Research Topic for the ParisTech/CSC PhD Program

Field : Materials Science, Mechanics, Fluids
Subfield: Fluid mechanics, fluid/structure interaction, continuum mechanics
Title: Origami: Designing the elastic response of an object in a fluid
ParisTech School: Ecole Polytechnique
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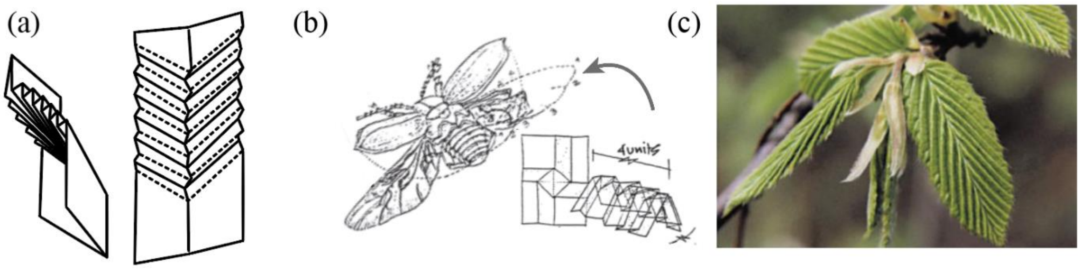

Figure 1: (a) Example of origami that undergo large shape changes while folding along a single degree of freedom. (b-c) Deployment mechanisms and folding patterns of the wing of a beetle and of a hornbeam leaf.

Short description of possible research topics for a PhD:
There is a long-standing interest in the use of compliant materials for robotic propulsion, or energy harvesting from flows [1]. Exploiting passive deformation is a simple way to increases performance without having to resort to complex mechanisms [2,3]. However, the structure has to deform in an appropriate way, that is specific to its function. It is thus important to understand the mechanisms governing the elastic response of an object under fluid loading, and to find ways to control it. Here, we will explore an unconventional route to tailor those deformations, making use of the unique properties of origamis. The geometry of the folds conditions the way the structure deforms, allowing only for certain motion while being rigid to other modes of deformation (Fig.1a). When placed in a flow, such a system will then display different behavior as a function of its orientation, folding into a compact object or conversely expanding. This is for example of interest for the flow-controlled deployment of underwater structures, or the design of valves. Such foldable structures are also commonly used in nature, for example in the opening of buds or the deployment of insect wings (Fig.1b-c). The resulting mechanical properties are likely to improve the wind resistance of plants, or to optimize flight performances of an insect by allowing for the wings to modify their shape in the ascending and descending phase of the flapping motion. We will study those biomechanical mechanisms on model geometries of origami in controlled flows, with potential applications in biomimetic engineering.

Required background of the student:
This PhD will combine experiments and theory. The candidate will have a pronounced taste for experimental work, and will build and study set-ups to understand the mechanical behavior of origamis in a flow. To develop a deeper understanding, this experimental work will be coupled to theoretical and numerical models, relying on tools developed at LadHyX for deformable structures under fluid loading [4]. Strong skills in fluid mechanics, continuum mechanics and/or fluid/structure interaction would be an asset.

A list of 5(max.) representative publications of the group:
[1] Antoine G. O., and de Langre E., and Michelin S. (2016). Optimal energy harvesting from vortex-induced vibrations of cables. Proc. R. Soc. A, 472(2195), 20160583.
[2] Ramananarivo S., Godoy-Diana R., & Thiria B. (2013). Passive elastic mechanism to mimic fish-muscle action in anguilliform swimming. Journal of The Royal Society Interface, 10(88), 20130667.
[3] Ramananarivo S., Godoy-Diana R., & Thiria B. (2011). Rather than resonance, flapping wing flyers may play on aerodynamics to improve performance. Proceedings of the National Academy of Sciences, 108(15), 5964-5969.
[4] Leclercq T. & de Langre E. (2016). Drag reduction by elastic reconfiguration of non-uniform beams in non-uniform flows. Journal of Fluids and Structures, 60 :114-129.