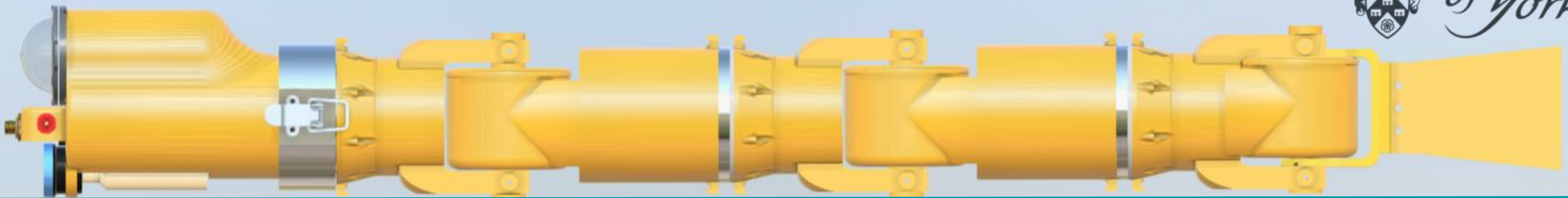


Autonomous Biomimetic Robot-Fish for Offshore Wind Farm Inspection

"RoboFish"

University of York Dept. of Electronic Engineering:

Dr Mark Post (mark.post@york.ac.uk); Dr Wael Gorma, wael.gorma@york.ac.uk

University of Strathclyde Dept. of Naval Architecture, Ocean and Marine Engineering:

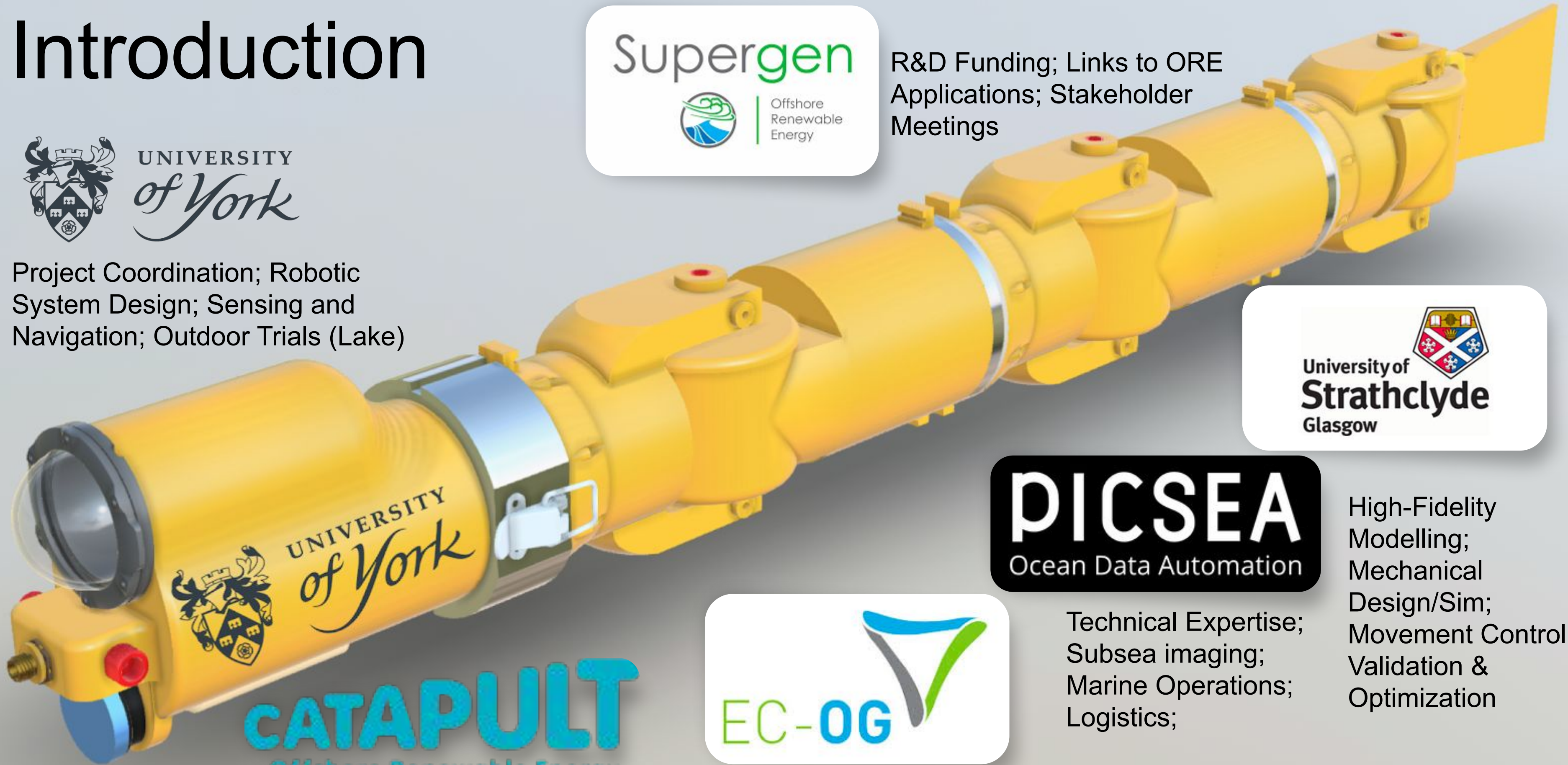
Dr. Qing Xiao, qing.xiao@strath.ac.uk; Mr. Marvin Wright, marvin.wright@strath.ac.uk; Mr. Yang Luo, y.luo@strath.ac.uk

