HYDROMAST

WHAT? HOW? WHERE?

Tallinn University of Technology
Centre for Biorobotics
Asko Ristolainen

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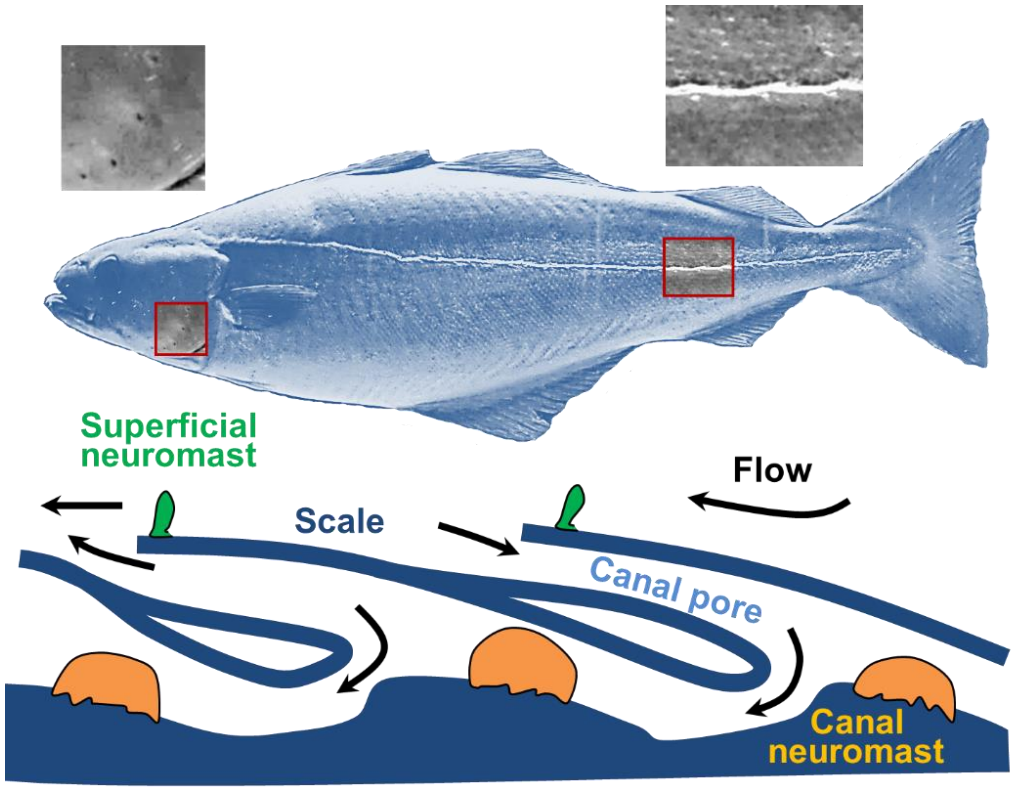
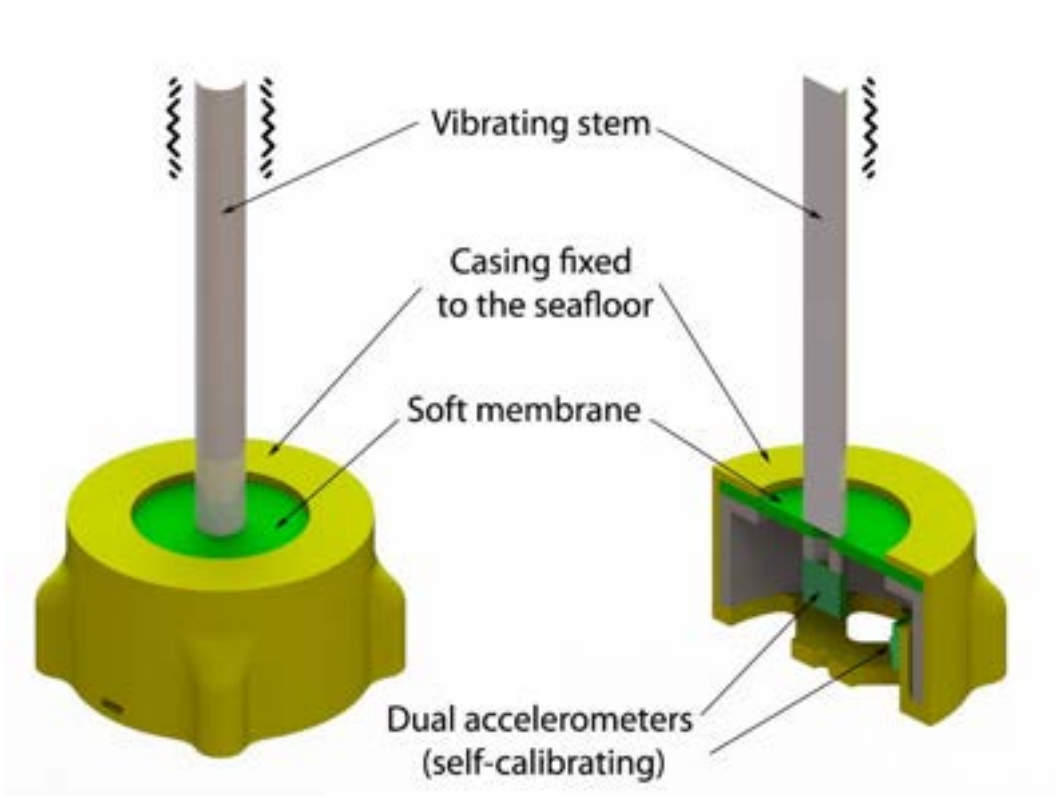
OVERVIEW

