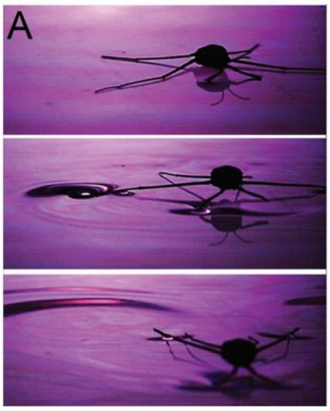
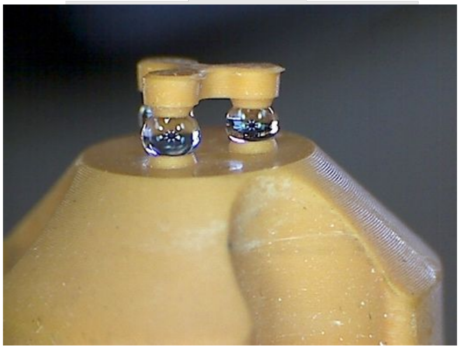
PHD OFFER

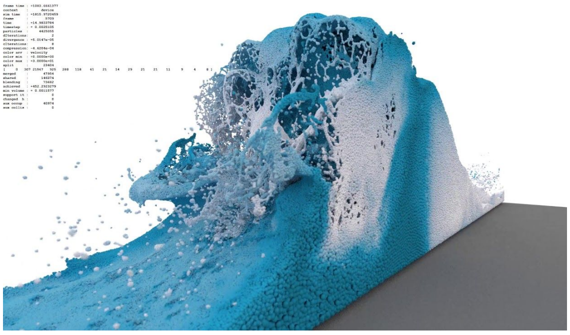
Design of a robotic simulator modelling capillary forces using SPH (Smoothed Particle Hydrodynamics) method



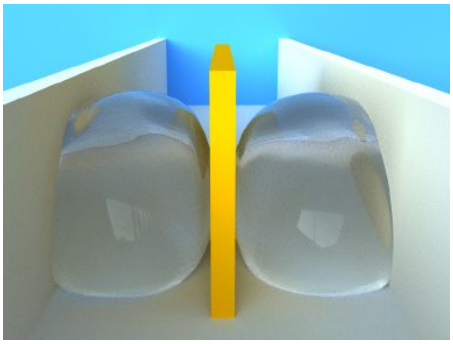
1/ Propulsion of an insect at the water surface



2/Microrobotic platform based on capillary effects



3/ SPH Wave simulation using openMaelstrom [video]



4/ SPH Suface tension simlation [video]

Laboratory: FEMTO-ST Institute, affiliated to the CNRS, SupMicroTech-ENSMM and the University of Franche-Comté.
Partner laboratory: INRIA - Lille - Nord-Europe.

Location: Besançon - a green city with a vibrant student life.

Context: The AS2M department of the FEMTO-ST institute specialises in small-scale robotics (microrobotics). Its researchers develop millimetric and submillimetric robots for medical and industrial applications. At small scales, the deformation of robots and their interactions with their environment is difficult to predict. In particular, capillary forces resulting from the surface tension between two fluids are particularly important at scales of between one micrometre and one millimetre. They can therefore have a major influence on the deformation of a structure and its adhesion to an object in humid environments. In nature, many mechanisms rely on these forces, such as the propulsion of insects on the surface of water [1], illustrated in Figure 1. Properly understood, they can be used as the basis for flexible droplet based micromechanisms, as shown in figure 2 [2]. It is therefore essential to propose simulation tools for deformable robots that incorporate capillary force models.

Topic: Among simulation methods, finite elements enable capillary problems to be solved very accurately. However, the problem definition , multiphysics interactions and boundary conditions definition (in particular the zones in contact with the liquid) are complicated to set up and vary greatly from one simulation to another. Alternatively, minimisation of the surface energy can also be carried out, allowing a rapid resolution of the problem, but limited to a quasi-static approach.
The aim of this thesis is to study the relevance of the Smooth Particle Hydrodynamic (SPH) method for simulating deformable microrobots interacting with liquid at millimetre and sub-millimetre scales. The SPH method represents the fluid by particles of constant mass, so the equations of the medium are approximated by interaction forces between these particles [3]. The advantage of this method is that it is very versatile, offering a simple definition of the wetting boundary conditions by representing the surface energy as an interaction force between the particles. Two examples of the application of this method are illustrated in Figures 3 and 4.

Expected results: This thesis first objective will be to implement surface tension in SPH models by adding an inter-particle force. The expression of this force will be studied in order to be robust to changes in resolution and materials, as well as to changes in topology such as the division of a drop into two sub-parts. The coupling between fluid mechanics and continuum mechanics will then be studied in order to propose a stable and efficient scheme for elasto-capillary problems (such as for example, the deformation of hairs by water). After validation of the method on case studies from the literature, its implementation in an existing calculation code will be considered. Finally, demonstrators will be produced, for example enabling the design and control of a micro-actuator based on the formation and destruction of drops or the design of a robot propelling itself on the surface of water inspired by water strider insect as shown on figure [1].

Required Profile: Student with an engineering degree or a Masters in one of the following domains : physics simulation, computer science, mechanics or applied mathematics.

Expected skills: Finite element methods, object-oriented programming (C++, Python), computer graphics (GPU, particles, physics engines). Knowledge of fluid mechanics is not mandatory but will be considered positively for the application.
Start of thesis: October 2024 (for a period of 3 years).

Salary: Between 2100 and 2300 euros/month (Gross salary).

Applications: Applications should be sent before 29 April with a covering letter, CV and transcript of grades for the last two years to : Antoine Barbot: antoine.barbot@femto-st.fr, and Guillaume Laurent: guillaume.laurent@ens2m.fr

Référence:

[1] Mahadik, G. A., et al. "Superhydrophobicity and size reduction enabled Halobates (Insecta: Heteroptera, Gerridae) to colonize the open ocean." *Scientific Reports* 10.1 (2020): 7785.
[2] N. Majcherczyk *et al.*, « Experimental characterization of Drobot: Towards closed-loop control », in *2014 IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, Besacon: IEEE, juill. 2014, p. 961-966. doi: 10.1109/AIM.2014.6878204.
[3] L. Li, L. Shen, G. D. Nguyen, A. El-Zein, et F. Maggi, « A smoothed particle hydrodynamics framework for modelling multiphase interactions at meso-scale », *Comput. Mech.*, vol. 62, nº 5, p. 1071-1085, nov. 2018, doi: 10.1007/s00466-018-1551-3.