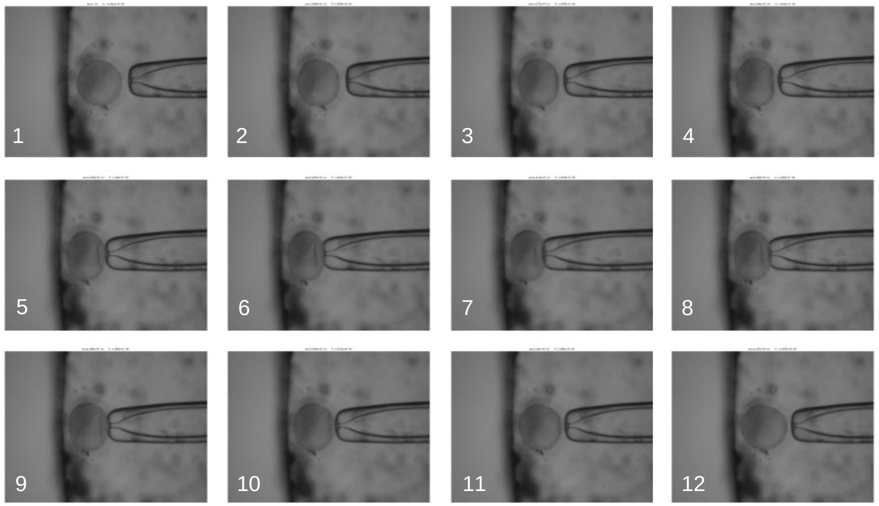
Pierre-Yves Bourgeois (TF) – programming expertise

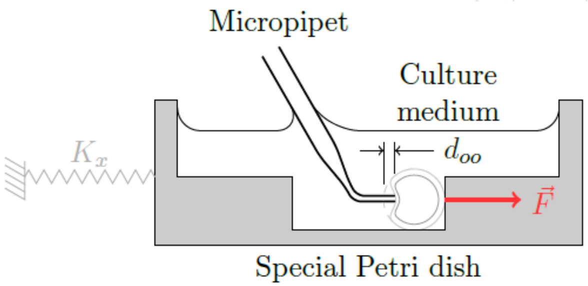
Gwenhaël Goavec-Merou (TF) – programming expertise

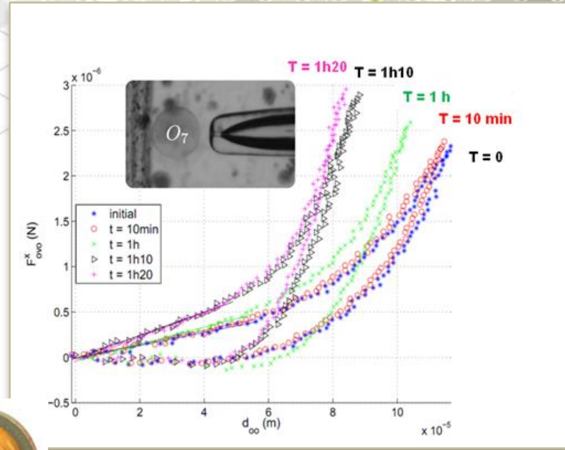
Bruno François (TF) – equipment loan

Oocyte mechanical characterization (RG, JAb, EP)