- Background
- Working principle
- Installation options
- Applications
- Future developments

BACKGROUND

- Hydromast was developed within H2020 Project LakHsMi (Project no 635568) - 2015 - 2019
- Developed for continuous cost-effective measurements of the near-field, large-scale hydrodynamic situation, for environmental monitoring in cabled ocean observatories, marine renewable energy and port/harbor security

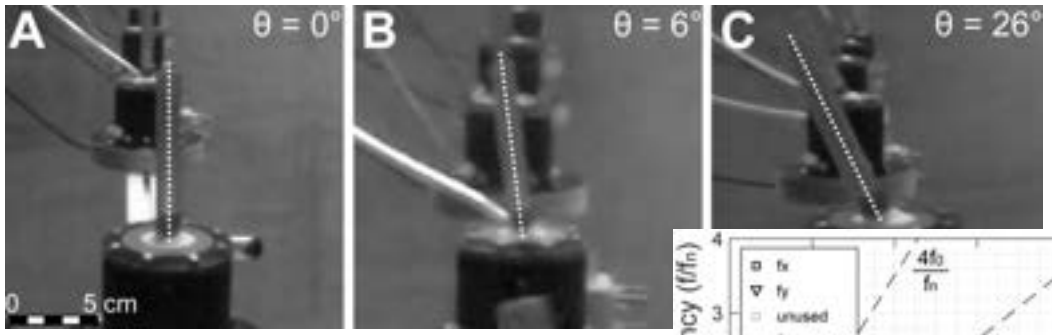


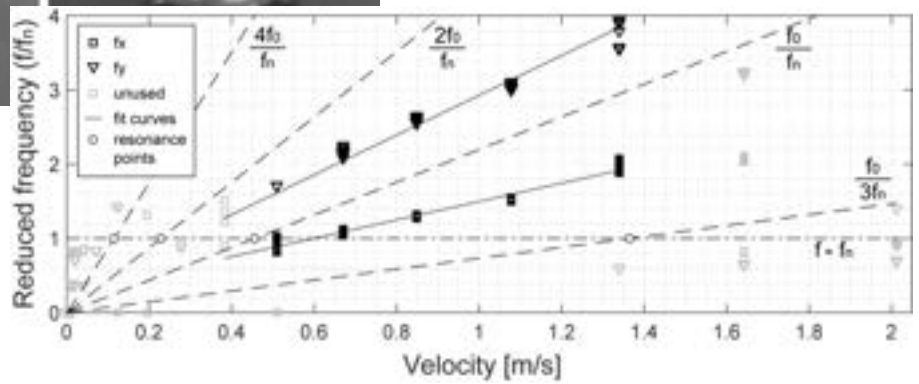


TAL TECH

SENSOR OVERVIEW

- Buoyant rigid mast, connected to a base with a flexible membrane, allowing for free movement of the mast
- Mast instantaneous location tracked with a magnetic field sensor, giving X and Y direction and tilt
- Two velocity detection modes:
  - Based on mast tilt
  - Based on vortex induced vibration (VIV) frequency
- Flow direction from mast tilt
- Incorporated pressure sensor for measuring
  - Waves (at shallow waters)
  - Sea level





