# Computational Design of Soft Robots


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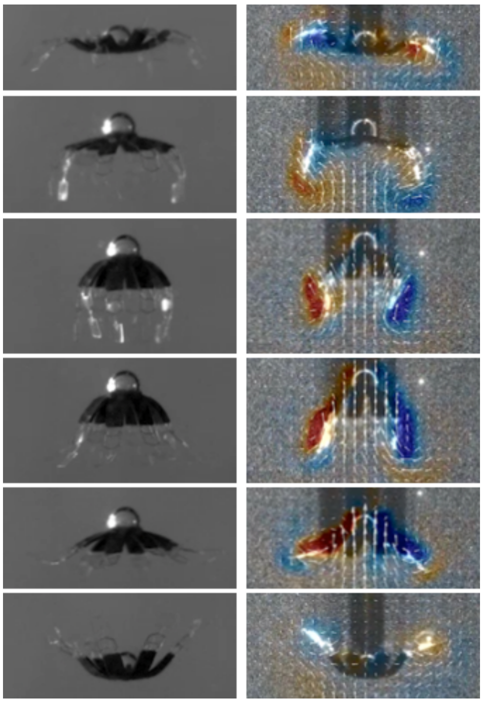
**Research objective**. Soft robotics is emerging as a new engineering field featuring robots made from soft, elastic materials which offers unique opportunities in areas in which conventional rigid robots are not viable, such as non-invasive surgery, drug delivery and artificial organs. Here, miniaturized swimming robots that are actuated by magnetic fields are especially promising due to their biocompatibility and unprecedented external control. Progress in the design of these robots, however, has been severely hampered by the lack of numerical techniques that enable the non-linear coupling of the Maxwell, Navier-Stokes and Solid Mechanics equations needed to magnetically drive the soft robotic swimmers. This is the aim of the current proposal.



Magnetic actuation of a soft robotic jellyfish subject to an oscillating magnetic field [Courtesy: M. Setti, Max Planck Institute].

**Research plan.** To couple the magneto-elastic equations to the fluid dynamics equations we will use the arbitrary Lagrangian-Eulerian (ALE) method for simulating fluid-structure interaction (FSI) problems that combines a Lagrangian representation of the motion of the solid structure with a Eulerian fluid flow description. Standard ALE methods fail if the structural displacements are large, as is the case in magnetic soft robotic swimmers. We propose a new ALE method that successfully deals with this problem by regularizing the fluid-structure coupling through a data-driven optimization technique that enforces mesh-alignment with the moving structure, by using compatible discretizations, and by introducing a preconditioned iterative coupling tailored to magnetically driven soft robotic swimmers.

**Interdisciplinarity, novelty and applications**. The proposed research is inherently interdisciplinary: a full synthesis of excellence in magneto-elastic modelling and numerical methods is required to simulate and ultimately design magnetically driven miniaturized swimming robots. Their attractive features (flexibility, compliance, magneto-responsiveness) also make them difficult to simulate numerically. The novelty of the proposal is therefore both fundamental and applied in nature: to make an important step forward in this exciting new field, advanced numerical techniques are essential. Swimming robots constitute an extremely complex dynamical system. Developing a simulation model opens the possibility for engineers to use the simulation model to design revolutionary new micro- and nano-robots that hold great potential in biomedical applications, enabling wireless control, in vivo sensing and navigation through complex biological media.

**Applications.** We are looking for an ambitious master student with affinity for computational modelling that has obtained (or is in the process of obtaining) an MSc degree in the field of Solid Mechanics, Mechanical/Aerospace Engineering, Applied Physics or Applied Mathematics. Candidates that have hands-on experience with in-house finite element/finite difference development and implementation are especially invited to apply. Candidates have the opportunity to write their own research proposal and will be selected based on proposal and CV. If you are interested, send a CV before March 21 to prof. Patrick R. Onck (p.r.onck@rug.nl) and prof. R.W.C.P. Verstappen (r.w.c.p.verstappen@rug.nl).