1. Summary

Rationale and Objectives

The **reason** for the project is to investigate scientific problems and to develop technologies that will lead to a breakthrough in underwater robotics as well as enhance our understanding of fish biology. Therefore, this project in FIsh LOcomotion and SEnsing (FILOSE) is addressing the bottlenecks of underwater robotics, namely the problems of how fish do, and robots could, sense the underwater environment and how they achieve high adaptability and reliability in these very unstable surroundings. We believe that solving these problems will lead to new underwater technologies that serve people better.

The overall **aim** of FILOSE is to acquire a deeper understanding of the principles underlying fish locomotion and sensing, in order to develop new technologies for underwater vehicles on the basis of biological evidence. A fish detects hydrodynamic patterns in the surrounding environment with its lateral line, thereby the lateral line plays a key role in adapting to environmental changes. An important component of this research is investigation of the sensing capability of the lateral line.

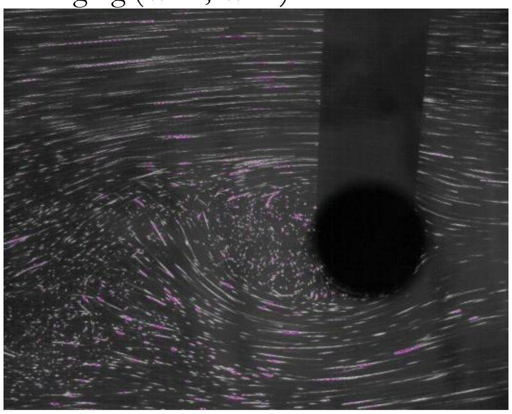
The more specific goals are captured by the following **objectives**:

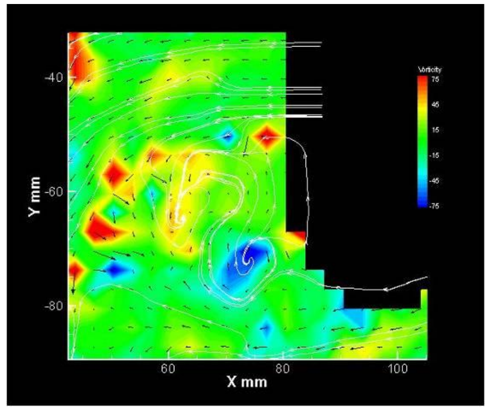
1. investigating fish locomotion in a controlled hydrodynamic environment, in particular addressing the issue of how fish react to changes in hydrodynamic patterns;
2. developing a novel mechanical design of an underwater fish robot, characterized by high maneuverability and low complexity;
3. developing a artificial lateral line with MEMS technology;
4. developing a control method for the artificial fish, aimed at reproducing locomotion patterns found in biological fish and based on a central pattern generator (CPG);
5. developing a method to characterize and classify hydrodynamic images, using the output of the artificial lateral line;
6. developing a classification method to couple detected hydrodynamic events with locomotion patterns found in biological fish;
7. conducting comparative experiments in a controlled hydrodynamic environment to assess the behavior of a robot fish with respect to the behavior of a biological fish.

To achieve the above-mentioned goals we will investigate fish behavior in controlled hydrodynamic environments to capture their response to hydrodynamic events using digital particle image velocimetry techniques. In parallel, we aim to achieve similar behavior with a robotic fish using mixed excitations of vibrating cords for creating undulating motion of fish fins and body. This mechanical design should reduce the complexity of the overall system, thus creating smaller, faster and more reliable underwater robots. These fins will be excited using bio-inspired Central Pattern Generator (CPG) control techniques. In addition, hydrodynamic events will be initially recorded, studied and classified by analyzing the output of a mechanosensory array. Those methods will later be applied to analyzing the response of an artificial lateral line developed for specifically for this project using MEMS clean-room technologies. Finally, comparative tests between real fish and artificial fish will be conducted to establish the similarities between their behavior in response to distinct hydrodynamic events.