SENSOR OVERVIEW

Measurement Ranges

- ***Flow Velocity:*** 0.1 - 1.2 m/s (300mm mast validated)
- ***Directionality***: 0 - 360°
- ***Pressure***: 0 – 2 Bar or 0 – 20 Bar

Resolution

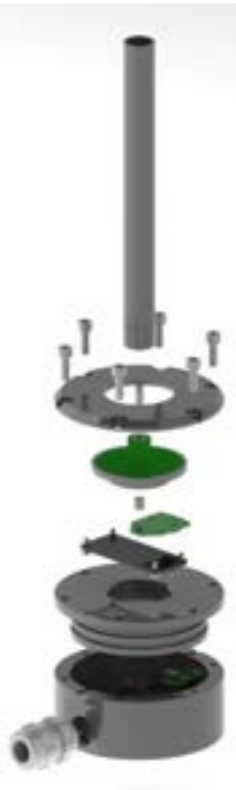
- ***Velocity***: 0.01 m/s
- ***Temporal:*** 1 Hz
- ***Direction****: 5°*
- ***Pressure***: 0.5 kPa

Accuracy

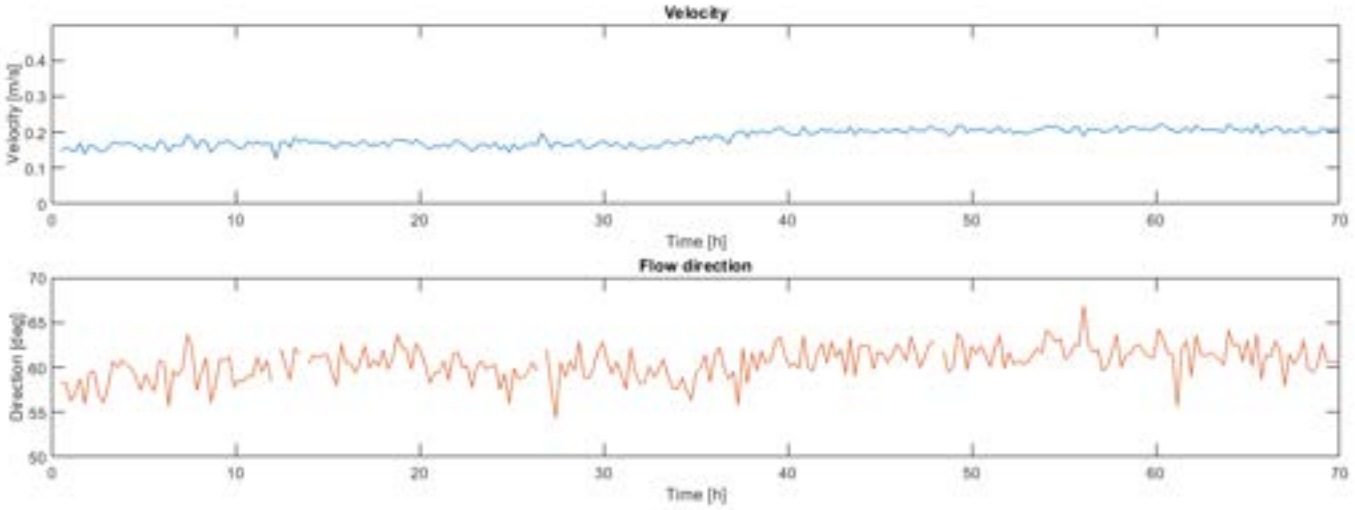
- ***Velocity***: 0.09 m/s (Against Nortek Vectrino ADV)
- ***Directionality:*** 5°
- ***Pressure***: 0.5 % FS

Data output options:

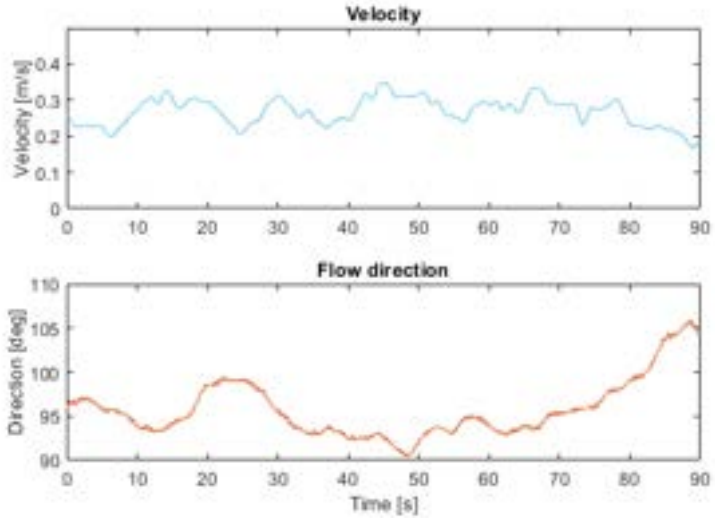
- Processed data (sampling rate selectable)
- Processed averages – desired time interval and averaging time
- Raw data (50 Hz) (RS485 protocol)



