On-line workshop:

‘La robotica ispettiva, di intervento e di monitoraggio per operazioni subacquee’

21 Febbraio 2022

Traiettoria 4 – Cantieristica e robotica marina

Ricerca in Robotica Marina presso l'Università di Firenze

Benedetto Allotta, ISME - UNIFI

On-line workshop, 21 Febbraio 2022

Summary of the presentation

- Ongoing funded projects
- Development of marine robotic assets
- Manipulation and intervention
- Autonomous inspection and perception
- Reconfigurable Underwater Vehicle

Summary of the presentation

- Ongoing funded projects
- Development of marine robotic assets
- Manipulation and intervention
- Autonomous inspection and perception
- Reconfigurable Underwater Vehicle

Ongoing funded projects @ISME-UNIFI

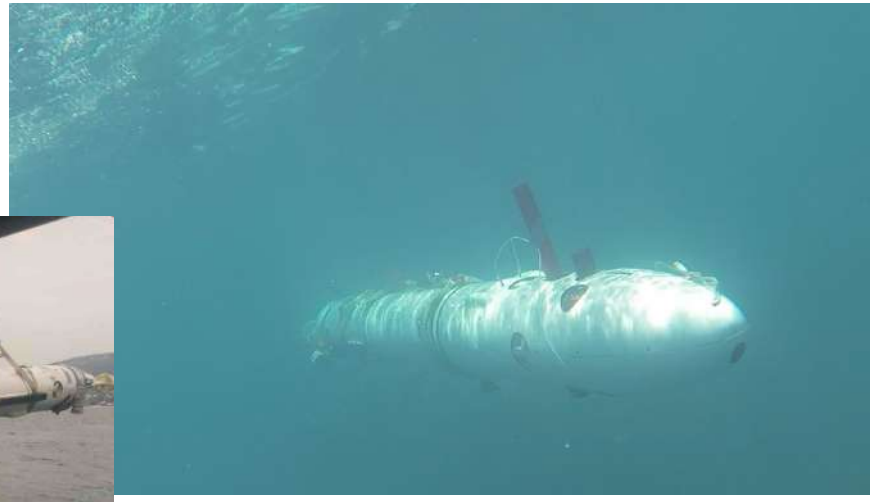
- **PASSport 2020-2023 (EU):** semi-autonomous aerial and underwater drones with high GNSS accuracy and autentication to improve Security and Safety in port areas
- **DAMPS 2020-2024 (PNRM):** passive distributed adaptive sonar system composed by a team of autonomous underwater vehicles with passive directive sensors
- **BOOMER 2020-2022 (PNRM):** acoustic measurements in challenging underwater environment through the employment of a fleet of autonomous underwater vehicles and autonomous surface vessel
- **SUONO 2014-2022 (MUR – Smart Cities)**: Hybrid Underwater Vehicle (HUV) with autonomous intervention capabilities
- **RUVIFIST 2021-2022 (MISE – POC):** Reconfigurable Underwater Vehicle for Inspection, Free-floating Intervention, and Survey Tasks
- **RECON–UV 2022-2025 (PNRM):** Support for underwater reconnaissance operations in shallow water through AUVs

Summary of the presentation

- Ongoing funded projects
- Development of marine robotic assets
- Manipulation and intervention
- Autonomous inspection and perception
- Reconfigurable Underwater Vehicle

AUV Development and operations

- Typhoon-class AUV
  - Vehicle design
  - GNC development
  - ROS-based software architecture
  - Optical and acoustical acquisitions
  - Underwater 2D mosaicing and 3D reconstructions
  - Target detection (Archaeology and MC



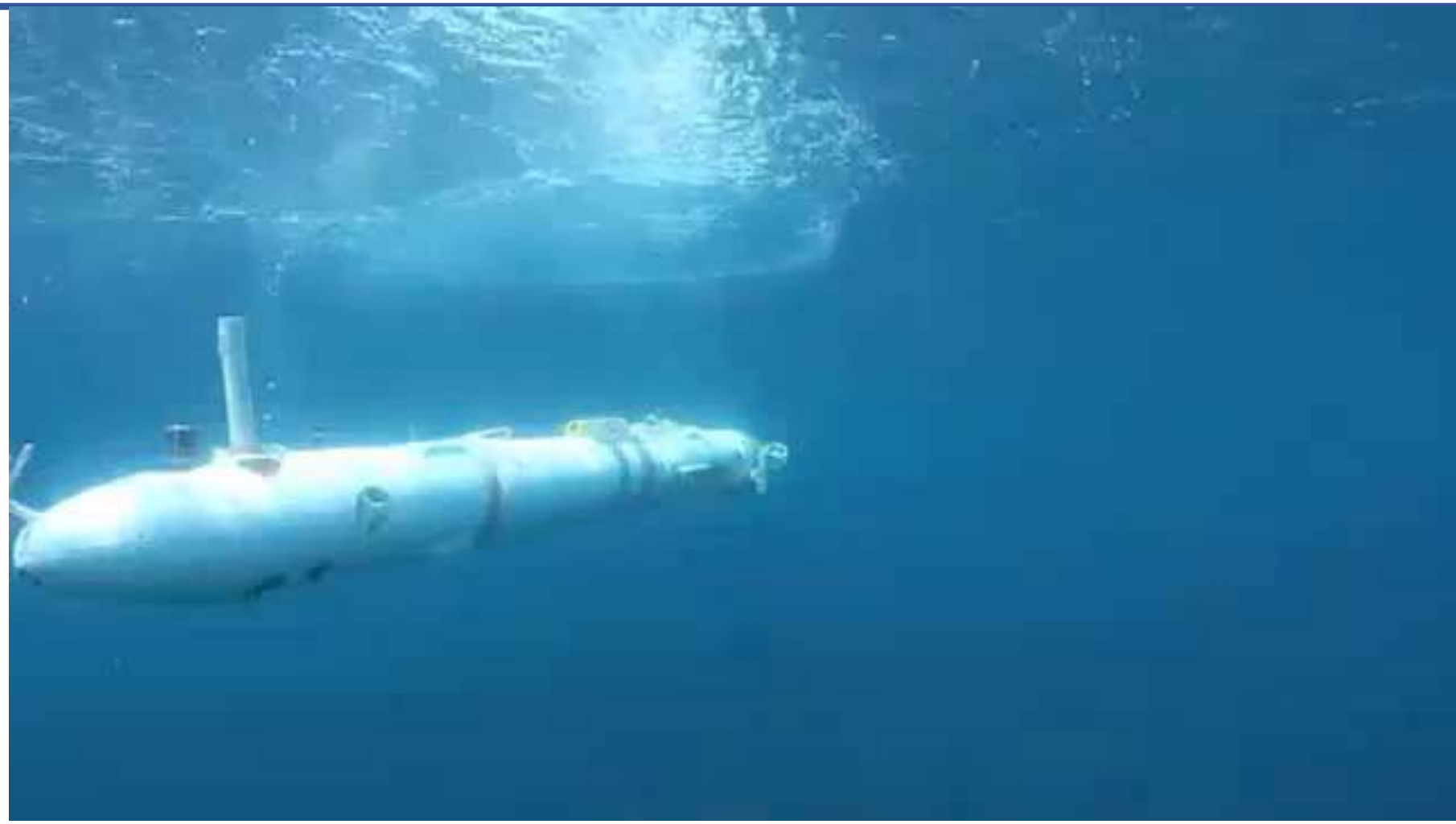
Contacts in Florence (University of Florence – ISME node):
Benedetto Allotta and Alessandro Ridolfi

ISME Partners

ISME
Integrated Systems for Marine Environment

BiG
Blue Italian Growth
Technology Cluster

AUV Development and operations



UNIVERSITÀ DEGLI STUDI FIRENZE
DIEF
DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

REGIONE TOSCANA

THESAURUS

AUV Development and operations

- MARTA and FeelHippo AUVs
  - Optical and acoustical payloads
  - HMI for multi-vehicle management
  - Mechanical and electrical modular archit
  - Mobile bridge for multi-vendor acoustic
  - Low-cost technologies to be used in diffe

fields, e.g. archaeology or geomorphology, biology,
environmental assessment

ISME Partners

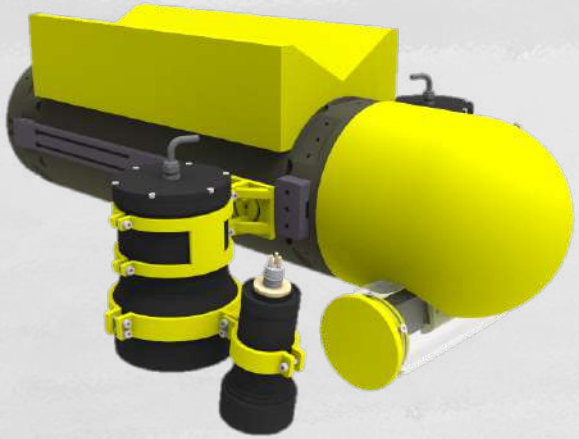
ZENO AUV

- ZENO AUV, jointly developed by UNIFI and MDM Team SRL, an official Spin-Off company of UNIFI
- Two-person portable, Reasonable cost, high performance
- Full hovering and Isotropy (capability to counteract lateral currents)
- 24/7 operation possible thanks to the quick battery release system
- User-friendly graphical user interface
- Integrated into the ARCHEOSUb network infrastructure
- Raw camera and sonar data available in real time in shallow water
- Cable-less ROV mode in shallow water