Main results of the first 12 months

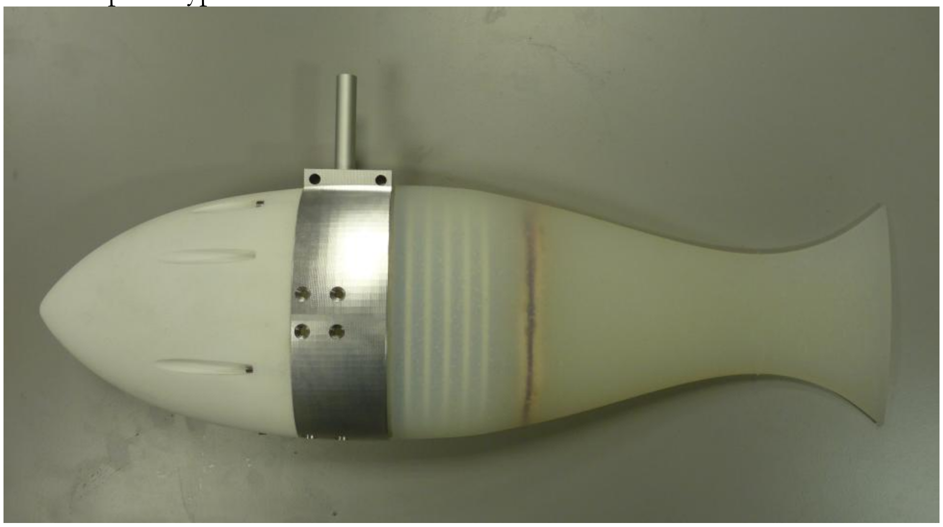
1. Test environments are set up in UB and TUT to create controlled flows and for hydrodynamic imaging (WP1, WP5).



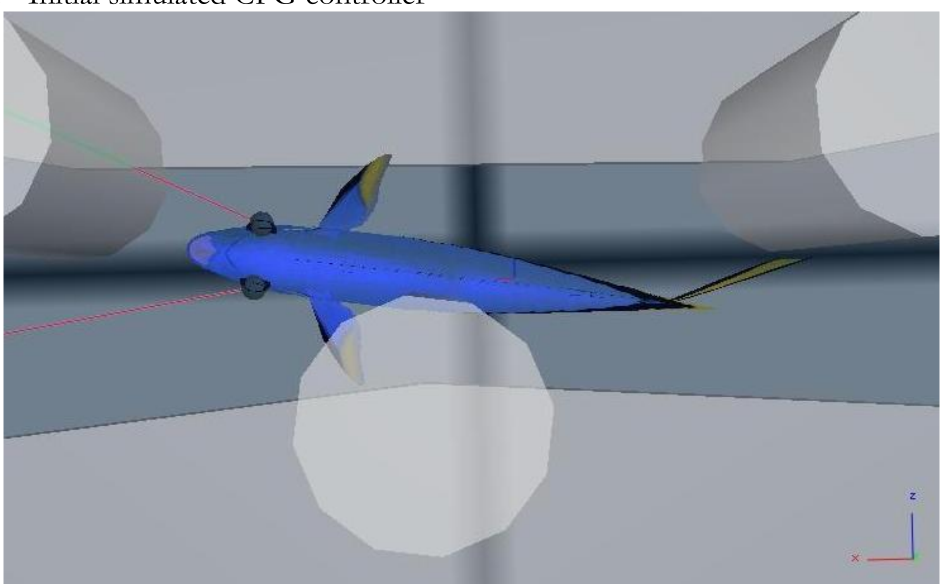


Test environment in TUT and in UB

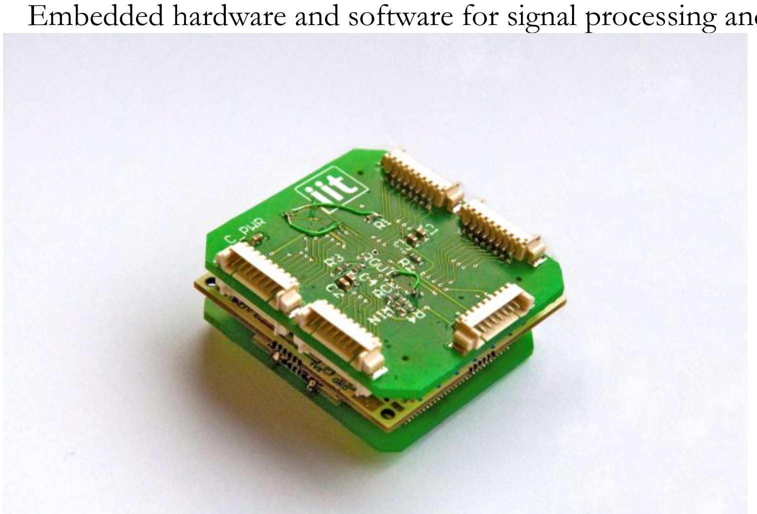
2. Initial prototype of a mechanical fish robot has been built