PicSea Ltd.: *Andrew Durrant andrew@picsea.co.uk*

EC-OG Ltd.: *Bodhi Sarkar bodhi.sarkar@ec-og.com*

Offshore Renewable Energy Catapult: *Alex Louden alex.louden@ore.catapult.org.uk*

Introduction



Project Coordination; Robotic System Design; Sensing and Navigation; Outdoor Trials (Lake)

R&D Funding; Links to ORE Applications; Stakeholder Meetings

High-Fidelity Modelling; Mechanical Design/Sim; Movement Control; Validation & Optimization

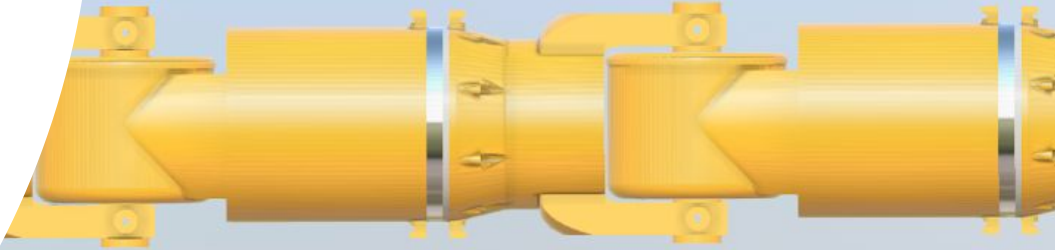
Technical Expertise; Subsea imaging; Marine Operations; Logistics;

Power & Energy Storage; Subsea Engineering & Interfacing/Docking

ORE Infrastructure and

Requirements Guidance; Industry Connections

Why Bio-inspired AUV?



Offshore wind farms provide clean, reliable and commercially viable energy. To ensure reliable production, regular Inspection Maintenance and Repair (IMR) tasks at high sea up to 100m depth need to be performed in a **cost effective** and **safe** manner. To extend Autonomous Underwater Vehicle (AUV) intervention time and perform IMR tasks the AUV needs to be efficient and flexible in operation.

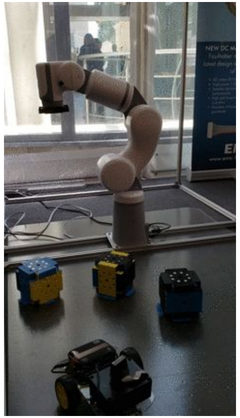
A biomimetic AUV, capable of autonomous navigation about dense and moving underwater structures, can continuously and autonomously locate and monitor structural damages **in limited spaces**. A fish-like AUV with a **modular design** can provide higher specific thrust efficiency at low swimming velocities and higher **manoeuvrability** in critical spaces during sensor data acquisition.

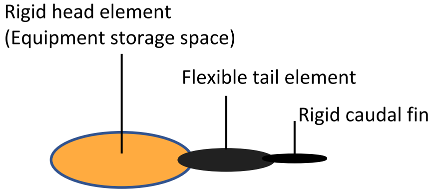
RoboFish is building on the progress of other projects of the *Space Robotics & Autonomous Systems Lab* led by Dr Mark A Post

Website: https://www.york.ac.uk/electronic-engineering/staff/mark_post/

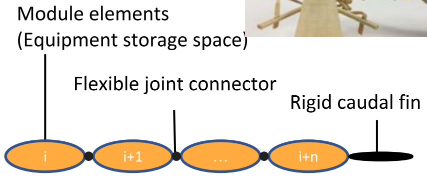
Modular, Self-Aware, and Self-Configuring Autonomous Systems