ISME Partners

ZENO AUV

NAVIGATION: VISUAL INERTIAL ODOMETRY

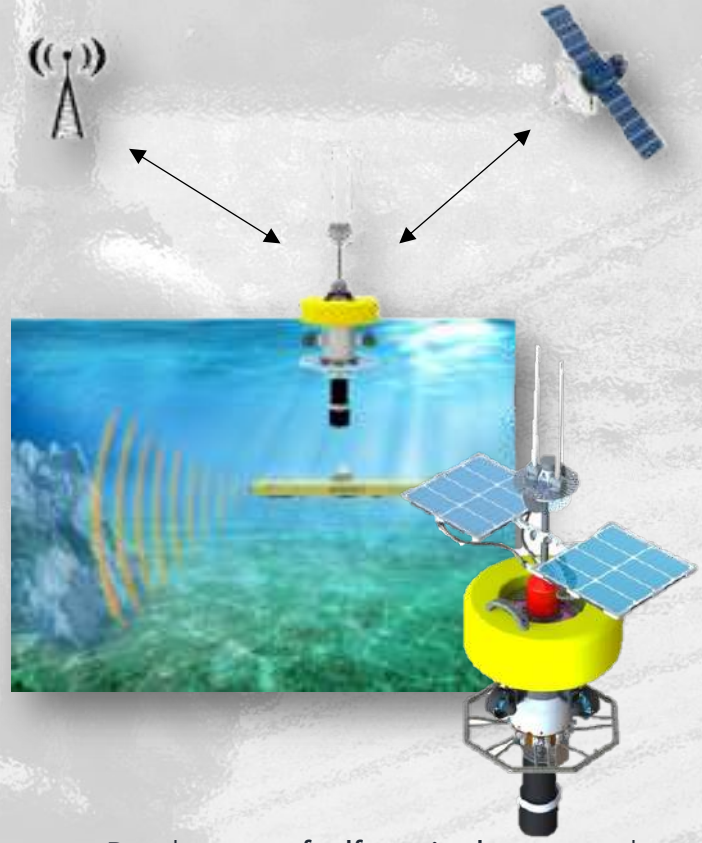


Development of a stand-alone module for **visual-inertial odometry** for AUVs

Camera SONY FCB-ER8550

IMU Advanced Navigation Orientus

2 Mono Cameras
Stereo Camera
IMU
Altimeter
Depth Sensor

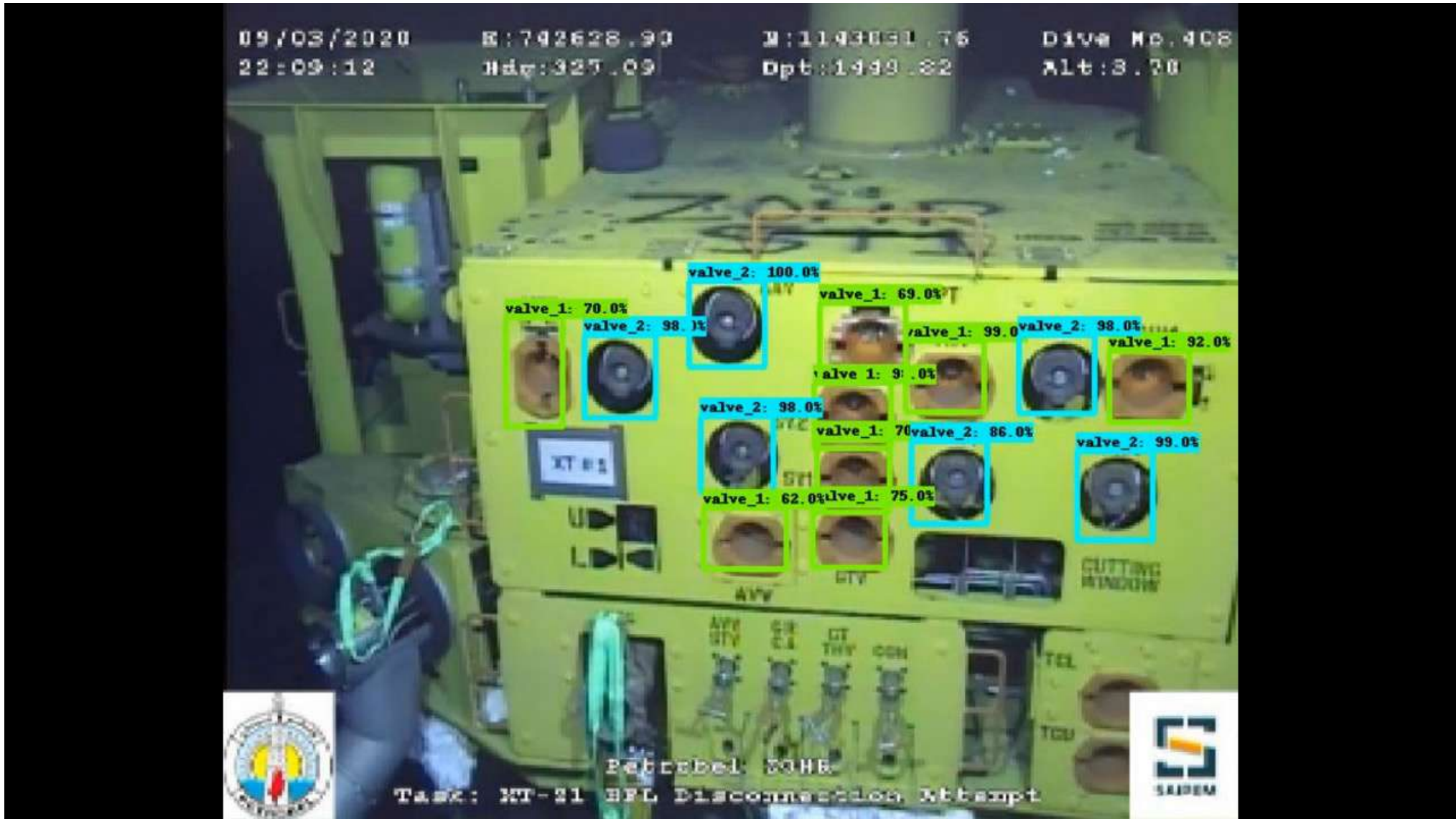


Development **of self-moving buoy** as a relay node for upwater-underwater transmission

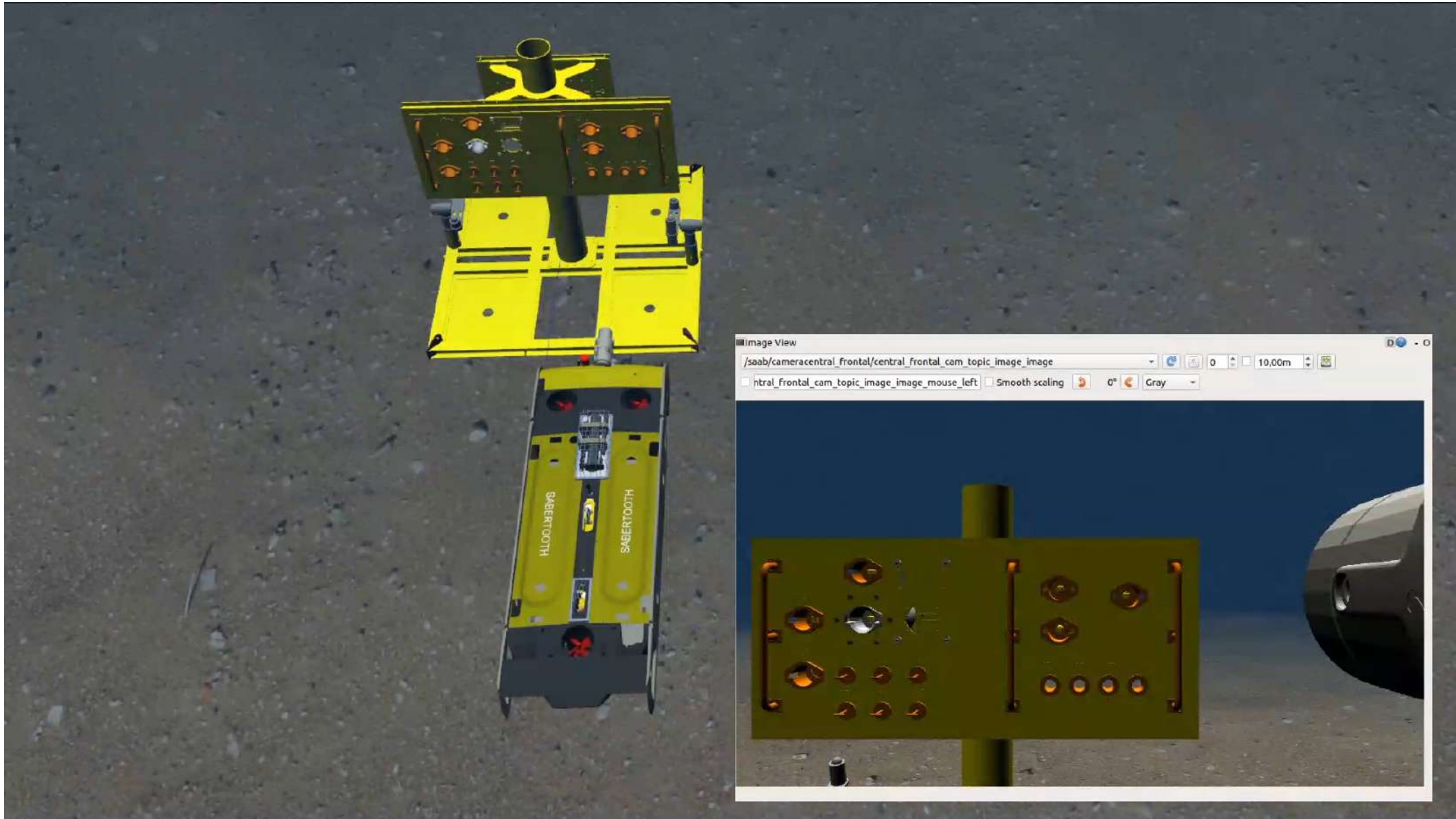
Summary of the presentation

- Ongoing funded projects
- Development of marine robotic assets
- Manipulation and intervention
- Autonomous inspection and perception
- Reconfigurable Underwater Vehicle

ATR: automatic target recognition



autonomous visual-guided intervention



OVERALL FRAMEWORK

HUV design and manufacturing

Manipulation and intervention

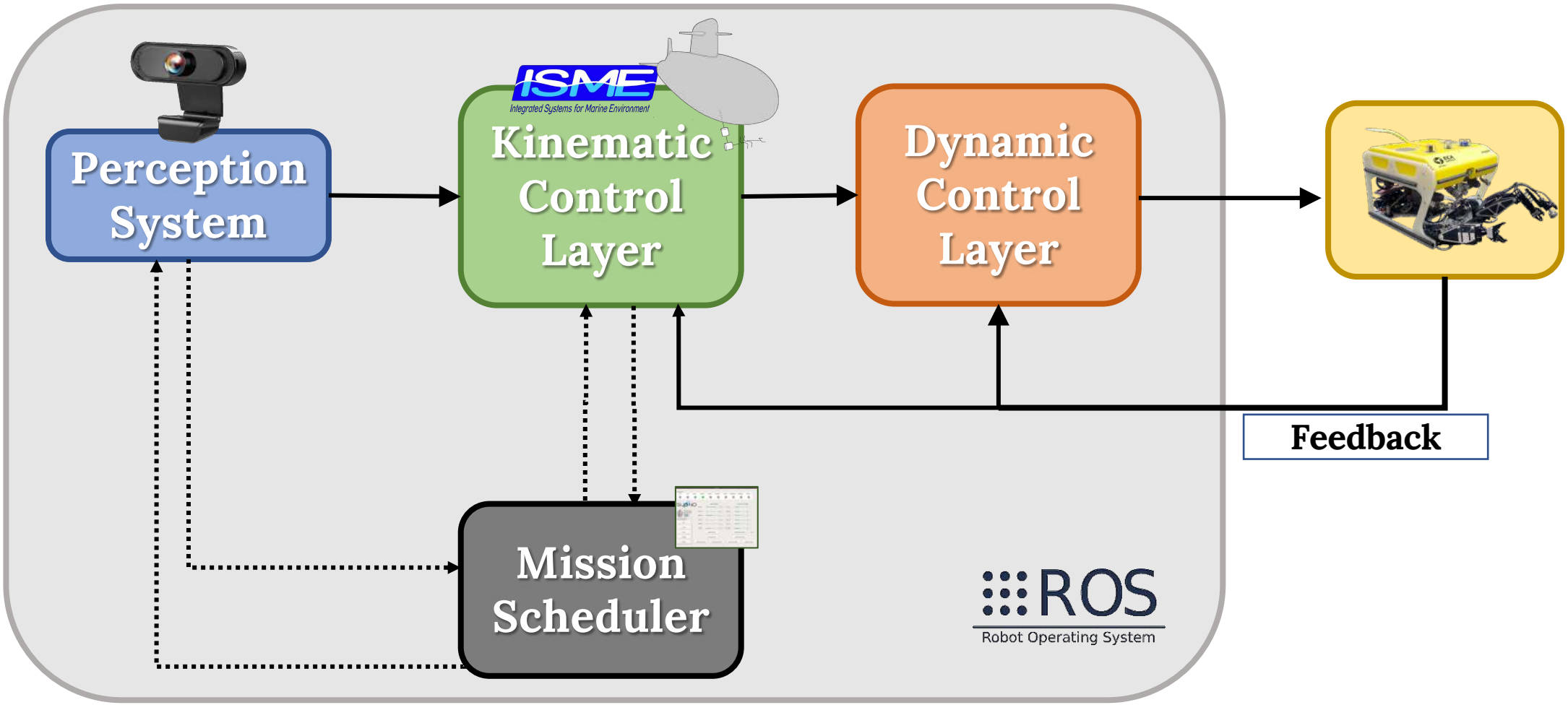
Ministero dell' Istruzione, dell'Università e della Ricerca

MIUR

Safe Underwater Operations iN Oceans (SUONO)

