Modeling, Design and Control of Miniaturized Parallel Soft Robots with Configurable Platforms

1 Scientific context

In the medical field (minimally invasive surgeries, etc.) and several industrial applications (nanosensors, etc.), developing manipulation solutions at small scales in confined spaces represents a strategic enabling technology. However, contact manipulation techniques at small scales suffer today from several **limitations** such as **bulky volumes**, **excessive masses and inertia**, **lack of dexterity and precision** as well as **limited rotation angles** [1]. To overcome these limitations, parallel miniaturized robots have been developed. For instance, a recent breaking result using soft joints technologies (polymer sheets) (published in Science Robotics) was the MilliDelta Robot from WYSS Institute that had 3 DoF in translation [2].

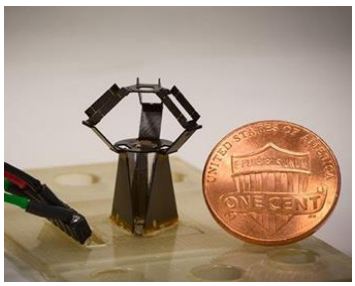

Figure 1: The MilliDelta from Harvard University & WYSS Institute https://wyss.harvard.edu/media-post/the-millidelta-robot/

However, none of the existing miniaturized robots combines 6 DoF motion, grasping capabilities and a large workspace (see Table 1). Using soft joints considerably increases the workspace but may severely decreases the robot accuracy. One of the factors that affect the precision of soft robots are the models that are used to control them where strong simplifying hypotheses are usually made (low deformation amplitudes, etc.).

In addition to all these limitations, it is usually not possible nor suitable to plug a gripper to a micro-robot (compactness and wiring issues). Current micro-robots are thus currently used as positioning tables or laser steering mirrors.

Ref.	Translation range	Rotation range
[8]	±20 µm	±3°
[9]	±8 ×12×8µm	±1.1×1×1.9°
[10]	±60 ×62×41µm	±1.4×1.5×2.4
[11]	±60 ×62×41µm	±1.4×1.5×2.4

Table 1: Motion ranges and technologies of 6 DoF micro-robots. One can notice that the rotation ranges are extremely small which does not allow dexterous manipulation and micro/nano-assembly.

2 Objectives of the PhD. thesis

The objective of the thesis is to model, design and control miniaturized parallel robots with configurable platforms that are able to perform 6 DoF dexterous micro/nano-manipulation in confined spaces. The configurable platform will be used to control the integrated grasping capability. To enlarge the robot workspace, that current micro-robots suffer from in translation and rotation (see Table 1), an elastomer such as the PDMS be used. In addition, redundant actuation and sensing will be exploited to control the robot position, force and stiffness and avoid singular and unstable configurations [3]. Redundant measurement will also be exploited to develop self-calibration methods. The developed robots will thus have several particularities such as: parallel structures, soft joints/links, redundant actuation/sensing and a configurable platform. A design example is shown in Figure 2.

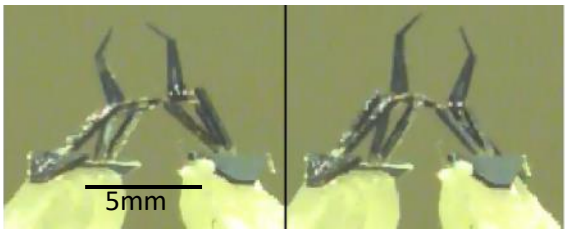

Figure 2: 7 DoF (3 rotations + 3 translations + grasping) miniaturized parallel robot with configurable platform and soft joints (Micron d'Or 2018, https://www.micronora.com/laureats-2018_en.html**).**

For such a class of robots, no model exists in the literature. Thus, **new generic methods for modeling 3D parallel soft robots under large deformations have to be developed**. To do so, the last

developments in the field [4][5] will be extended. One of the most promising models that has recently been used in soft parallel robots modeling is the **Cosserat model that can be exploited to obtain the kinetostatic model**. In addition, the **dynamic equations** can be derived using this elastic rod model [6].

3 Surrounding of the PhD. thesis

The PhD. fellow will be part of the FEMTO-ST Institute which is a joint research institute affiliated to four representative entities: CNRS, UFC, ENSMM and UTBM. FEMTO-ST hires more than 700 employees (among biggest French laboratories in engineering sciences) involved in different fields of engineering science, it is A+ ranked (best mark at the national level). It is organized according to 7 research departments and runs a microfabrication technology facility (MIMENTO). Among them, the AS2M department (Automatic Control and Micro-Mechatronic Systems) is one of largest teams involved in the fields of micro-nano-robotics, micromechatronics and control especially for micro and nano-assembly in Europe and in the world. PhD. Students benefit from a stimulating and fruitful working environment that enables them to get the best of their potential.

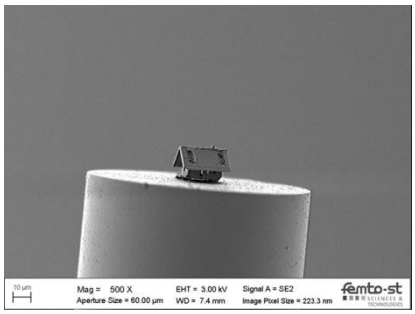

Figure 3: Illustration of MICRO-ROBOTEX abilities in handling and nano-assembly. The house is 20 µm in length, 10 µm in width. The walls have been made by folding 1 µm-thick silica film.

In addition to MIMENTO, FEMTO-ST also hosts the MICRO-ROBOTEX platform that provides a highly competitive and very recent instrument at the international level to academic and industrial researchers in nanorobotics. MICRO-ROBOTEX represents a unique environment for automated micro/nano-assembly and position/force feedback manipulation and characterization of micro and nano systems. Figure 3 shows the smallest house in the world that has been assembled and fixed at the tip of an optical fiber.

4 Requested skills

The proposed thesis is for curious, inventive, dynamic applicants having a strong scientific background and a sense of communication in a collaborative and multidisciplinary environment. Technical Skills in robotics and mechanics with a strong interest in modeling and simulation (Matlab, ANSYS/COMSOL, etc.) are mandatory. Knowledge or experience in mechatronics at the micro and nanoscales will be a plus.

5 Advisory team of the PhD

Redwan Dahmouche - Associate professor at UFC - redwan.dahmouche@femto-st.fr

Guillaume Laurent - Associate professor at ENSMM - https://gjlaurent.github.io/

Michaël Gauthier - Senior Scientist at CNRS - michael.gauthier@femto-st.fr

6 Contract

3 years' duration doctoral contract, the PhD thesis may start in October 2019.

Doctoral school SPIM (Engineering Sciences and Microtechnologies) : http://ed-spim.univ-fcomte.fr/

Additional activities such as teaching will be possible (to be discussed).

7 Application

Please send your application **as a single PDF file** to Redwan Dahmouche: redwan.dahmouche@femto-st.fr, with "**MSPR 2019**" as the email title. The PDF file must include: **a detailed CV, a specific motivation letter, the transcripts of the last 5 years, and two references** (typically your supervisor for a training period, master thesis or responsible of your master diploma).

Deadline: May 23rd 2019. Applications will be reviewed on a rolling basis.

References

[1] C. Shi *et al.*, "Recent advances in nanorobotic manipulation inside scanning electron microscopes," *Microsystems Nanoeng.*, vol. 2, no. April, p. 16024, Jun. 2016.

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