- RoboFish will build on a self-configuring modular architecture
- Segments will be autonomic cellular elements that operate in unison as a complete "organism" and are fault tolerant

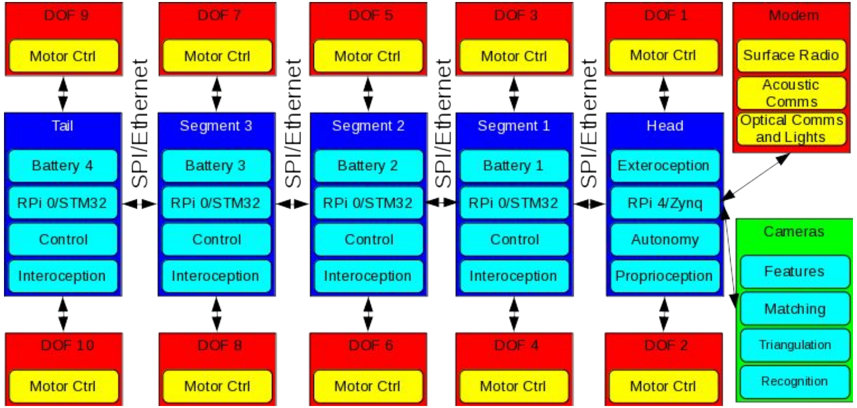




Rigid Head- flexible tail

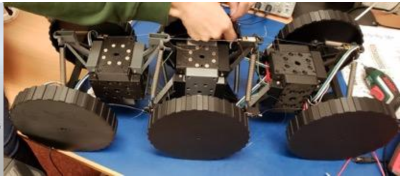


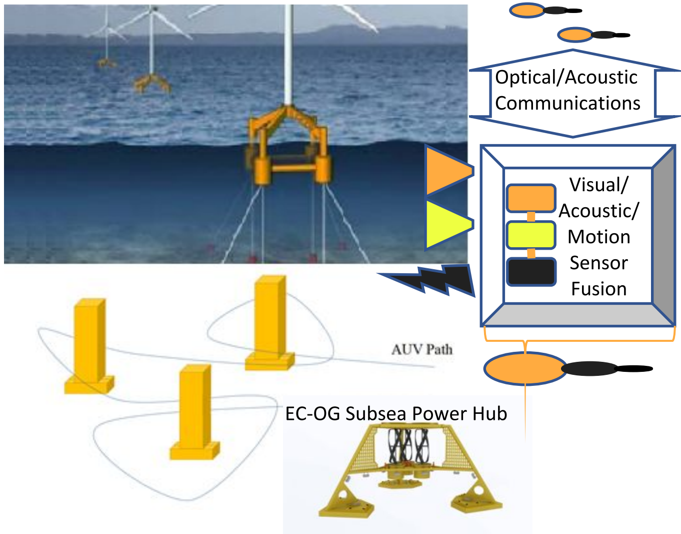
Multi-segment modular architecture



Adaptable, Bio-Inspired, Robust Robots for Harsh Environments

- RoboFish will maneuver and dock using a flexible, adaptable body
- Designs include the use of "biotensegrity" and smart materials





Robofish is a biomimetic AUV capable of self-sufficient navigation about underwater structures

- It is intended for the purpose of locating and monitoring structural damage to wind farms.
- It moves like an eel/trout through full-body movement, allowing high agility in proximity.
- Its first 3D printed prototype could be spun out to a successful commercial product.

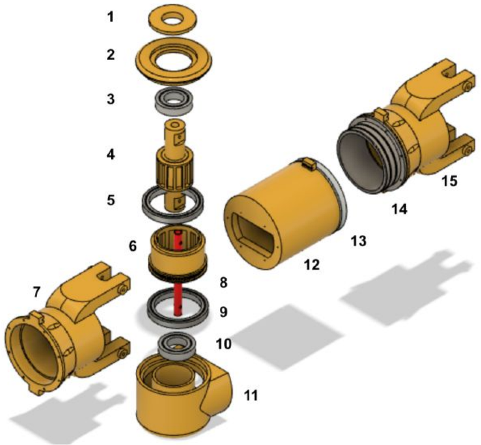
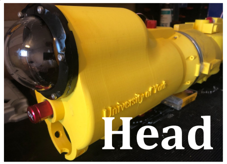
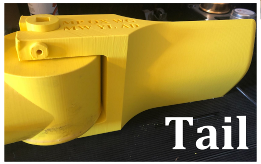
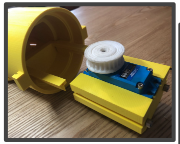
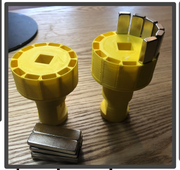


