Opening of a postdoc position in visual servoing and robotics

Title:	Visual servoing and control of a poly-articulated AFM based nano-robotic system for *In situ* characterization of muscular cells inside a SEM.
Laboratory:	Institut des Systèmes Intelligents et de Robotique, CNRS UMR 7222, University Pierre et Marie Curie, Sorbonne Universités.
Address:	4 Place Jussieu, CC 173, Pyramide - T55/65, 75005 Paris
Partners:	- Centre de recherche en Myologie (UMRS 974). - Institut de Biologie Paris-Seine (IBPS –FR3631) - Electron microscopy facility
Duration:	12 months
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Starting date:	As soon as possible

A 1-year post-doctoral position will be opened on visual servoing and control of multi-dof nano-robotic systems. The selected candidate will join the group microrobotics at the "Institut des Systèmes Intelligents et de Robotique (ISIR)" in University Pierre et Marie Curie, Sorbonne Universités.

1- Context

The observation and the mechanical characterization of the inner structure of cell membranes is a major scientific issue for the understanding of cellular mechanisms. The unroofing technique allows to directly observe the internal structure of cells using a Scanning Electron Microscope (SEM) or a Transmission Electron Microscope (TEM). It has been the main standard technique in this field [1]. In the case of muscular cells, such methods are important for the analysis of a neuromuscular disease called centronuclear myopathy (CNM) [2]. However, to date, there is no technique that allows to precisely measure the height of cells structures and to analyze some of their physical parameters such as the mechanical stiffness. The Atomic Force Microscope (AFM) is a powerful tool to deal with this issue [3]. Nevertheless, one of the main limitations of standard AFM is that they are very slow, they have not enough degrees of freedom to deal with a 3D imaging and characterization and they do not have the ability to perform an accurate positioning of the AFM tip on a specific region inside the cell membrane.

The project PolyREM aims at addressing control issues of a novel Atomic Force Microscope (AFM) based on a multi dof nano-robotic system and operating inside a SEM. The aim is to propose advanced visual servoing and control methods for a precise and an automated 3D

positioning of the AFM tip into the internal structure of muscular cells and to achieve high-speed 3D topographies and force measurements. This will merge the best capabilities of SEM and AFM towards a new method for cell characterization.

2- Objectives

The poly-articulated AFM system will be composed of a class of serial and parallel nano-robotic systems using inertial actuators, a tuning fork with a sharp tip for *in situ* force measurements [4] and a high bandwidth XYZ positioner for high speed AFM. The tuning fork will be the end effector of the nano-robotic structure.

The main objective is to propose advanced visual servoing methods using SEM images to control the position of the AFM tip so that it can be brought automatically into specific regions of the internal structure of a muscular cell. A high speed AFM scan can be performed using the XYZ positioner as soon as the distance tip/sample is about few nm. The region of interest is not necessary in the horizontal plan; the dof of the parallel structure and that of the serial structure must be controlled in closed loop to deal with orientation issues of the sample. SEM images and AFM images can be thereafter combined to deal with 3D reconstruction of the internal cell structures. Another objective, depending on the skills of the candidate, is to address the issues of geometric and dynamic modeling of the parallel nano-robotic structure. This work will be based on our recent results on modeling and control of Piezoelectric Stick Slip actuators [5][6][7]. Such models must however be adapted to deal with the global dynamic of the parallel nano-robotic structure. As such, control algorithms of the parallel nano-robot that are available in the laboratory can be improved in terms of robustness with respect to some nonlinear effects.

3- Partners of the project

The project is deeply related to visual servoing and robotics. It will be performed at the "Institut des Systèmes Intelligents et de Robotique (ISIR) UMR 7222". The selected candidate will also collaborate with researchers and engineers from:

- the "Centre de recherche en Myologie (UMRS 974)" with the main skills in the analysis of CNM muscular disease and in the unroofing technique for cells preparation,

- the "Institut de Biologie Paris-Seine" with its expertise in Cryogenic SEM.

4- Required skills

We are seeking a highly motivated Ph.D in the field of visual servoing and robotics. A solid background in visual servoing for robotic systems is required. An experience on modeling and control of parallel robots will be highly appreciated.

5- Environment

The Institute for Intelligent Systems and Robotics (ISIR) is a multidisciplinary research laboratory that brings together researchers and academics from different disciplines of Engineering Sciences and Information and the Life Sciences. The ISIR is a joint research laboratory (UMR7222) which belongs to the University Pierre et Marie Curie (UPMC) and the Centre National de la Recherche Scientifique (CNRS). The ISIR is linked to the Faculty of Engineering of UPMC (UFR 919) and also to the Institute for Science and Systems Engineering (INSIS) of the CNRS. The microrobotics team in ISIR has profound experience in the analysis of the specificities of adhesion forces for micro-robotic manipulation, in Atomic Force Microscopy (AFM) based nanorobotics, in modeling and control of nanorobotic systems and in haptic feedback teleoperation for micromanipulation and microassembly. Research activities of this

team have been published in several well-known international conferences and selected journals and have been rewarded many times. The division was involved in several research projects such as the European Research Council (ERC) PoC "RELAX".

6- Application

Applications should include a detailed CV, a motivation letter, a link to the Ph.D. thesis and the names of at least three references. The documents can be sent to mokrane.boudaoud@isir.upmc.fr

[1] Heuser, J. Three-dimensional visualization of coated vesicle formation in fibroblasts. *J Cell Biol*. 84:560-83. 1980.

[2] Vassilopoulos, S., C. Gentil, J. Lainé, P.O. Buclez, A. Franck, A. Ferry, G. Précigout, R. Roth, J.E. Heuser, F.M. Brodsky, L. Garcia, G. Bonne, T. Voit, F. Piétri-Rouxel, and M. Bitoun. In Press. Actin scaffolding by clathrin heavy chain is required for skeletal muscle sarcomere organization. *J Cell Biol*, VOL 205, 2014

[3] Binnig, G., Quate, C. F., and Gerber, C. "Atomic-Force Microscope". Physical Review Letters. 56: 930–933,1986.

[4] J.-O. Abrahamians, B. Sauvet, J. Polesel-Maris, R. Braive, and S. Régnier. A nanorobotic system for in situ stiffness measurements on membranes. IEEE Trans on Robotics, vol. 30, pp. 119–124, 2013.

[5] T. Lu, M. Boudaoud, D. Hériban and S. Régnier. Nonlinear modeling for a class of nano-robotic systems using piezoelectric stick-slip actuators. IEEE International Conference on Intelligent Robots and Systems (IROS), Hamburg, Germany, 2015.

[6] M. Boudaoud, S. Liang, T. Lu and S. Régnier. Voltage/frequency rate dependent modeling for nano-robotic systems based on piezoelectric stick-slip actuators. IEEE International Conference on Intelligent Robots and Systems (IROS), Deajeon, South Korea, 2016.

[7] S. Liang, M. Boudaoud, B. Cagneau and S. Régnier. Velocity characterization and control strategies for nano- robotic systems based on piezoelectric stick-slip actuators . IEEE International Conference on Robotics and Automation (ICRA), 2017