Advanced Underwater Manipulation Systems: an Overview of the SUONO Project

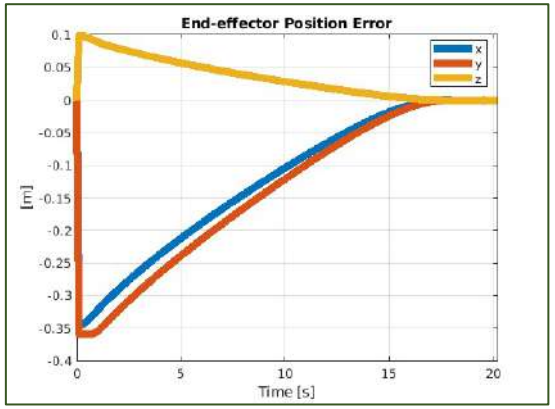
THE SUONO ARCHITECTURE

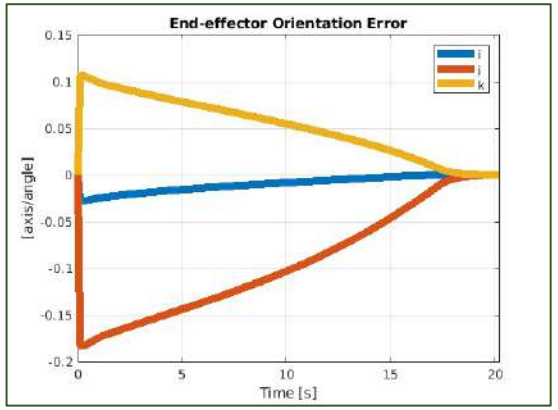


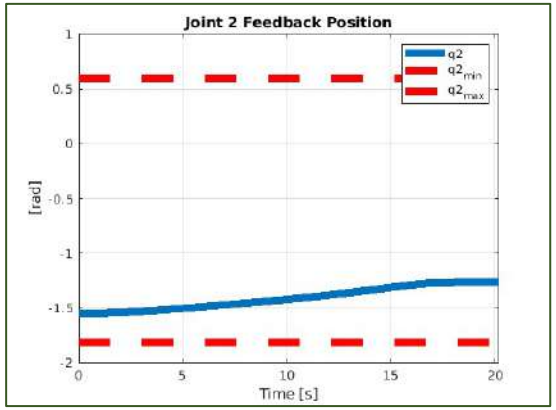
UNIVERSITÀ DEGLI STUDI FIRENZE
DIEF DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

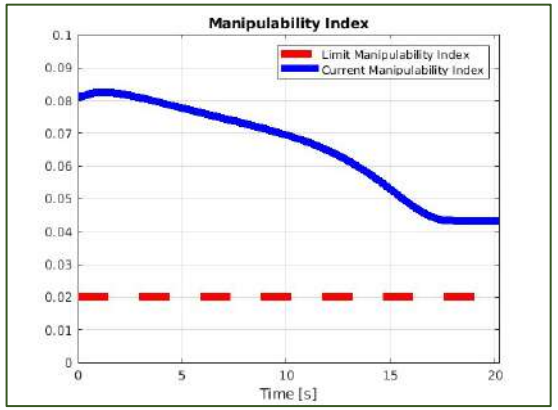
SUONO

PRELIMINARY EXPERIMENTS





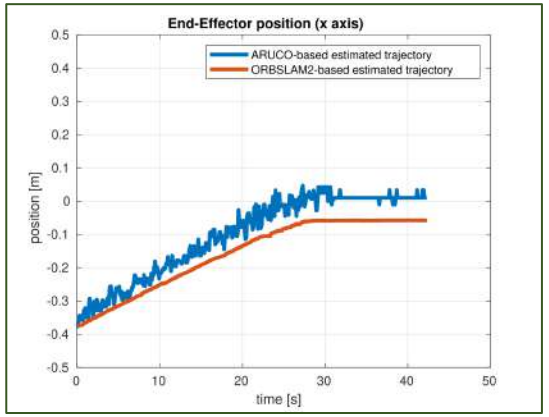


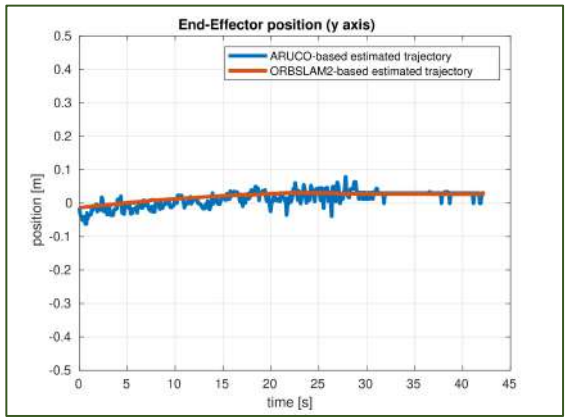


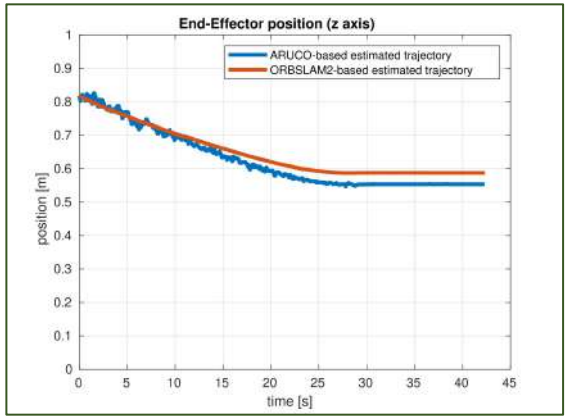
UNIVERSITÀ DEGLI STUDI FIRENZE
DIEF DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

SUONO

PRELIMINARY EXPERIMENTS



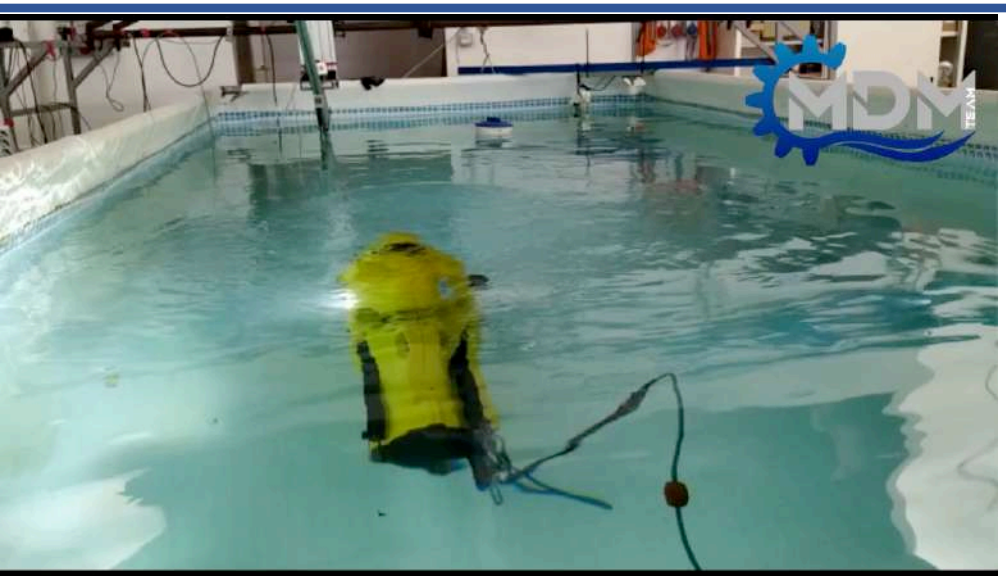


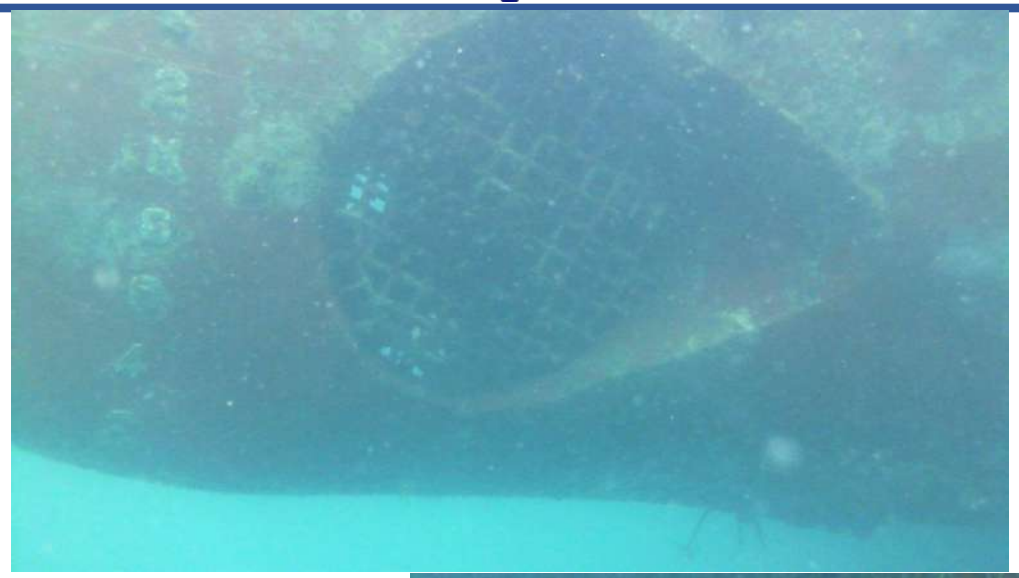


Summary of the presentation

- Ongoing funded projects
- Development of marine robotic assets
- Manipulation and intervention
- Autonomous inspection and perception
- Reconfigurable Underwater Vehicle

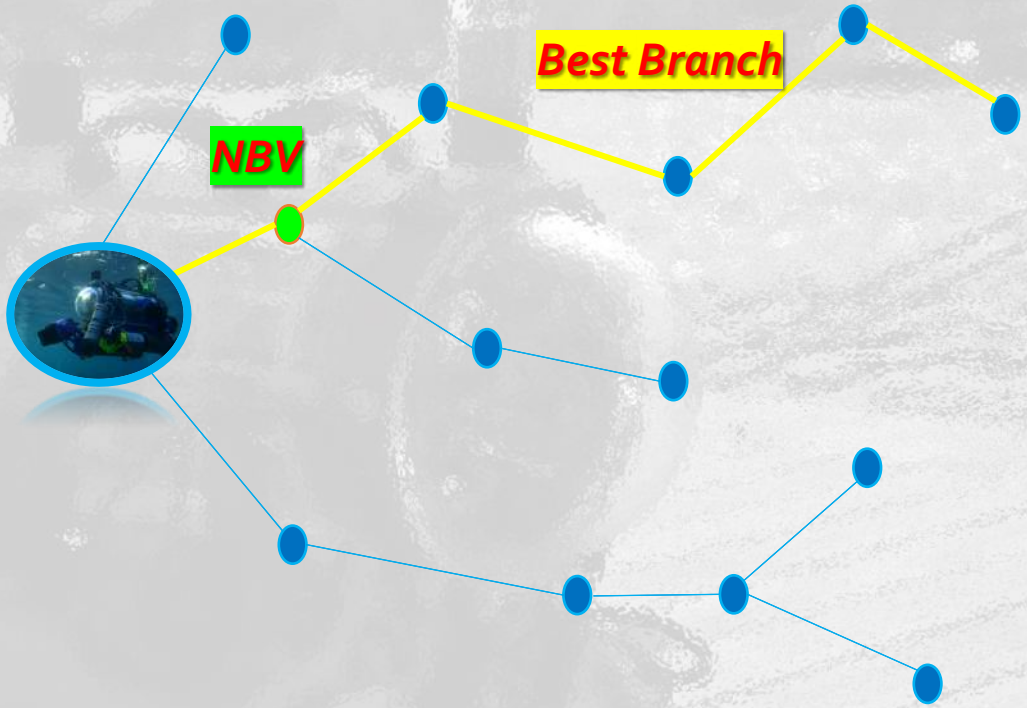
ZENO AUV





MOTION PLANNING: AUTONOMOUS INSPECTION

- **Sensor-driven methodology** for autonomous inspections that transform the AUV into an active acquisition system (i.e., the AUV is aware of acquired data)
- Viewpoints are generated as nodes in random **trees** that are grown in an RRT fashion to exploit its Voronoi-biased exploration
- **Next-Best Viewpoint** (NBV) is selected as the first node of the best tree branch, i.e., the branch expected to collect more new data. The **last best branch** is stored and used to initialize the new tree realizing a **Receding-Horizon Coverage Approach** (RHCA)
- **Dubins kinematic constraints** to grow feasible trees
- Solution suitable for any exteroceptive sensor