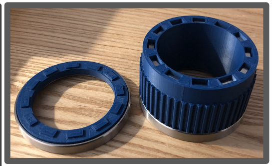
Fig. 4: All parts compromising one tested RoboFish segment: 1- Inner joint housing lid; 2- Outer joint housing lid; 3 & 10- Zirconia full ceramic bearing; 4- Driven shaft; 5 & 9- Stainless steel bearing; 6- Driving shaft; 7 & 15- Electronic housing; 8- Reinforcement Aluminum bar; 11- Joint housing; 12- Servo housing; 13- Female Stainless steel ring; 14- Male Stainless steel ring











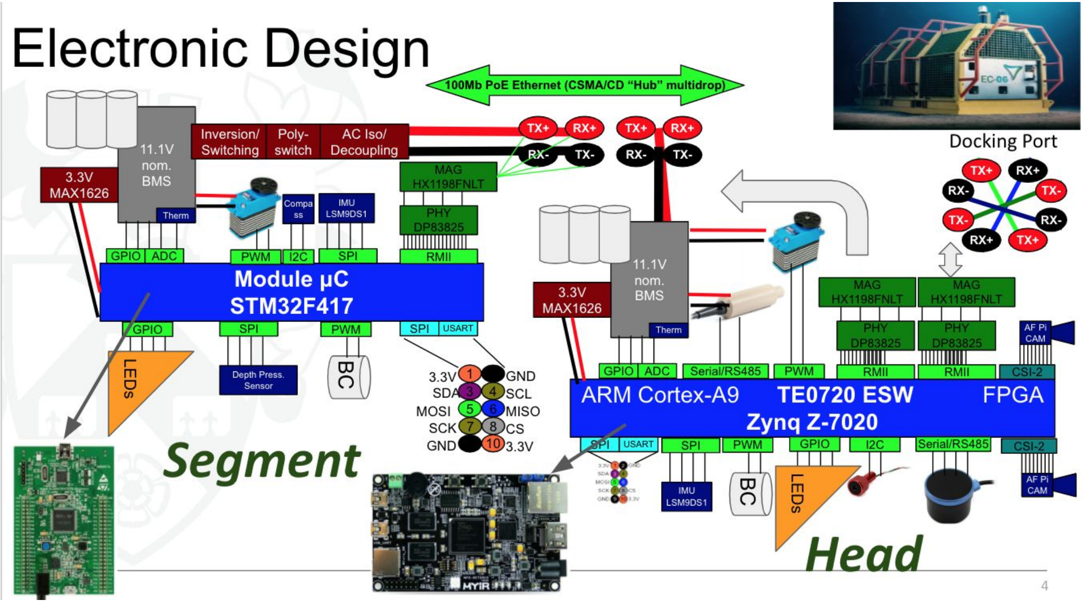
Magnetic joint technology was developed as a solution for a watertight jointed and 3D printed body.

- The design avoids dynamic interfaces and rotary seals.
- Magnetic blocks bond a free rotating inner shaft and a driven outer shaft for the joint to work.
- To provide 3D printed parts with the toughness and tolerance that O-rings need, two stainless-steel rings are incorporated in each segment as an intermediate connection and to allow disassembly.

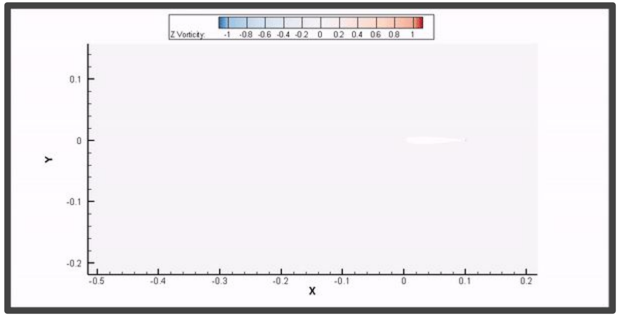
Modular System RoboFish uses a modular software and hardware architecture.

- Each segment is self-contained and includes self-managed battery power, and actuator control using a low-cost microcontroller.
- Communications and power transfer between segments is through Ethernet and ZeroMQ messaging.
- The head segment contains a powerful Xilinx Zynq SoC that serves as a master control node, communications router, and FPGA-accelerated vision platform
- An acoustic rangefinder adds obstacle and target ranging to monocular vision.
- An acoustic modem provides low-rate communications at medium range for remote control, telemetry, and inter-vehicle coordination.