70 hours of data



90 seconds of data



TAL TECH

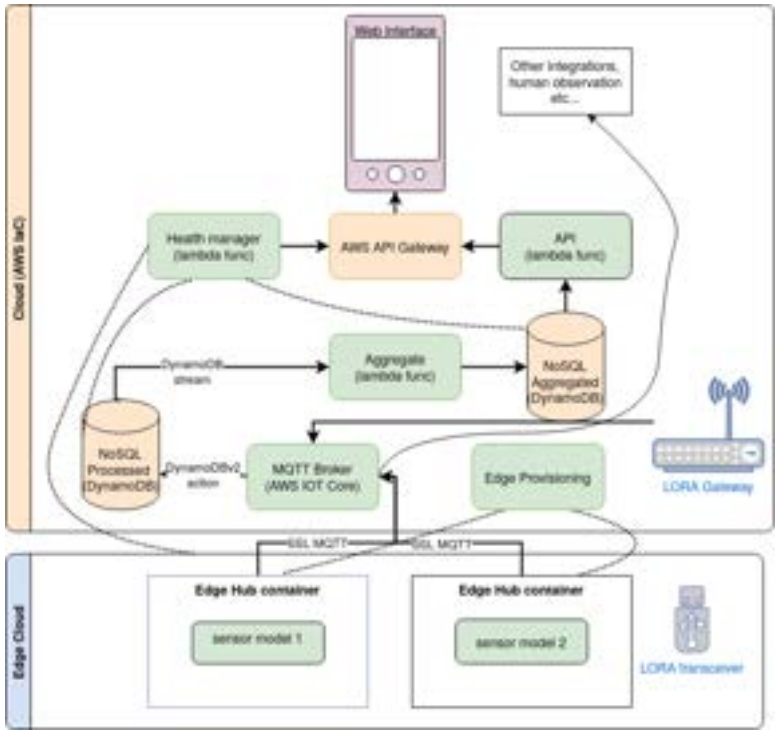
COMMUNICATION POSSIBILITIES

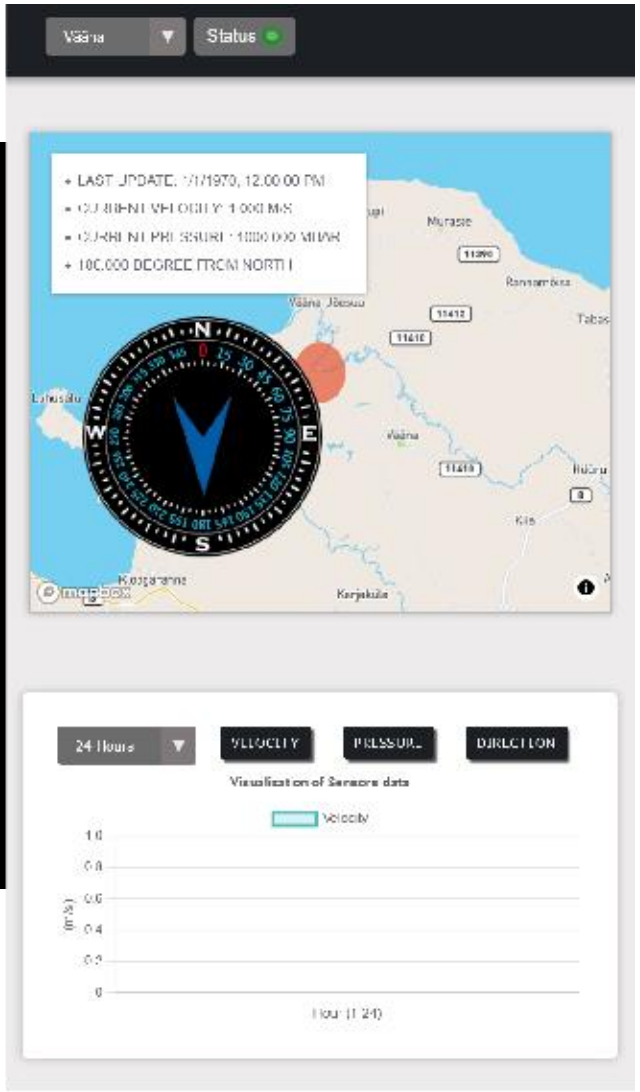
- Communication possibilities
  - Directly from device – USB, RS-485 (RS-232)
  - Connection via a sensor hub (based on a minicomputer, such as Beaglebone Black or Raspberry Pi 3):
    - Ethernet
    - GSM (2G, 3G, 4G)
    - WiFi
    - LoRa (LoRaWAN)
    - Serial: RS-485 (possible to add RS-232)
- Additionally offline logging possible

TAL TECH

ACCESSING THE DATA

- Raw data from the sensors is transferred via MQTT protocol to AWS server from sensor hub
- Data accessible through AWS API for different pilots





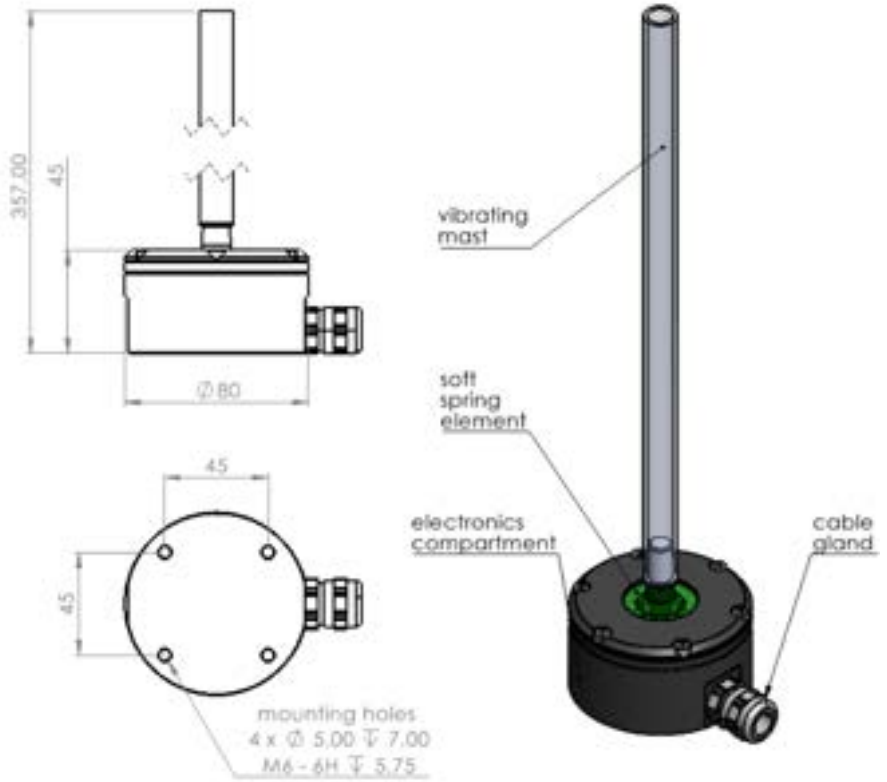
ENERGY CONSUMPTION

- Sensor only (Hydromast):
  - <150 mW (5V max 30 mA), up to 500 mW with voltage converter
- Ethernet:
  - <3W
- GSM:
  - always online using 4G: average 6.5W (13V 0.5A)
- WiFi:
  - <5W
- LoRa:
  - with sensor hub 2W, direct connection to sensor <500mW
- RS-232:
  - with sensor hub 2W, direct connection to sensor <300 mW