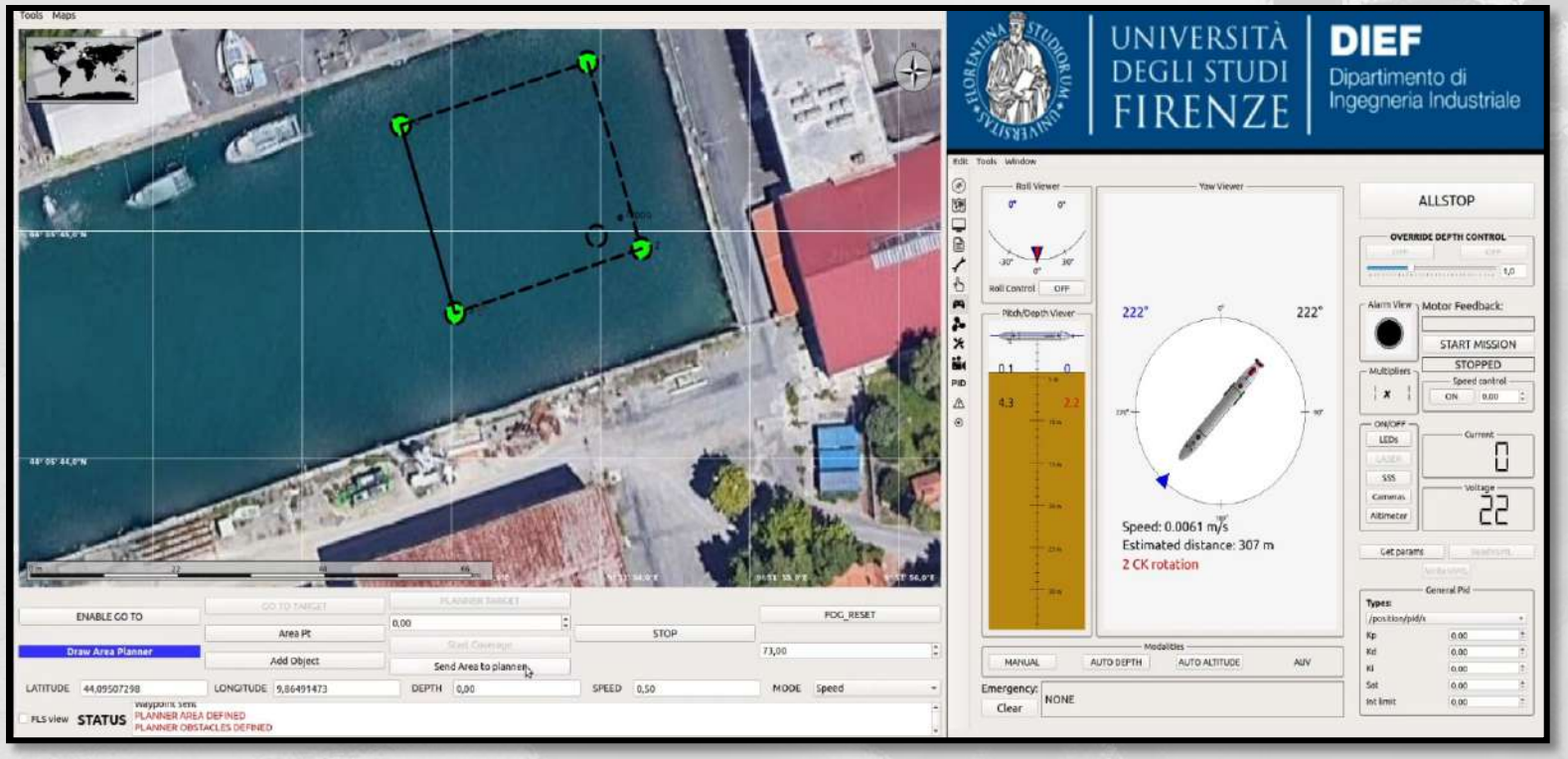


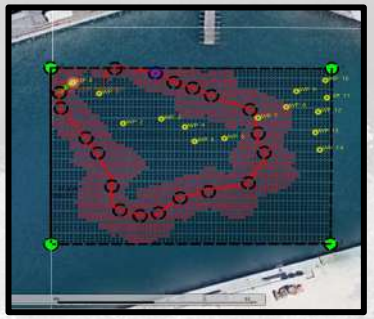
Zacchini, L., Ridolfi, A., & Allotta, B. Receding-horizon sampling-based sensor-driven coverage planning strategy for AUV seabed inspections. In 2020 IEEE/OES Autonomous Underwater Vehicles Symposium (AUV) (pp. 1-6)

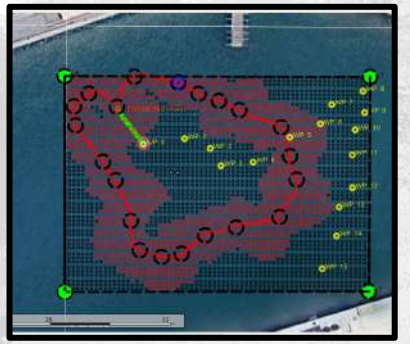
MOTION PLANNING: FLS SEABED INSPECTIONS

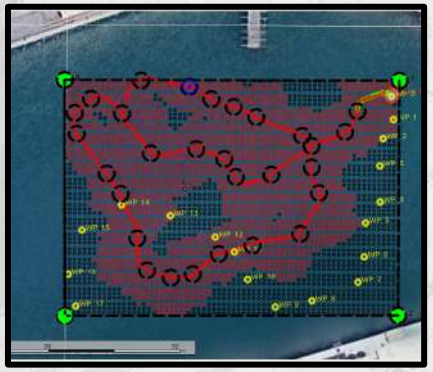
The AUV **actively considers** the acquired data and **adapts** its mission

The RHCA guarantees **adequate coverage levels**









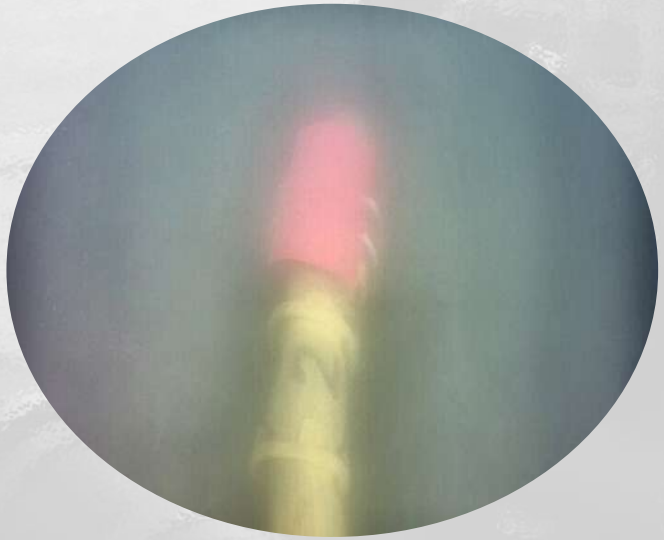
PERCEPTION: OPTICAL ATR

Optical images
acquired by means of a
Microsoft Lifecam
Cinema Camera

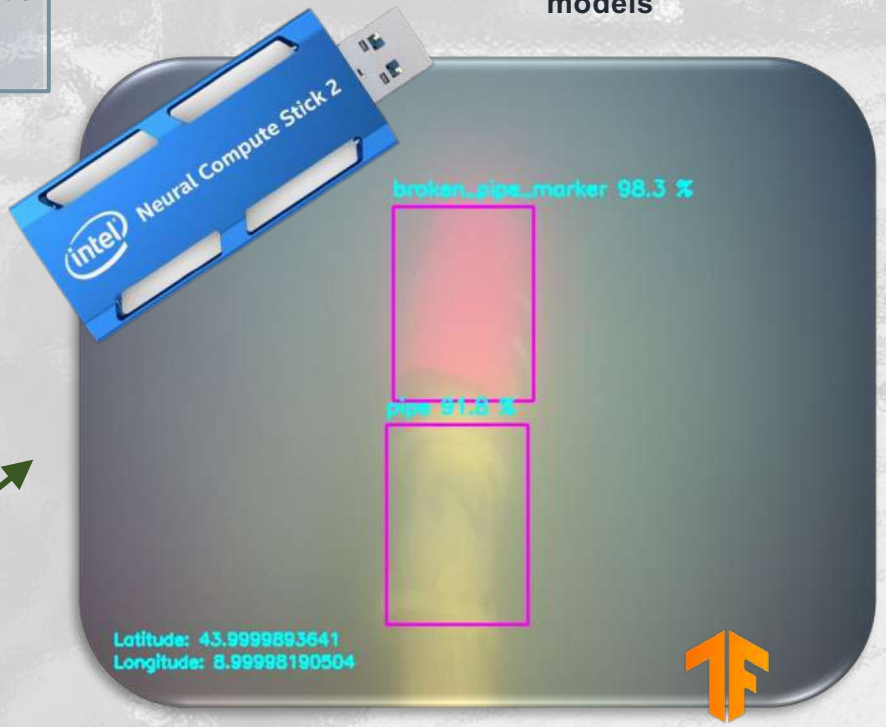
Zacchini et al., "AUV Deep Learning for on-board AUV Automatic Target Recognition for Optical and Acoustic imagery", IFAC World Congress 2020.

