FishView: environment investigation methods for an underwater robot

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Abstract

There is a strong dependency of the life-cycle of migrating fish on the environmental conditions in the Baltic Sea and its connecting rivers. Establishment and maintenance of fish passes is key region of intensive human activity to sustain a healthy ecosystem. The paper introduces the FishView project where we plan to develop an intelligent solution for the study of environmental flows using a robotic fish developed in the Center for Biorobotics of Tallinn University of Technology. The robot fish should sense water flows surrounding it and estimate hydrodynamic forces acting on it. This will allow to measure functionality of fish passes and reveal desired and undesired properties of them.

Keywords: biomimetics, underwater robot, computational fluid dynamics, flow sensing, modeling of fish motion, hydrodynamic imaging.

1 Introduction

Establishment and improvement of the passes for fish migration in the Baltic Sea catchment has a significant ecological and economical impact. The majority of the existing fish passes are non-functional or only accessible for a limited number of species. Currently there is no accurate method for modelling of fish passes and predicting their functionality. In order to collect the information and analyse the fish passes a fish-shaped robot sensor can be used.

One of the current trends in robotic design are bio-inspired systems [Pfeifer et al. 2007]. The major challenge is how with the current technological advances to achieve the same performance level as living organisms by mimicking their behavior. Fishes sense flows around them with their lateral line and perform undulatory motions helping to swim upstream [Reid et al. 2012]. While fishes utilize flows for effective swimming state-of-the-art design of underwater robots often treats flows and turbulences as disturbances [Toming et al. 2012]. Understanding the fish locomotion and behavior would allow to build devices that would use flows for intelligent navigation and understanding environment.

The FishView project originates from the FILOSE project where a robotic fish prototype was designed and built [Salumäe and Kruusmaa 2011]. A rainbow trout served as the prototype for the robot. Stiffness distribution and geometrical properties of trout were utilized for robot manufacturing. Similar kinematic behavior was achieved with a single point actuator mechanism that enable the fish-like undulatory movements. Five pressure sensors are mounted on robot’s head to sense the flows around. Currently, the flows for underwater robots are measured with a Doppler Acoustic Profiler (DACP) that demonstrated a successful performance in many applications being, however, too bulky to be used on board of such small underwater vehicles as the developed robotic fish [Jung et al. 2013]. Moreover, the DACP measures bulk flows around the vehicle. The pressure sensors located on the robot’s head provide information on the local flow around the fish-robot that has a potential for on-board flow-related control.

This paper introduces the FishView project with the goal to develop an intelligent solution for an underwater robotic fish that would be able to effectively sense and exploit flows around for economic swimming. This would enable understanding the underwater environment and could be applied to analyze fish passes. The analytical approach is via the theoretical background of the phenomena of fluid dynamics to build a virtual model of flows around a fish in motion. By utilising the full virtual physical model and control theory, we can program the robot fish to fully operate in true environment - deviations from the model can be modelled as a noise. Another approach is completely data driven, where we collect a huge number of training data, we can still utilise the physical model as a

1http://www.filose.eu
training bias and then train a modern machine learning method to automatically “reverse engineer” the problem similar to [Shotton et al. 2011].

2 Project background

The robot (see Fig. 1a) consists of a rigid head equipped with five pressure sensors, a microprocessor, and electronics. A rigid middle part contains a servo motor controlling an actuation plate located in the flexible tail. The length of the robot is 50 cm and the maximum width 8.5 cm. The tail was manufactured from the material according to the properties of a trout which enables the robot to mimic fish-like motions.

In order to study what forces are acting on the robot a series of experiments was performed [Toming et al. 2012] with a passive robot in uniform flow and regular turbulence. The results demonstrated that the lateral forces to the robot change considerably depending on the robot position. The authors suggest that an efficient navigation is possible searching for stable regions in flow where the forces are small and utilizing the energy collected in vortices.

At the moment the flow information is retrieved with Particle Image Velocimetry [Visentin et al. 2011]. The images are obtained with a camera overlooking the water tank where the experiments are performed (see Fig. 1b). It was demonstrated that there is correlation between the flow information and readings from the pressure sensors. Using signal processing techniques it is possible to detect flow events from the pressure sensors [Akanyeti and Fiazza 2011].

In [Jung et al. 2013] the authors show the importance of knowing flow parameters by comparing two strategies for path following: a flow strategy when the robot was navigating with response to the flow and still water strategy when the robot was control not taking acting forces into account but trying to stick to the desired path. The results demonstrated that the flow strategy outperforms the still water strategy especially when the desired path goes perpendicular to the flow.

3 FishView project

In order to analyse the conditions of fish passes, we need to understand the flow patterns around fish and their interpretation. Constructing a flow pattern map is a non-trivial task, but currently interests scientists [Dagamseh et al. 2010]. Proper solutions would allow to analyze flows not only under water but also in the air, discover flow patterns, and construct vehicles behaving efficiently and economically according to the flows. The task becomes even more challenging when the system is active and required to do path planning and control optimisation online while investigating its environment.

The first goal of the FishView project is to investigate flow numerical models around the fish robot using the Computational Fluid Dynamics (CFD) methods. 3D model of the robotic fish can be modelled in CFD software that provides the computational flows given parameters. For example, in Fig. 1c a simplified model of a fish was created in the FreeCAD software, after that the laminar flow was computed with OpenFoam, and the flows were plotted in the ParaView software. Modifying the environment around the fish and changing the flow properties, we will study the effect of different flow conditions on the robot and generate artificial data (prior model) for machine learning methods. The software also provides an analytical tool to investigate motions in laminar and turbulent flows and how the flow energy can be utilized by the robot.

At the moment the robot can sense flows with its pressure sensor. The second task will be to study the correlation between pressure sensor readings and flow properties, i.e. how to interpret the data from five pressure sensors and utilize it to detect novel events in the flow signature. The next step in robot sensor development is utilization of an artificial lateral line that is being also under development in the project [Qualtieri et al. 2012].

The third goal is to teach the system to understand flow events and model features that define desired and undesired properties of hydrodynamic structures. This would enable to establish metrics to measure functionality of fish passes by comparing functional and non-functional fish passes.

4 Conclusion

This paper discussed the preliminary challenges and potential solutions for design of bio-inspired underwater robots utilised in the starting FishView project. The goal of the project is to develop an intelligent solution for the robotic fish developed in FILOSE project. The designed system would allow the robot to sense, recognize, and learn the flow patterns and act accordingly to the flow events utilizing the flow energy for efficient swimming and recognizing its environment. This will provide a theoretical background for the design of new fish passes as well as analysing and improving the existing ones.

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References