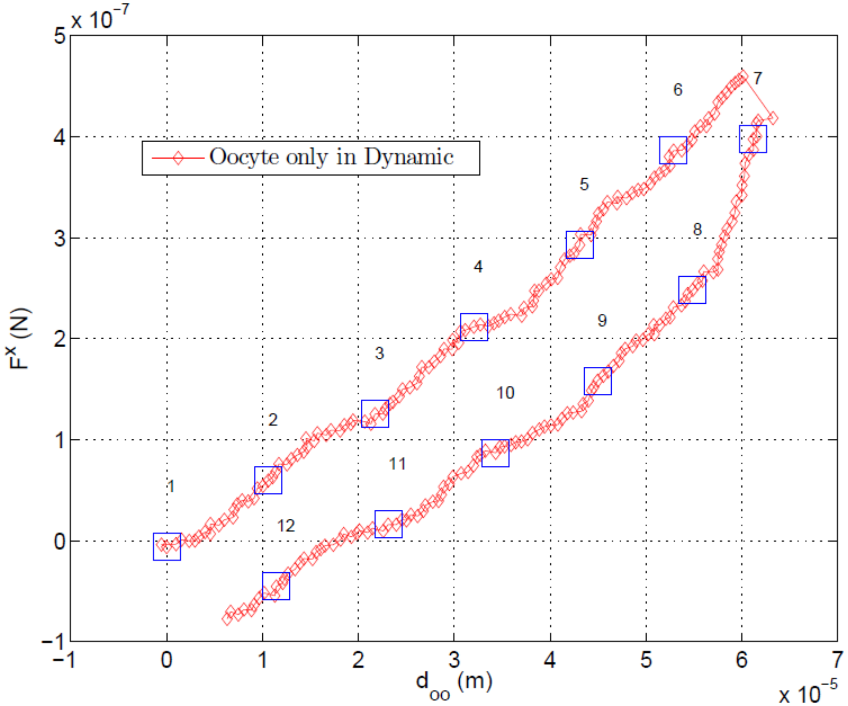






Parametric modeling of mechanical behavior

1 publi dans Sensors and actuators B: Chemical



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List of projects with internal partnership

Projects distribution into SPECIMeN topics

Research applications and projects scope

Micro-force sensing for multi-asperity nanotribology (in air and vacuum)

MEMS-Nanotrib, LabEx ACTION, Equipex ROBOTEX (SPECIMeN, MN2S/MINAMAS)

Electronic vision based nanopositioning for nanomembrane characterization

ANR project NanoRobust, Equipex ROBOTEX (CODE, SPECIMeN)

Proprioceptive measurement of microgripper end-effectors position

Industrial project MiM-HaC with Percipio Robotics company (CODE, SPECIMeN)

Micro-technologies and systems for robot-assisted laser Phonomicrosurgery

European project µRALP EC FP7 ICT (MiNaRob, SPECIMeN)

Microstructures and interfaces characterization, force measurement & calibration

Regional project FIMICAP (MiNaRob, MN2S/MINAMAS, SPECIMeN, …)

Multi-criteria diagnosis of human oocytes maturity

Regional project MICROBE (Biom'@x femto-st transversal axis, SPECIMeN, PHM)

Scanning electron microscopy for surface acoustic waves characterization

SEMSAW, LabEx ACTION, Equipex ROBOTEX (SPECIMeN, MN2S/MINANO)

High resolution 3D reconstruction of surfaces/volumes using SEM images (4.5 k€ functioning)

HARRIS, LabEx ACTION, Equipex ROBOTEX (SPECIMeN, Digital Surf)

Last edition: 2013-06-15

Part 2: a focus on the SEMSAW project

(API programming with the SEM Auroga 60)

http://www.femto-st.fr/fr/Departements-de-recherche/AS2M/Accueil/

Future SPECIMeN contribution

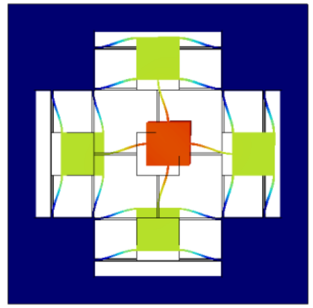
Adapt the stroboscopic SEM approach to our local context for structures and surfaces moving with a given dynamic range.

2013 Reminder

What can be adjusted?

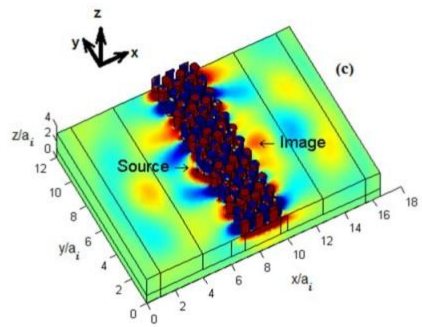
- scan speed
- sample averaging
- target region (or segment) of interest
- time and duration of the pixel acquisition

⇨ State estimation of moving micro-nano-structures using visual servoing and autosynchronization with the velocity of the structure.



A trade-off adjustment between resolution / range measurement / bandwidth

Constraint : we are dependant of the Auriga 60 API …



SEMSAW project:
Scanning Electron Microscopy for surface acoustics waves characterization

⇨ A first investigation (6 months internship at a master level)

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AS2M Dep^t – Automatic Control and Micro-Mechatronic Systems

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