Targets detected with **CNN models**

MICROSOFT Lifecam Cinema camera



Optical images enhanced by using the **CLAHE algorithm**



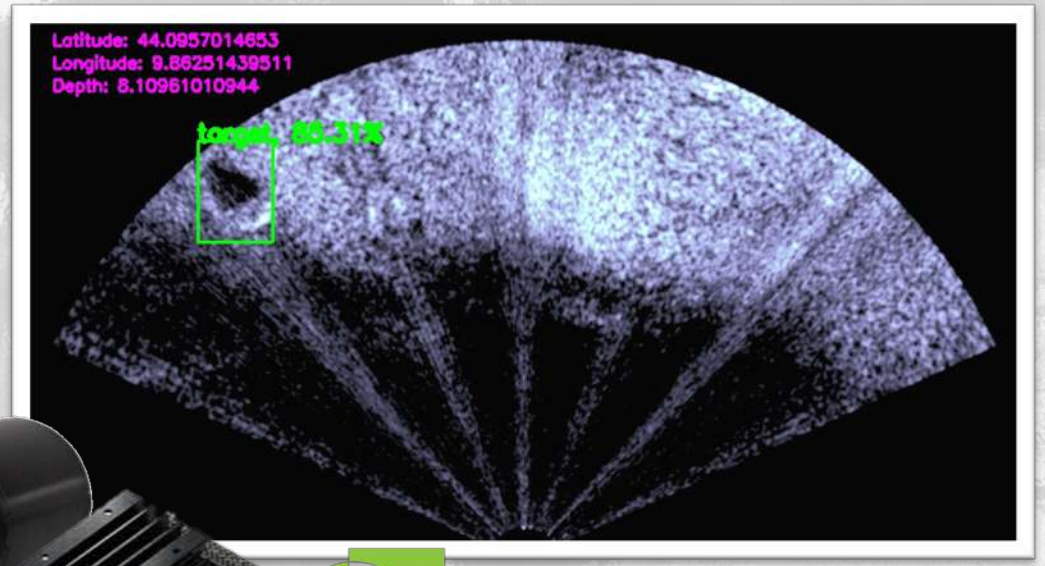
TensorFlow

PERCEPTION: ACOUSTIC ATR

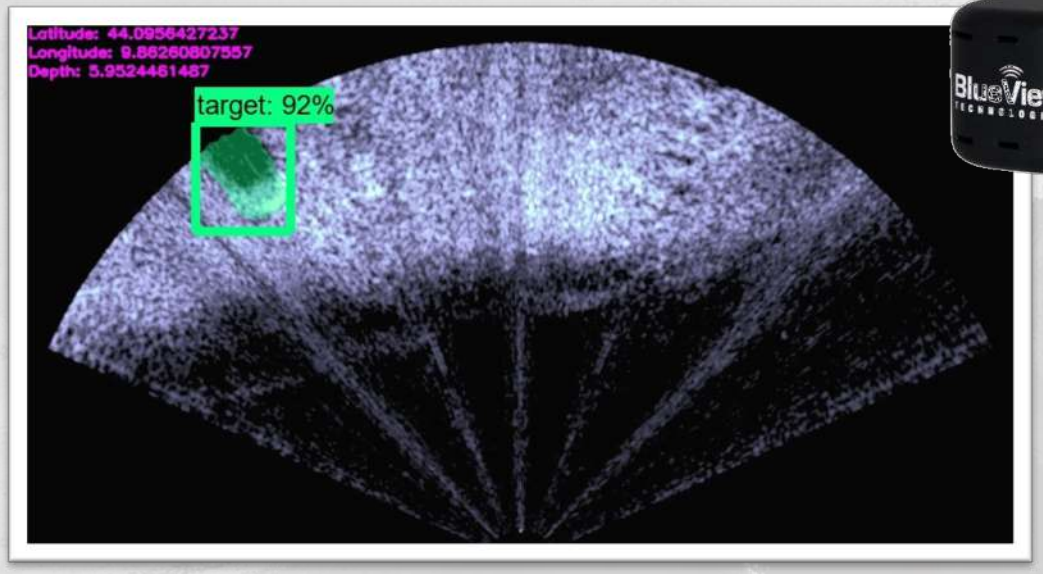
Design and development of an ATR **CNN-based architecture** to detect and gelolocalize potential targets of interest on **FLS imagery**

Test of CNN models (**MASK R-CNN**, **SSD**) on embedded hardware to achieve an optimal tradeoff between classification performance and required computational cost

SSD



MASK R-CNN

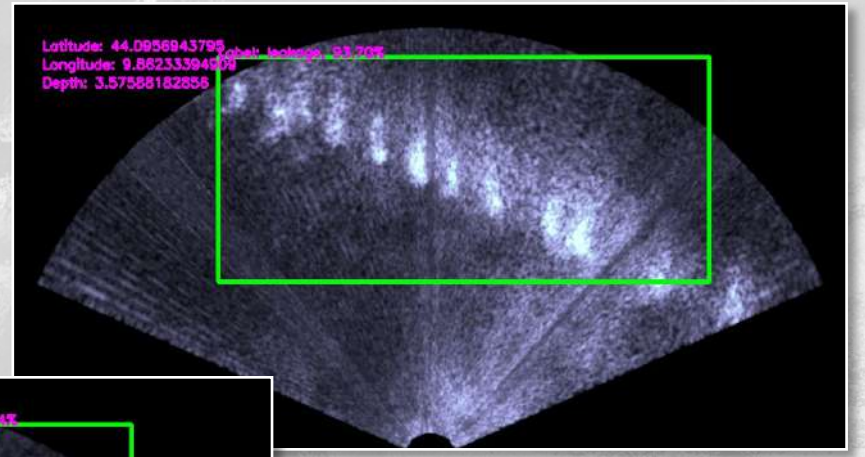


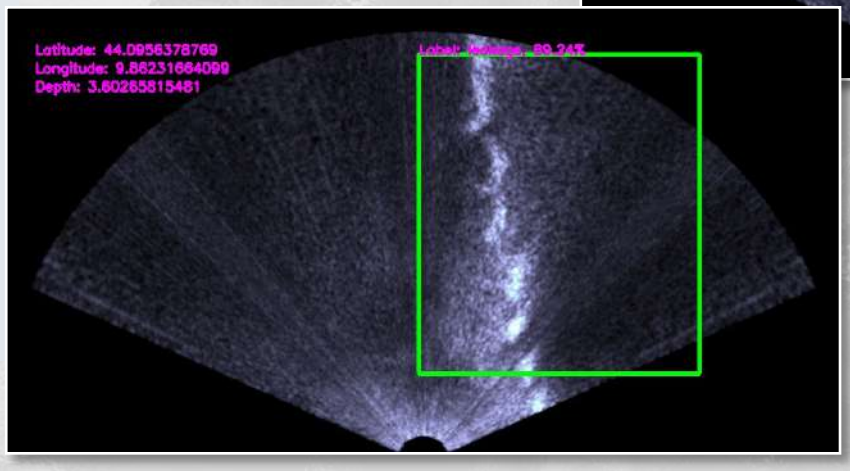
NVIDIA.

TensorFlow

Zacchini et al., "AUV Deep Learning for on-board AUV Automatic Target Recognition for Optical and Acoustic imagery", IFAC World Congress 2020.

PERCEPTION: CO2 SEEPS DETECTION





Data collected during **tests** at Vulcano Island and La Spezia, Italy, in the framework of the EUMarineRobots H2020 project

Video of the **TNA LAUA** experiments

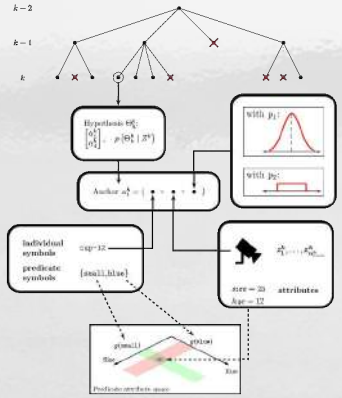
SSD Mobilenet

Running onboard on the Nvidia Jetson Nano @6-8 fps

FLS images provided by a Teledyne Blueview M900-130

PERCEPTION: ATR

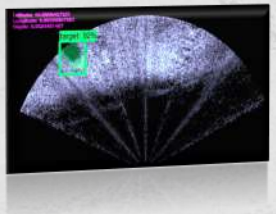
MULTI-VEHICLE TEST



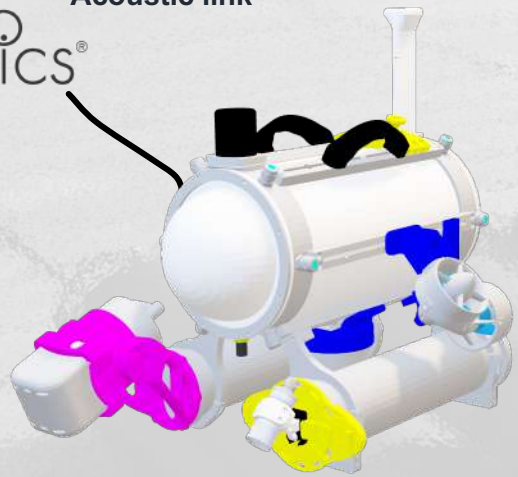
Data association with Probabilistic Multiple Hypothesis Anchoring

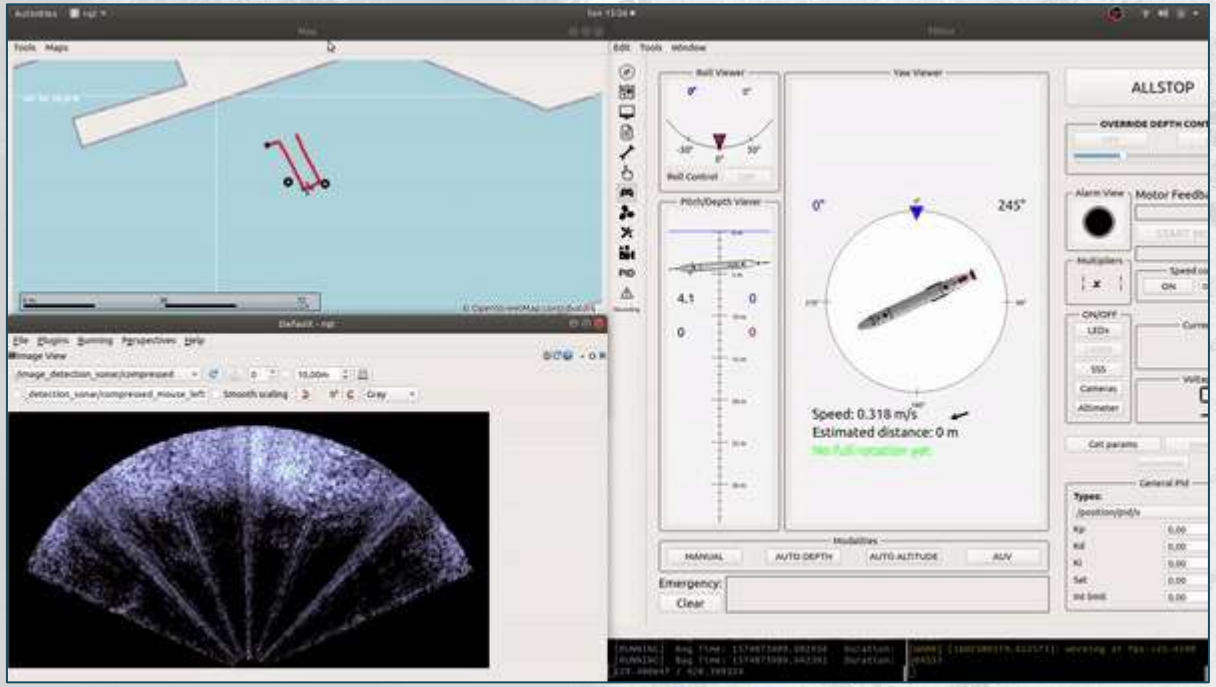
Zacchini et al., "Forward-Looking Sonar CNN-based Automatic Target Recognition: an experimental campaing with FeelHippo AUV", 2020 IEEE/OES Autonomous Underwater Vehicles Symposium (AUV).