EC-OG Halo Energy Gateway



Wind Farm



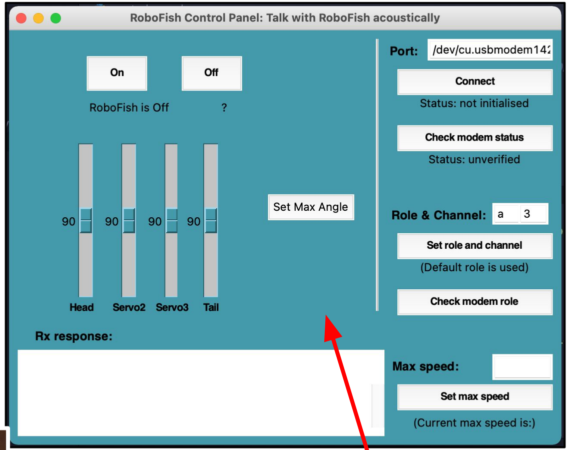
CFD/FSI model of bio-inspired robotic fish created in the project

Hydrodynamic Control is accomplished through control derived from CFD/FSI study of swimming movement.

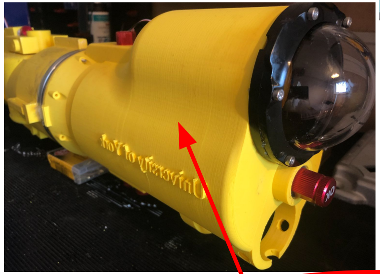
- Various swimming gaits are possible
- High agility, mitigates risk of fouling
- High efficiency in placement of the head can be achieved for docking

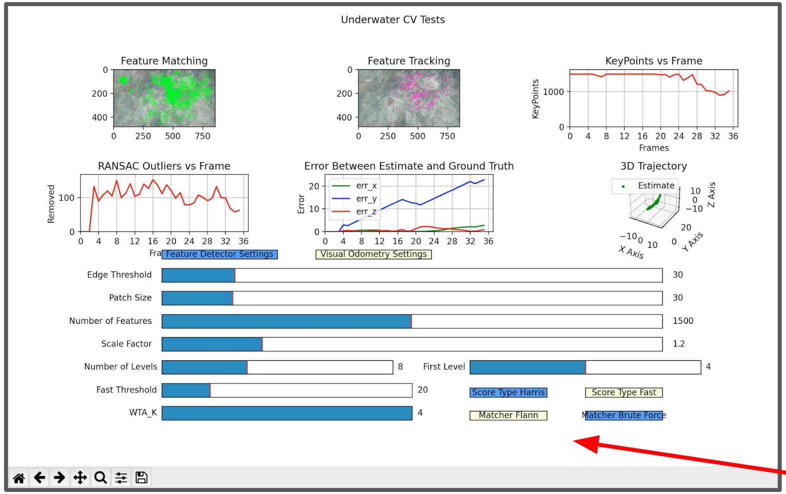
Acoustic Communication & Computer Vision

- The RoboFish-specific powerful Xilinx Zynq SoC is designed to serve as a master control node, communications router, and FPGA-accelerated vision platform and convert various range of DC voltages to the modems, rangefinder and camera..
- A half-duplex 64bps acoustic modem, called M64, provides low-rate communications at medium range for remote control, telemetry, and inter-vehicle coordination. A working Python GUI has been developed to run the RoboFish manually from a distance over the acoustic link. The modem has a configurable data link and can be used to implement other MAC protocols.
- Another working Python GUI, running a computer vision algorithm based on pattern recognition has been created. It trains a computer on a massive amount of visual data, labels objects on them, and finds patterns in those objects.

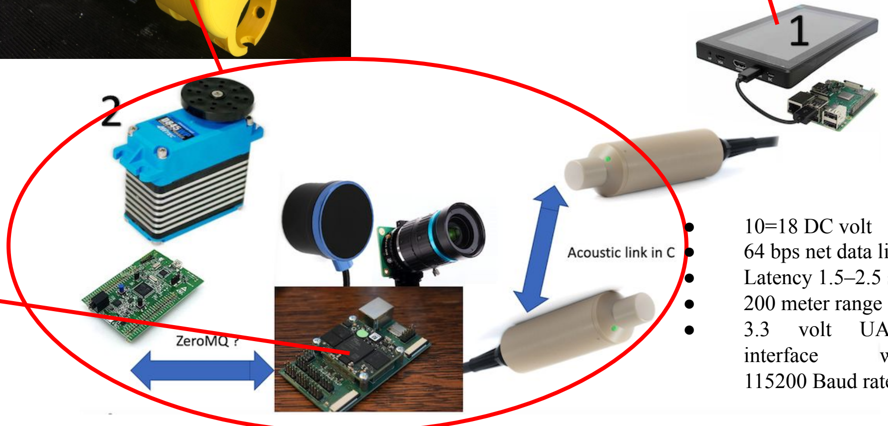


GUI to acoustic modem interface for manual remote control





Testing an accelerated visual perception for underwater environments (YORK_UNI_DATASET)