TAL TECH

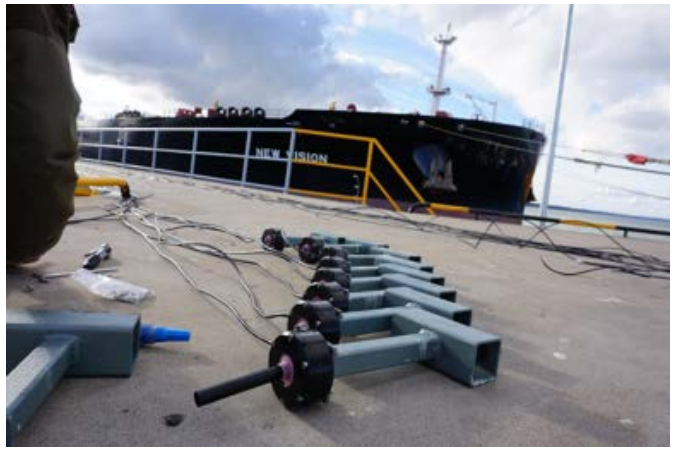
INSTALLATION

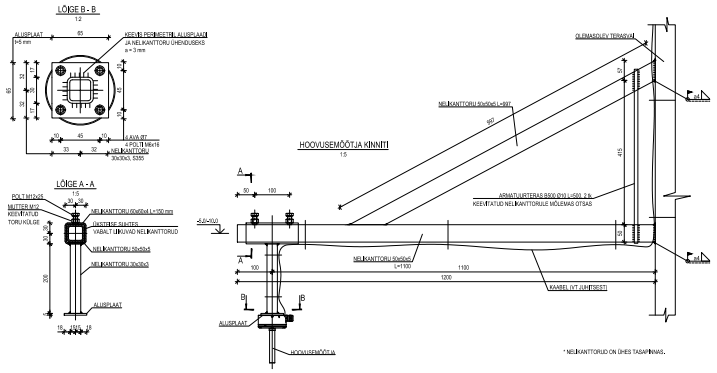
- The hydromast should be installed rigidly to structures or should be fixed to an anchor to avoid movement of the device during measurements
- The hydromast has 4 x M6 mounting holes underneath the sensor as shown on right →
- The hydromast should be placed away from any obstructions to avoid disturbance of vortices from nearby objects
- Cables to the sensors should be fixed to structures to avoid wear and tear
- Underwater wet connectors used to allow stepwise installation (e.g. for harbours)
    1. Installing sensor frames
    2. Fixing cables
    3. Installing sensors