Acoustic link



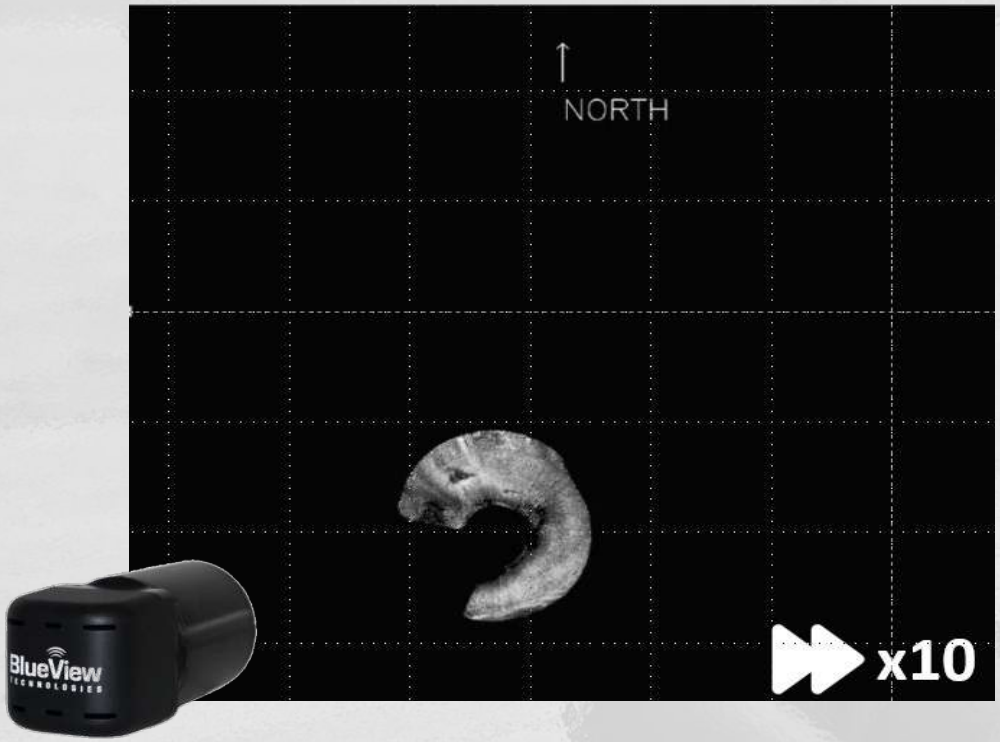
CNN-based real-time **onboard ATR**



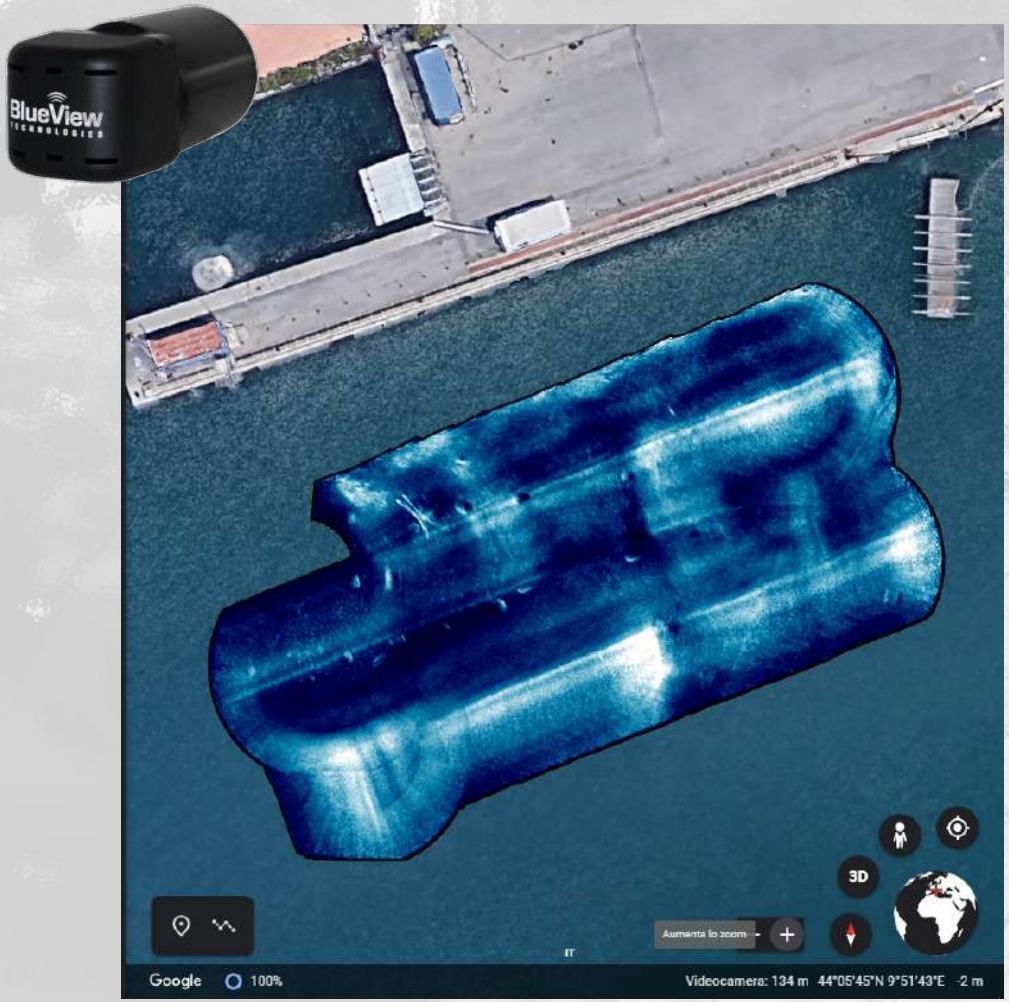


PERCEPTION: MOSAICING AND 3D RECONSTRUCTING

2D acoustic mosaicing of the sea bed making use of navigation data and images for stitching

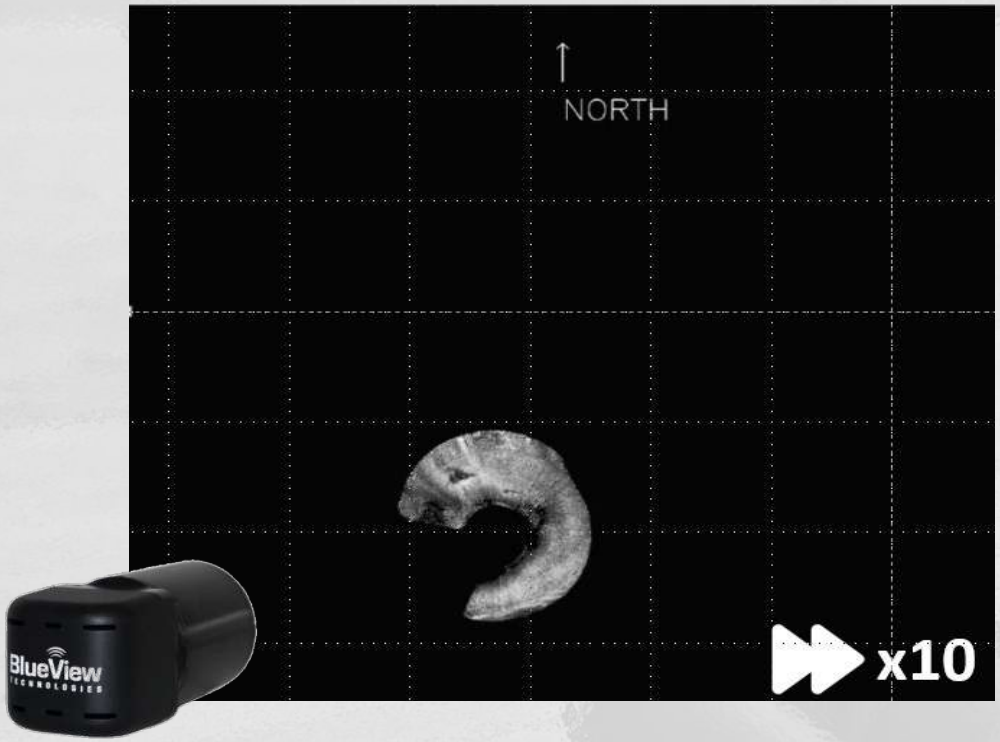


Franchi et al., "A forward-looking sonar-based system for underwater mosaicing and acousticodometry". In 2018 IEEE/OES Autonomous Underwater Vehicle workshop (AUV)(pp. 1–6).



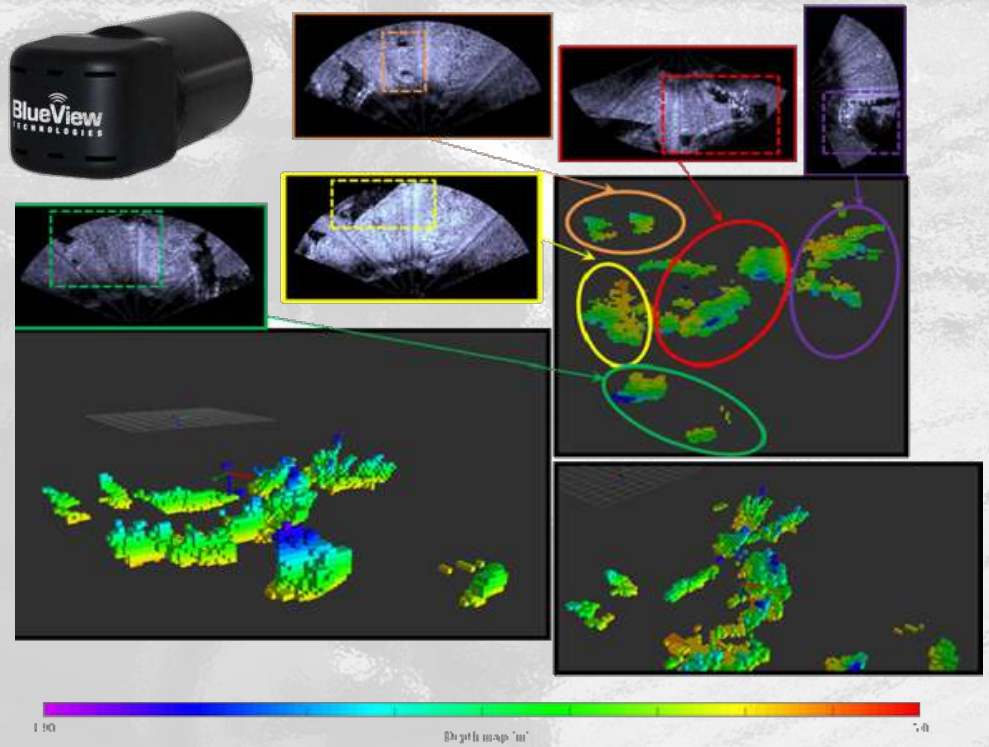
PERCEPTION: MOSAICING AND 3D RECONSTRUCTING

2D acoustic mosaicing of the sea bed making use of navigation data and images for stitching



Franchi et al., "A forward-looking sonar-based system for underwater mosaicing and acousticodometry". In 2018 IEEE/OES Autonomous Underwater Vehicle workshop (AUV)(pp. 1–6).

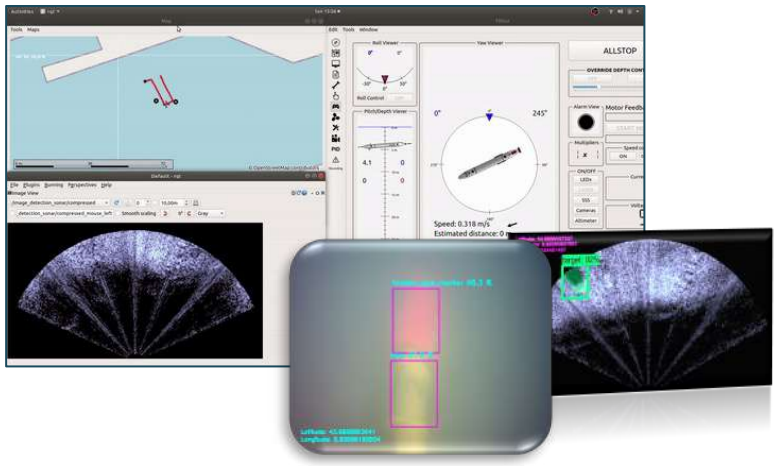
Franchi et al.,"A Probabilistic 3D Map Representation for Forward-Looking SONAR Reconstructions". 2020 IEEE/OES Autonomous Underwater Vehicles Symposium (AUV).