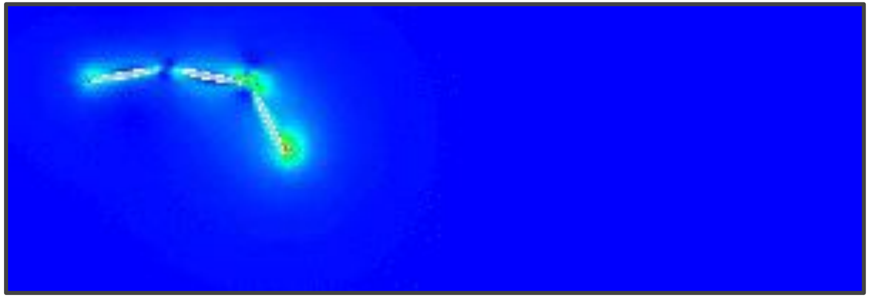


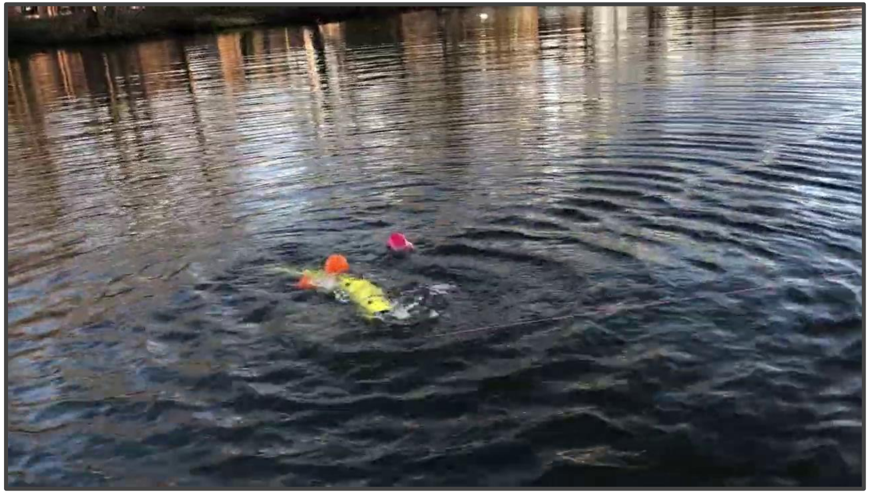
- 10=18 DC volt
- 64 bps net data link
- Latency 1.5–2.5 sec
- 200 meter range
- 3.3 volt UART interface with 115200 Baud rate

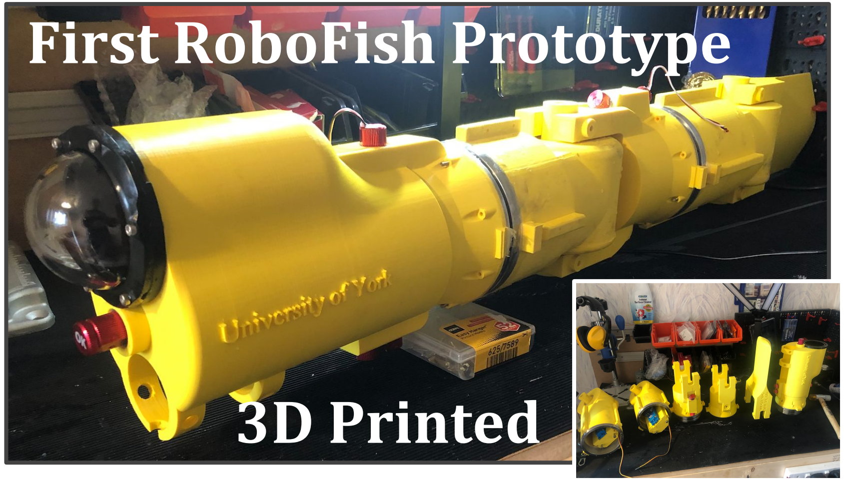
Initial Lake tests proved water-tightness, joint functionality and body propulsion. Acoustic communication and rangefinding worked successfully in a tank. FPGA-accelerated visual software & hardware, and the rest of electronic system have all been designed & put together ready for field tests.

Future: The use of modular electronics & actuation, networking architecture, 3D printing approach, and most of all the magnetic joint design are novel contributions to the state of the art that will enable new opportunities and future research projects.