INSTALLATION - HARBOURS

- On pier posts



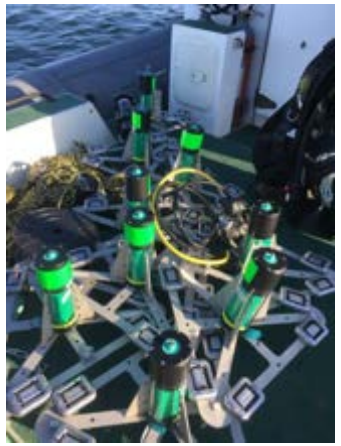


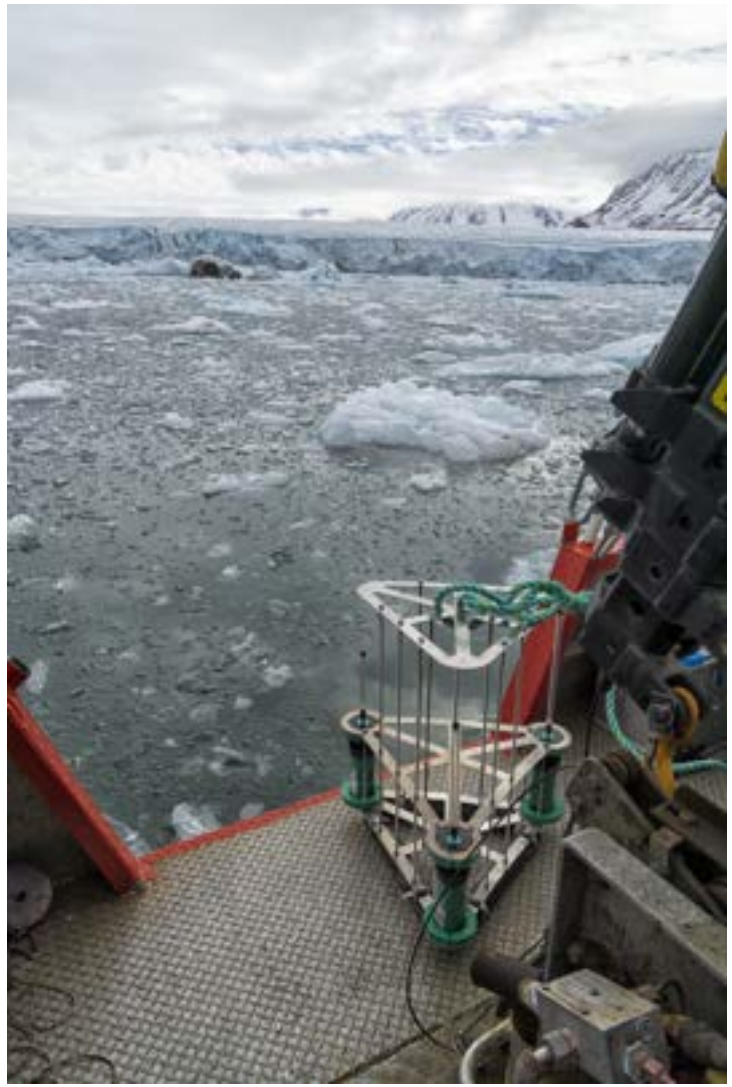
- On pier walls

INSTALLATION - SEABED

- On concrete base

- On metal frames





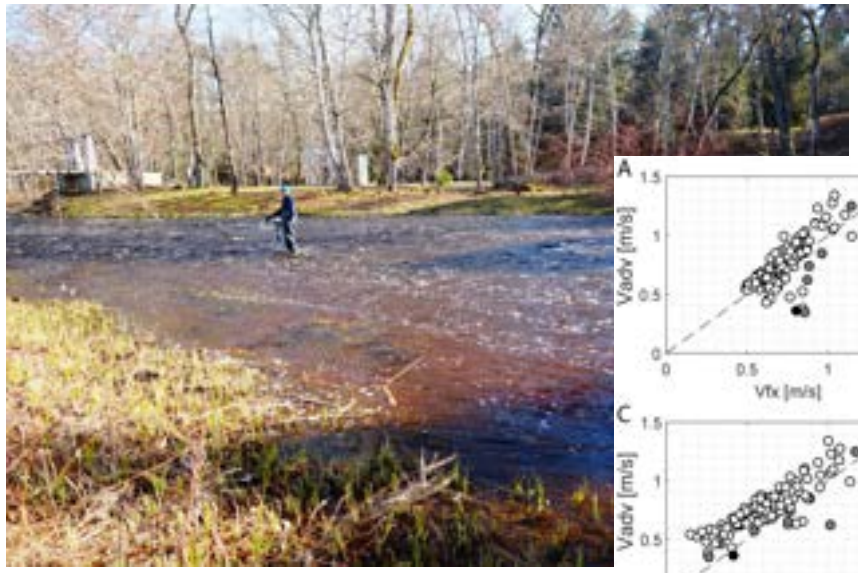
TAL TECH

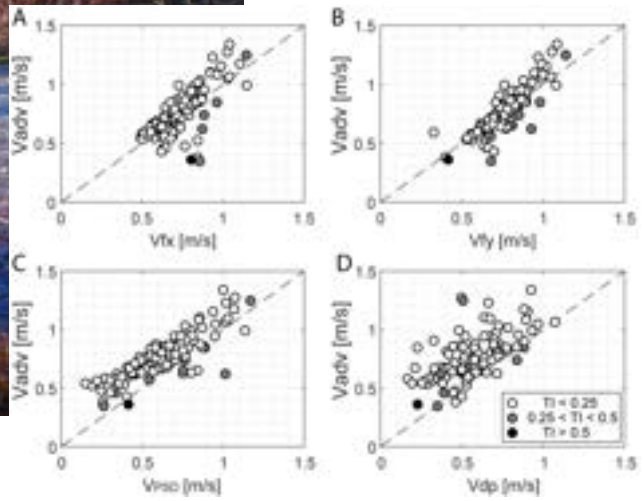
INSTALLATION - SEABED

- Large frames

APPLICATION - RIVER

- Sensor validation[1]
- Flow characterization[2]
- Fish habitat investigations[2]
- Flow changes over long time periods[3]

