PhD Thesis Opportunity in Dexterous Robotic Micro/Nano-manipulation

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Keywords: trajectory planning, dexterous manipulation, artificial intelligence, micro/nano-robotics, soft robots, parallel robots

1 Scientific context

In the medical field (minimally invasive surgeries such as middle ear surgery, see Figure 1) and several industrial applications (nanosensors, etc.), developing manipulation solutions at small scales in confined spaces represents a strategic challenge. Although, 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, new generations of micro-robots have been developed. For instance, a recent breaking result using soft joints technologies (published in Science Robotics) was the MilliDelta Robot from Harvard University and WYSS Institute that had 3 DoF in translation [2] (Figure 2). Despite significant developments efforts, no micro-robot is currently able to perform dexterous (i.e. 6 DoF, grasping capability, wide rotation range) micro/nano-manipulation as shown in Table 1. **During the last few years, several dexterous (micro)-robotic structures were developed at UBFC/FEMTO-ST** (see Figure 3 and Figure 4) [3]–[7]. In this work, planar manipulation of several micro-objects of down to 120µm size was performed using a dexterous micro-hand having three 7µm-carbon fibers as fingers. An 8-DoF parallel structure with soft joints and a configurable platform has also been designed to manipulate micro-objects within the robot's fingers. After several proofs of concept, the next step will be to focus on the **efficiency and robustness** of the performed tasks in terms of **precision, speed and robustness**. The **controller design** and the **automatic trajectory generation** of the developed robots to perform **dexterous micro/nano-manipulation** will be the main challenges in this thesis.

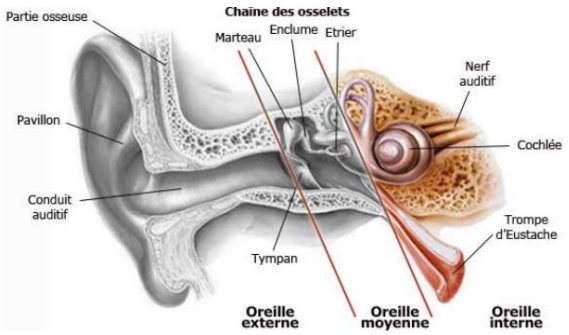

Figure 1: Insight of the space constraint in minimally invasive surgery of the middle ear

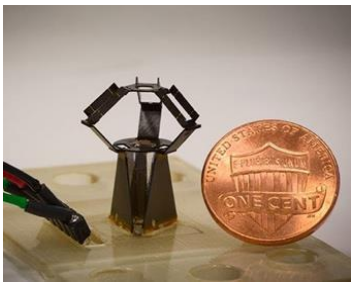

Figure 2: The MilliDelta from Harvard University & WYSS Institute
https://wyss.harvard.edu/media-post/the-millidelta-robot/

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 of 6 DoF micro-robots. One can notice that the rotation ranges are extremely small which does not allow dexterous micro/nano-manipulation.

2 Objectives of the PhD thesis

The objective of this PhD thesis is to develop manipulation-planning algorithms that perform dexterous micro/nano-manipulation tasks, which has several particularities compared to classical dexterous manipulation. One particularity of micro/nano-manipulation is the presence of adhesion forces that make the manipulated object stick to the manipulator. In addition, the manipulation is often performed in confined spaces. In minimally invasive surgical applications for instance,

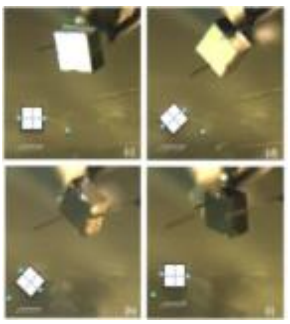

Figure 3: 3 - fingers in-hand dexterous manipulation of a Silicon micro-object of 120µm side with 7 µm diameter Carbon fiber

the accessible space is limited by the accessible space to access the targeted tissue inside human body. Industrial applications are also often constrained by the limited accessible space inside the Scanning Electron Microscopes.

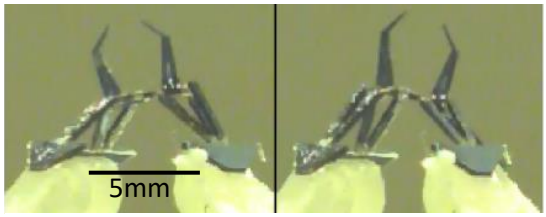

Figure 4: 7 DoF (3 rotations + 3 translations + grasping) miniaturized parallel robot with configurable platform and soft joints (Micron d'Or 2018, link to video).

The planning algorithm has thus to ensure the sufficient dexterity, precision and robustness and comply with the robot kinematics as well as the available space. Several planning algorithms that take into account arbitrary shaped planar objects have already been developed and validated. The former PhD student who worked on this subject was awarded the 2nd Best Robotics Thesis in France.

To go further, the PhD candidate will extend the dexterous manipulation algorithm capabilities to arbitrary shaped 3-D micro-objects and take into account particular robot's kinematics as well as the constraints on the accessible space. The output of this thesis will have impact on several fields of robotics which will allow the successful candidate to develop skills in several domains (AI, motion planning, graph search algorithms, micro/nano-robotics, automatic control, robots kinematics and statics). The successful candidate would thus be eligible for a wide range of career opportunities after his PhD thesis.

3 Requested skills

The proposed PhD thesis is for **curious, inventive, autonomous, dynamic** and **self-motivated** applicants who have a Master's degree or equivalent in **Robotics, Mechatronics, Computer Science, Mechanics** or related fields. The candidate is expected to have very good **communication aptitude** in a context of a multidisciplinary collaborative environment, excellent **scientific methodology** and strong **programming skills** (C++ or Python, Matlab). Competence in **robots modeling**, with a strong interest in **experimental validation** are also mandatory. Experience in **graph search algorithms** (A*, D*, etc.) and/or **machine learning** would be appreciated.

4 Surrounding of the PhD. thesis

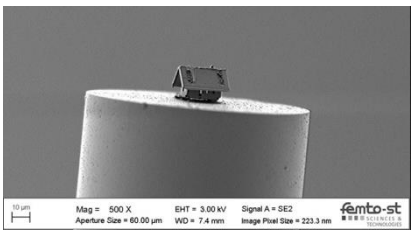
Figure 5: Illustration of MICRO-ROBOTEX abilities in handling and nano-assembly. The house is 20 µm in length, 10 µm in width. The walls have been made by folding 1 µm-thick silica film.

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.

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 5 shows the smallest house in the world that has been assembled and fixed at the tip of an optical fiber.

5 Application

Please send your application **as a single PDF file** to Redwan Dahmouche: redwan.dahmouche@femto-st.fr, with "**DEXTER-2020**" as the email's object. The PDF file must include: **a detailed CV, a cover letter, the transcripts of the last 5 years, and two references** (typically your supervisors for projects or MS thesis). **Applications will be processed on a rolling basis until the position is fulfilled. Applications after 7 June 2020**

will not be processed. The PhD thesis will typically start in October 2020. Depending on the candidate, it would be possible to start with 6 months engineering contract.

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