New versions of a smaller size RoboFish, with particular focus on modularity, provide a flexible platform for numerical data validation & experimental investigation within a towing tank, providing further insight to disseminate the hydrodynamic performance under different flow conditions, to especially support the targeted underwater docking.







Initial functionality trial at Uni of York lake; body is watertight & actuating with slow propulsion

RoboFish Impact

RoboFish established itself as a vibrant, dynamic, manufacturing collaborative endeavour, and is already delivering significant benefits that represent just a fraction of its long-term potential. It has brought together leading university researchers, technological companies and future-focused businesses, and generated further fundings, contributions to knowledge & society.

Collaborations

- Several partners including University of York, University of Strathclyde, Supergen, PicSea, Catapult and EC-OG
- Partners are from both industrial and academi
- Collaborations with other researchers and PhD students from robotics, communication, hydrodynamic research groups

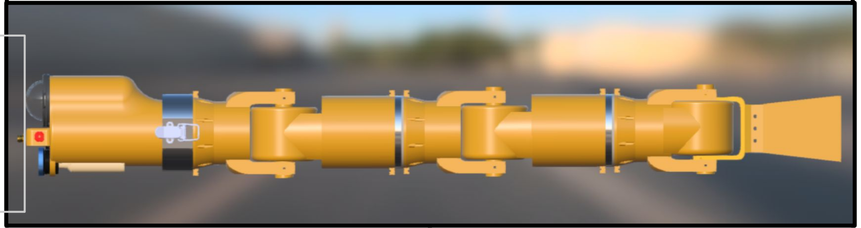
Contribution to knowledge

- Two conference papers were published
- Two journal papers are well underway
- An EPSRC Impact Case study was made
- An larger EPSRC industrial Impact Case study is underway
- Successful studentship projects completed
- RoboFish G drive research resource

To use with RoboFish

- Python/C
- Fusion360
- EAGLE/kicad
- STM32CubeIDE
- Circuit Design
- System Assembly

- Acoustic Communication
- Computer Vision
- Navigation
- Autonomy
- Control
- 3D printing
- Fluid dynamics



Further funding

- White Rose Collaboration Fund of £11,000
- EPSRC IAA fund application has been made
- The eventful consortium Skype channel has created a think tank that has suggested numerous useful ideas that helped some of our partners in securing further funding.

Contribution to Society

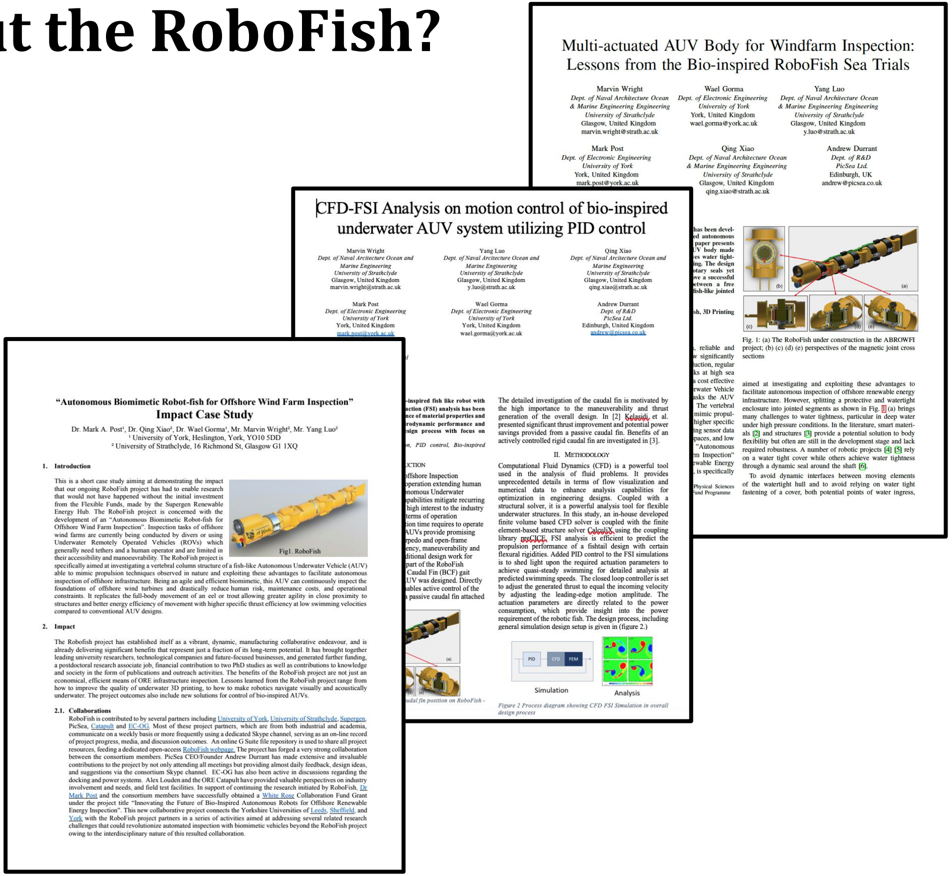
- Financial contribution to RA role
- Financial contribution to PhD studies
- Financial contribution to RA role
- RoboFish webpage
- outreach lectures
- group seminar