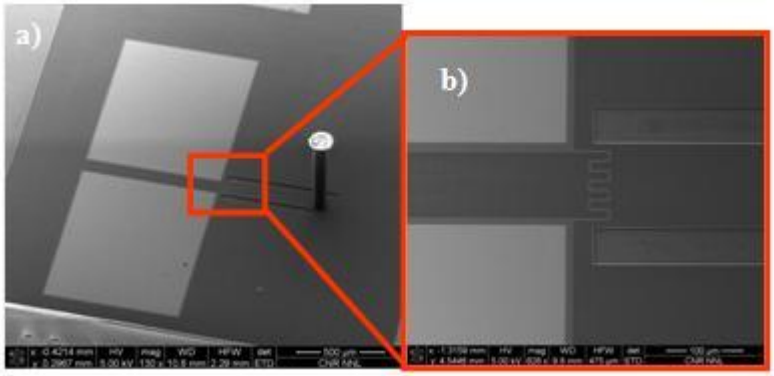
3. Initial simulated CPG controller



4. Embedded hardware and software for signal processing and control

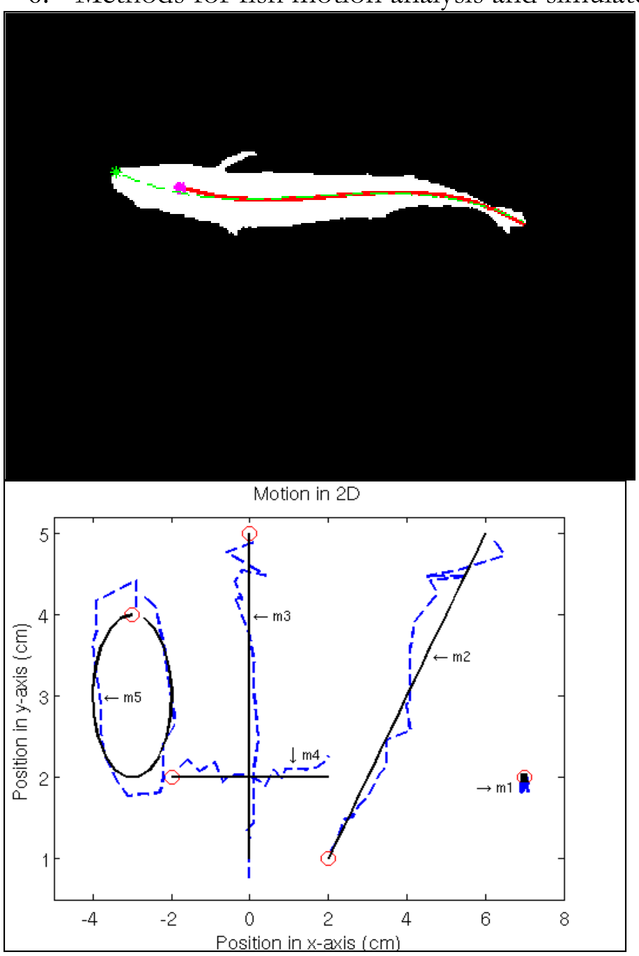


5. Artificial lateral line MEMS sensor developed and tested



The flow sensor has an in-plane geometry with a Cilium on the free end of the cantilever. This cantilever is made in Silicon, using Silicon on Insulator (SOI) substrates. An original approach has also been proposed, which is under patent filing. More details will be given soon.

6. Methods for fish motion analysis and simulated artificial lateral line sensing algorithms



7. The project has its own logo:

8. The FILOSE project has a public website www.filose.eu including general project data and all relevant public project information.

The expected final result

The **innovation** envisioned by FILOSE lies in using a novel mechanical design concept to develop a robot capable of reproducing the locomotion gaits found in biological fish. The robot will be equipped with a lateral line sensing mechanism, which has not been tested on a fish robot before. Also, FILOSE will develop sensing and control methods to respond to environmental changes in a manner akin to biological fish.

Potential impact and use

We believe that the proposed investigations are key to building underwater robots that improve on the existing by exhibiting a greater degree of autonomy, adaptability to environmental changes, maneuverability, stability. The result will be a robot with lower overall lower complexity that moves more efficiently and quietly. These results of FILOSE are applicable in water, which covers 2/3 of The Planet. As a consequence, it gives opportunities for highly innovative SMEs to develop new products. The **FILOSE project results can be applied and used in the following fields**: underwater humanitarian demining, environmental monitoring, search and rescue, anti-terrorist activities, surveillance of harbors, coast security, entertainment, edutainment and fishery.