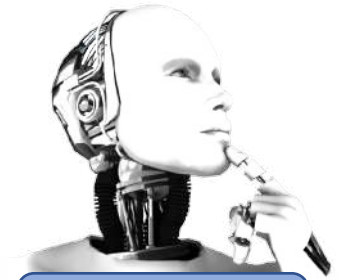
3D reconstruction intended as **3D occupancy grid mapping**. Ill-posed inverse problem due to elevation angle lost during 2D image formation, FLS images non-intuitive to interpret (blurry and noisy)

AUV TASK PLANNING

When the **world state changes**, replanning is requested online



The robot uses a **model of the world** to reason about possible courses of action



Planner

Executive

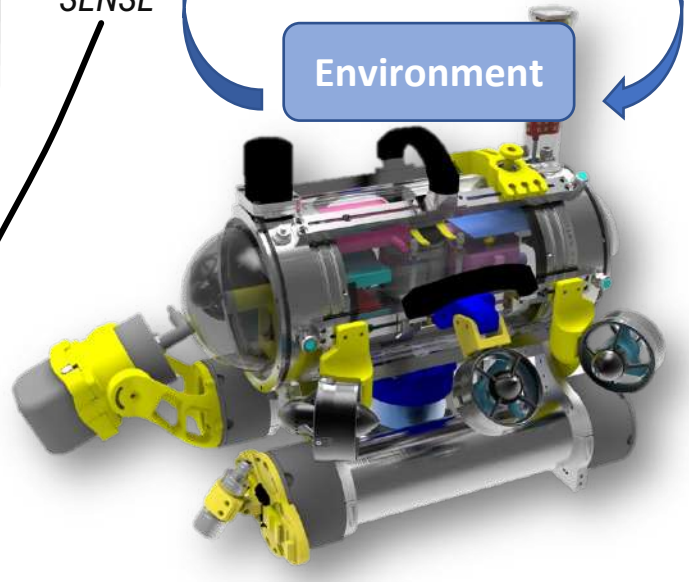
Environment

REPLAN

PLAN

SENSE

ACT

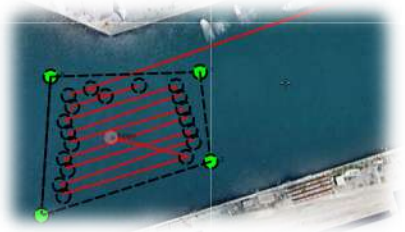


An **AI planner** (e.g., POPF) provides a plan (sequence of actions) to achieve the requested tasks (PDDL expressed)

```
(define (problem inspection)
(:domain hippo)
Show hierarchy
(:objects
    current_wp wp2 wp3 wp4 wp5 wp6 wp7 wp8 wp9 wp10 - waypoint
    wp1 - area_point
    area1 - area
    hippo - robot
    manta_mine spherical_mine - opi
```

```
0.000: (goto_area hippo current_wp wp1 area1)  [75.759]
75.760: (goto hippo wp1 wp2 area1)  [72.000]
75.760: (find_opi hippo area1 manta_mine)  [100.000]
75.760: (find_opi hippo area1 spherical_mine)  [100.000]
147.761: (goto hippo wp2 wp3 area1)  [6.000]
153.762: (goto hippo wp3 wp4 area1)  [78.000]
231.763: (goto hippo wp4 wp5 area1)  [6.000]
237.764: (goto hippo wp5 wp6 area1)  [72.000]
309.765: (goto hippo wp6 wp7 area1)  [6.000]
315.766: (goto hippo wp7 wp8 area1)  [72.000]
387.767: (goto hippo wp8 wp9 area1)  [6.000]
393.768: (goto hippo wp9 wp10 area1)  [72.000]
465.769: (inspect_opi hippo wp10 manta_mine)  [120.000]
```

The current action is translated into **lower-level navigation** and/or **perception commands**



Summary of the presentation

- Ongoing funded projects
- Development of marine robotic assets
- Manipulation and intervention
- Autonomous inspection and perception
- Reconfigurable Underwater Vehicle

State of the art and innovation needs (1)

- Torpedo-shaped vehicles (most of existing AUVs) and Stocky vehicles (existing ROVs) are at the opposite sides of the "Design Space";
- There is a need for vehicles which can effectively perform either surveys or close inspection and intervention.

State of the art in Reconfigurable Underwater Vehicles

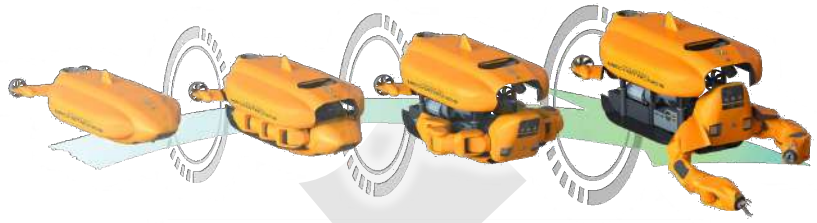
Eelume
SUBSEA INTERVENTION

Panel operations

Manipulation and intervention

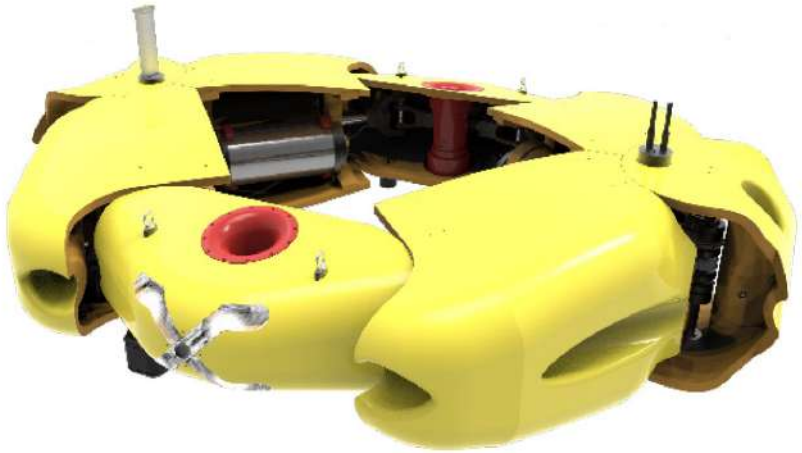
Pipeline Inspection and sea-bottom surveys

HOUSTON MECHATRONICS
KNOW WHAT'S POSSIBLE.



AUTONOMOUS UNDERWATER RECONFIGURABLE VEHICLE

Our Solution: RUVIFIST



The Mutant Drone modifies its shape and thruster positions according to the task to perform:

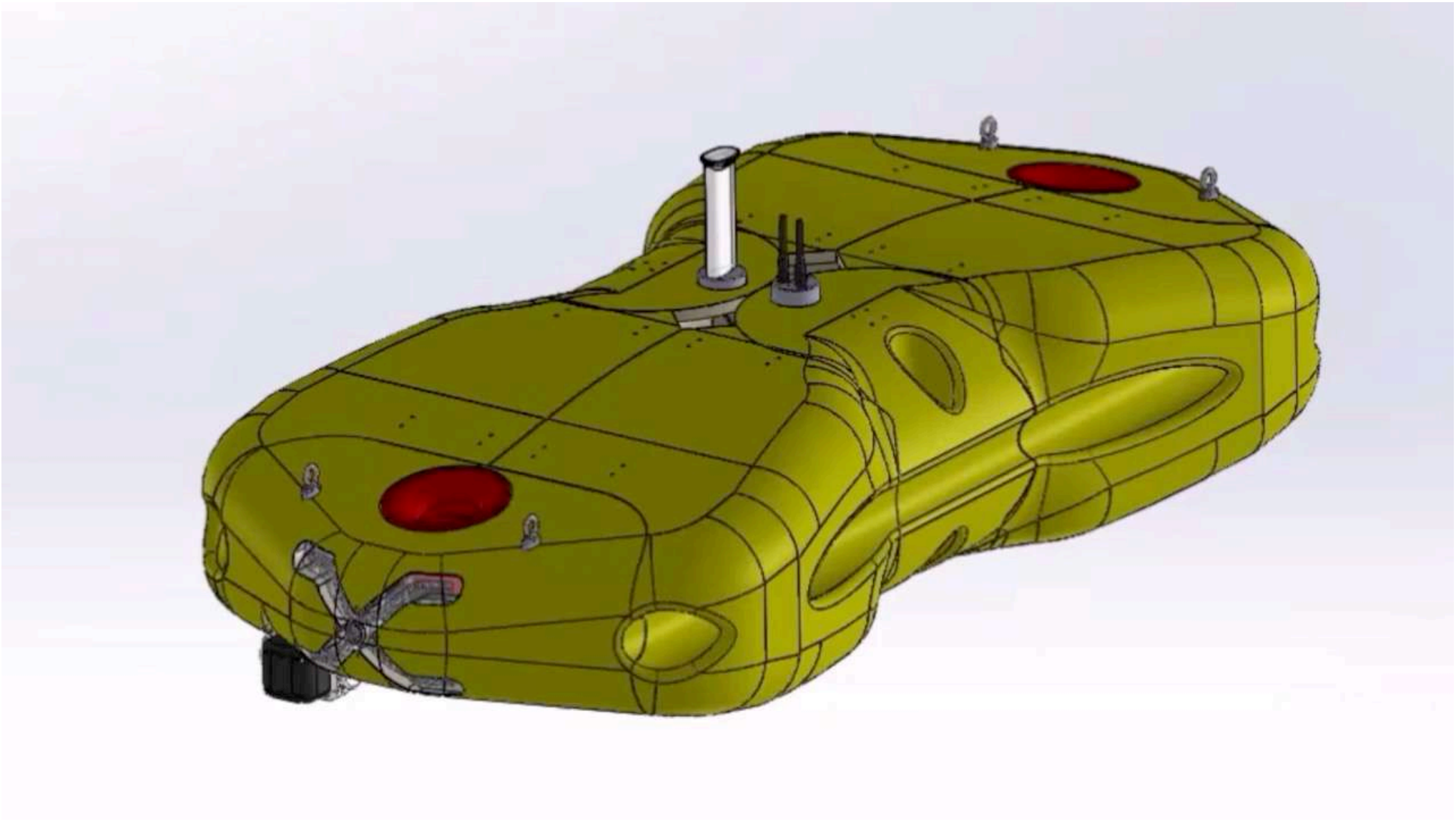
- To perform close inspection and intervention the shape is stocky and actuators are placed far from each other for best motion and thrust isotropy;
- To perform fast surveys on large tracks of seabed, the shape is changed into a slender, hydrodynamic one, and the 4 horizontal thruster are aligned with the surge axis.

ISME
Integrated Systems for Marine Environment

UNIVERSITÀ DEGLI STUDI FIRENZE

DIEF
DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

SUONO



ISME
Integrated Systems for Marine Environment

UNIVERSITÀ DEGLI STUDI FIRENZE
DIEF
DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

SUONO

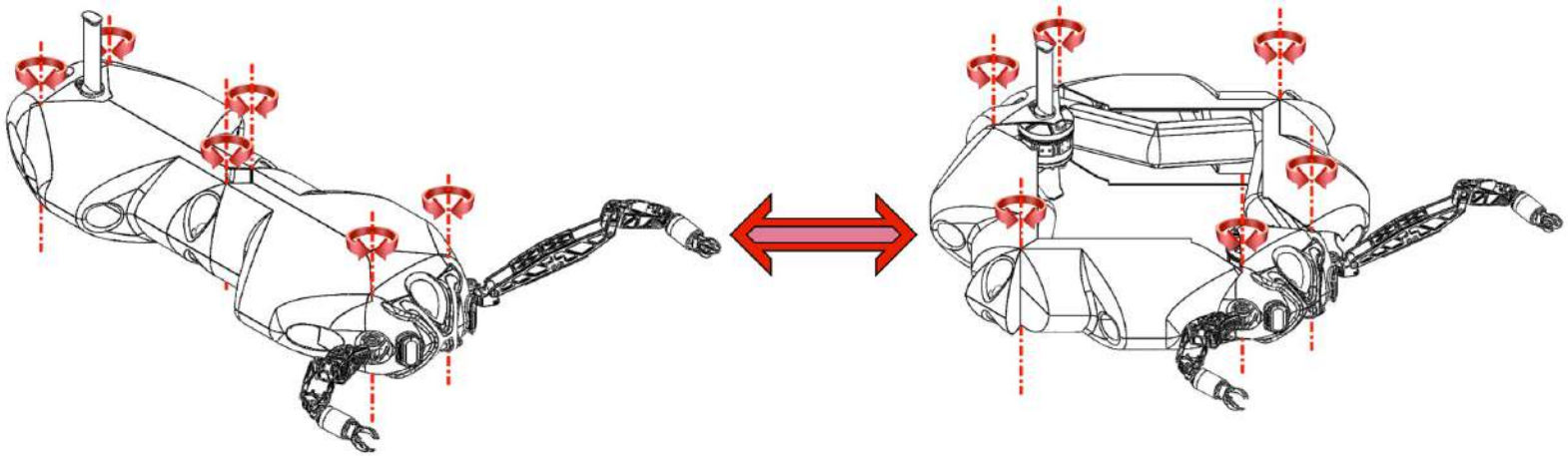
IPR: The University of Florence has filed the PCT patent application PCT/IB2019/056266