Opportunities

- Innovative mechanical & Electronic designs are novel contributions to the state of the art that will enable new opportunities
- Potential future versions of a smaller size RoboFish, with particular focus on the modularity providing a flexible platform for experimental investigations within a towing tank

Where can I know more about the RoboFish?

- RoboFish WebPage
- IEEE AUV 2020 RoboFish Paper 1
- IEEE AUV 2020 RoboFish Paper 2
- Impact Case Study
- ..

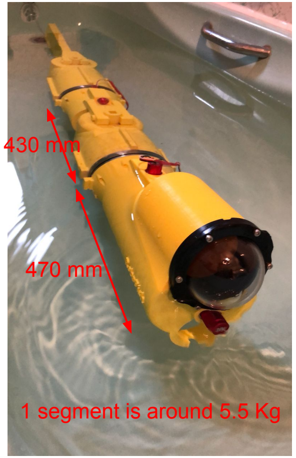


Thank You

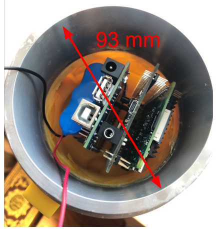
Mark Post
mark.post@york.ac.uk

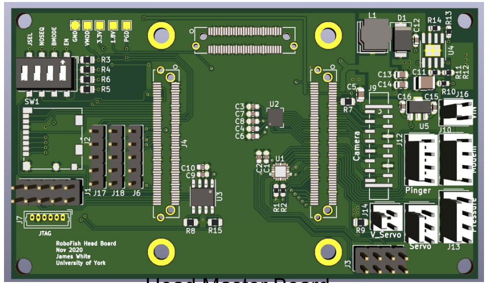
Wael Gorma
wael.gorma@york.ac.uk

Technical Information (Optional)




Echosounder



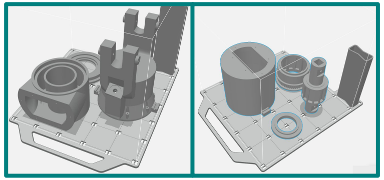


Head Master Board

TABLE II: List of the 3D printer parameters

Parameter	Value	Comment
Layer height	0.254 mm	Standard
extrusion width	0.5mm	Standard
Wall thickness	2.032 mm	To print more perimeters per layer
Solid infill	Enabled	To help preventing water ingress
Variable width fill	Enabled	To fill any small gaps
Room temperature	25°	Enclosure

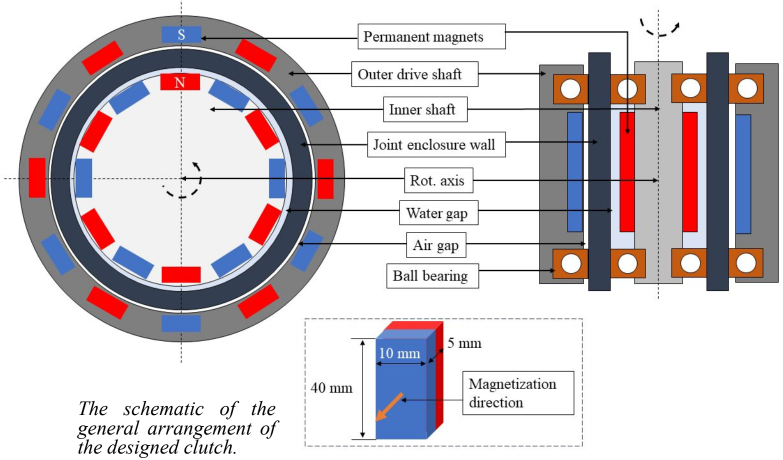
3D Printing



Sanding

Acetone treatment

Water-tightness test



The schematic of the general arrangement of the designed clutch.

*The tested joint uses 12 magnetic blocks of (40 mm * 10 mm * 5 mm) on the outer shaft and an equal number on the inner shaft of grade N42. With a 100 mm lever, the magnetic coupling appears to break at around 10 Kg load.*