PATENT STATUS:
Granted

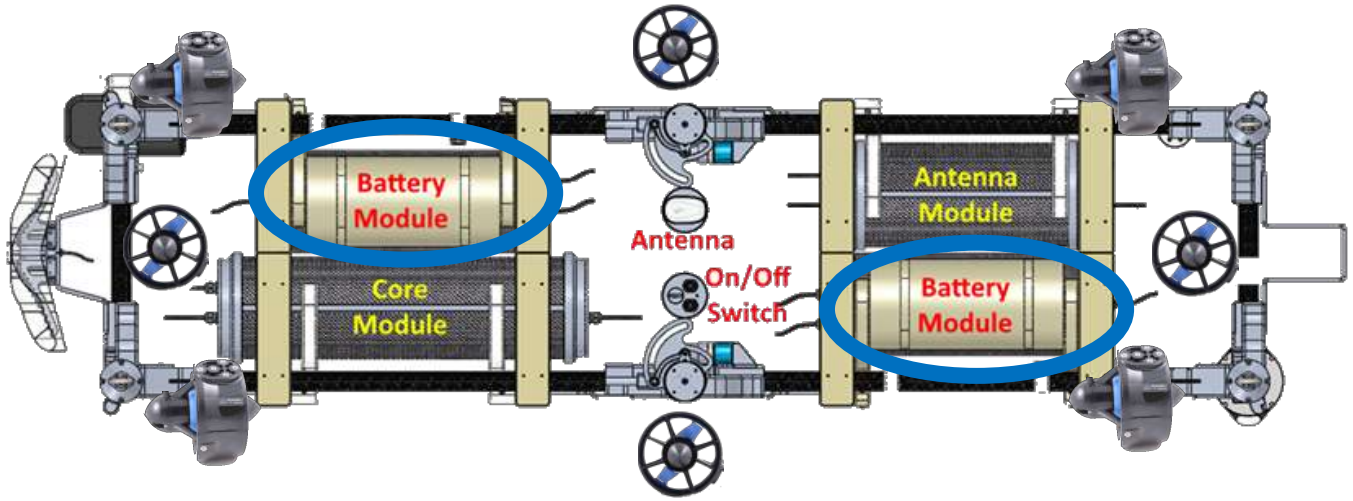
PRIORITY:
102018000007463

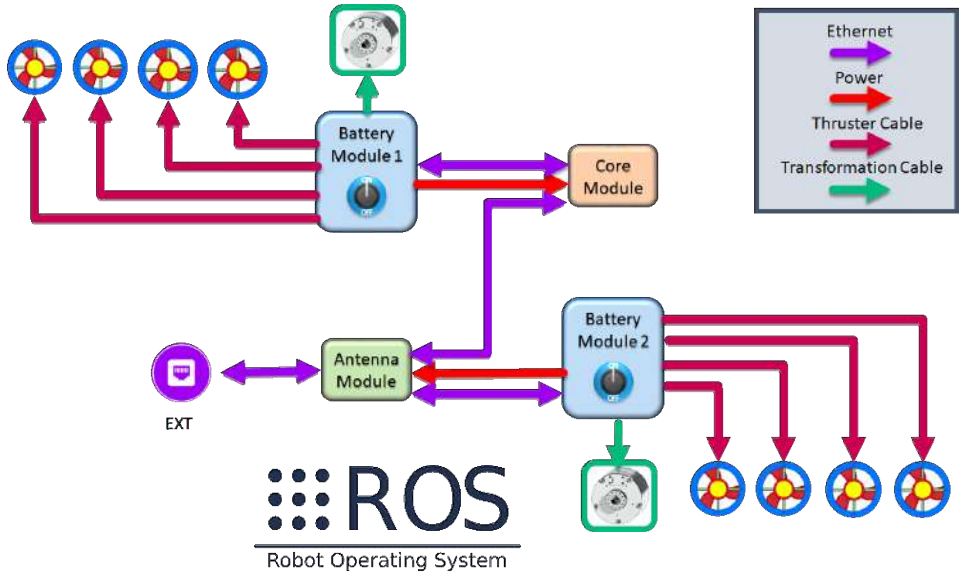
Date:
31 July 2020

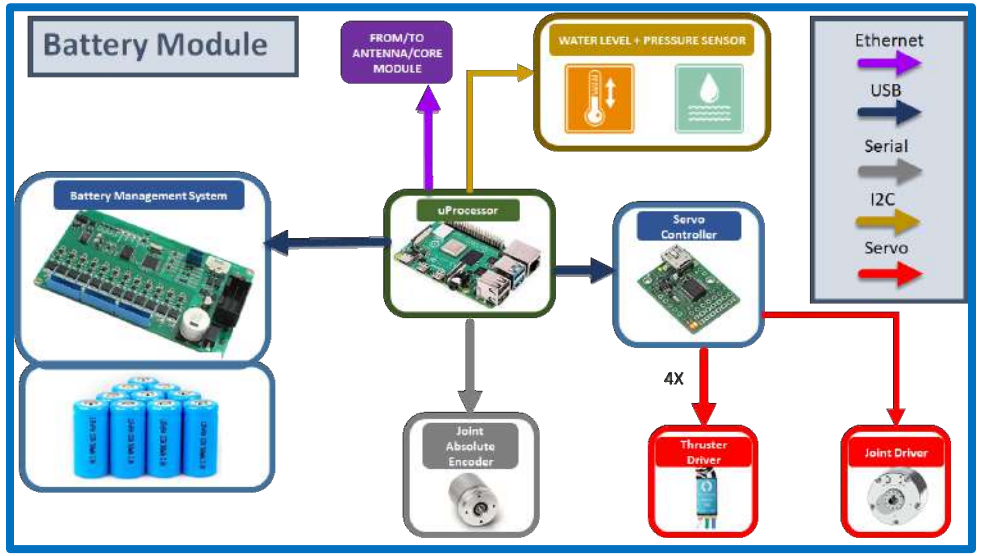
EXTENSION: WO2020021442A1;
KR20210038575A



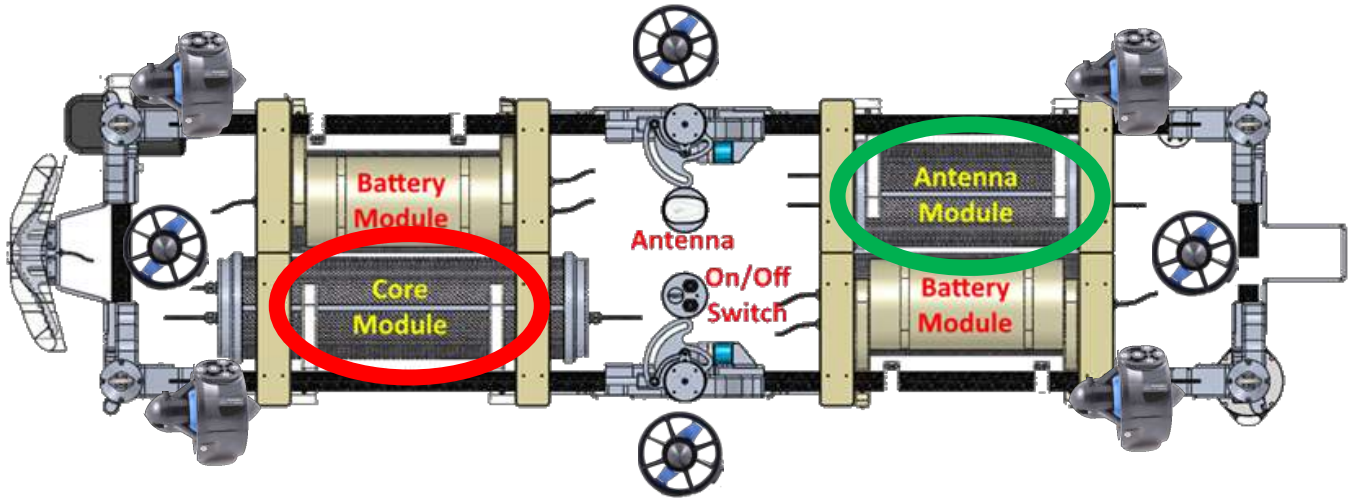
RUVIFIST PROTOTYPE: DESIGN AND MANUFACTURING

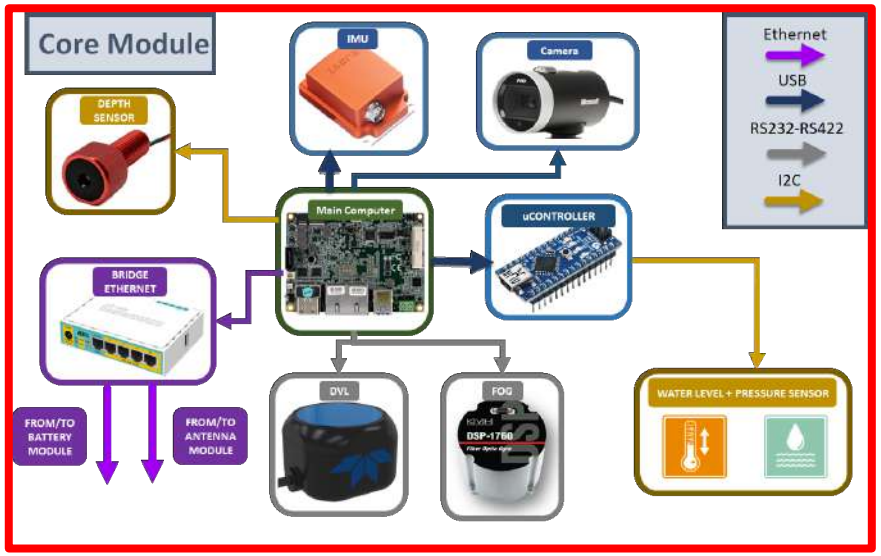


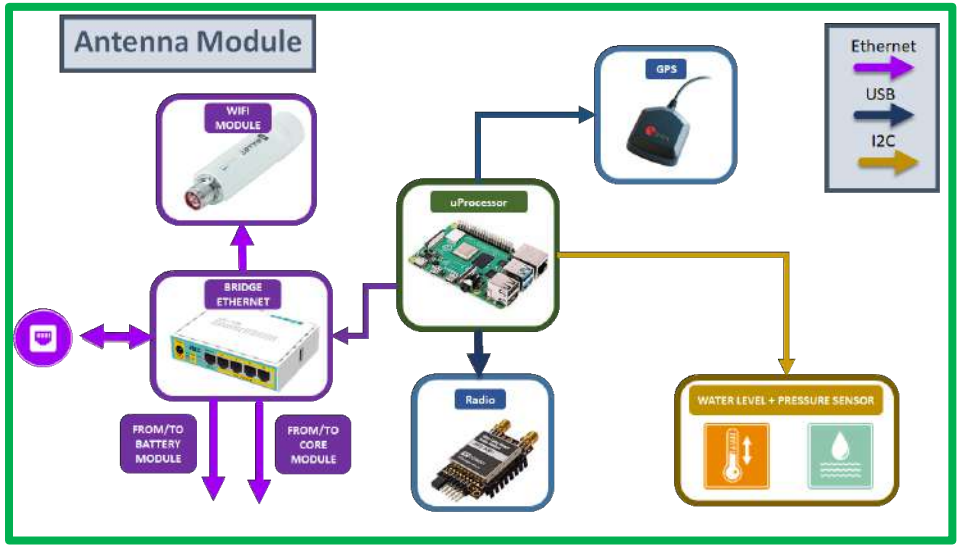




RUVIFIST PROTOTYPE: DESIGN AND MANUFACTURING







UNIVERSITÀ DEGLI STUDI FIRENZE | DIEF DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Contacts:

Prof. Benedetto Allotta
Department of Industrial Engineering
University of Florence

benedetto.allotta@unifi.it Office +39 – 055 – 2758762, Cell. +39 – 348 – 2106952