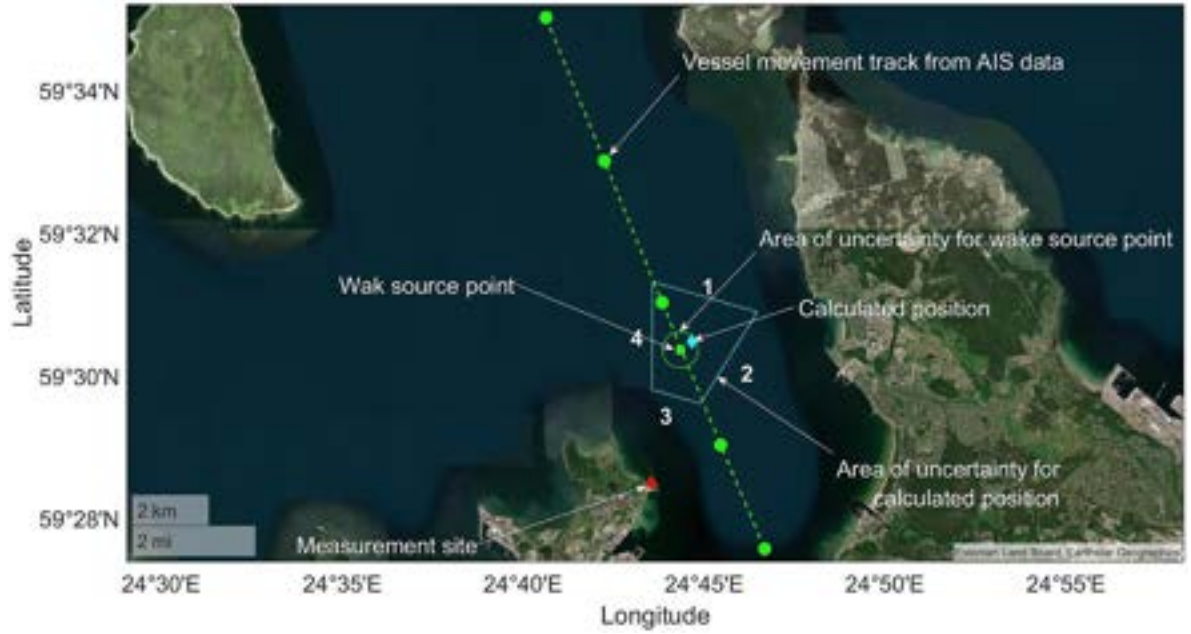


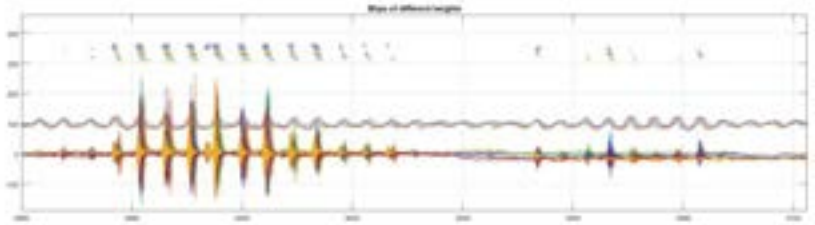


[1] A. Ristolainen, J. A. Tuhtan, A. Kuusik, and M. Kruusmaa, "Hydromast: A Bioinspired Flow Sensor with Accelerometers," vol. 8064, Living Machines Conf.Springer Berlin Heidelberg, 2016, pp. 510–517.
[2] A. Ristolainen, K. Kalev, J. A. Tuhtan, A. Kuusik, and M. Kruusmaa, "Hydromorphological Classification Using Synchronous Pressure and Inertial Sensing," *IEEE Trans. Geosci. Remote Sens.*, vol. 62, no. 11, pp. 1–11, Nov. 2018.
[3] A. Ristolainen, J. A. Tuhtan, and M. Kruusmaa, "Continuous, Near-Bed Current Velocity Estimation Using Pressure and Inertial Sensing," *IEEE Sens. J.*, vol. 19, no. 24, pp. 12398–12406, Dec. 2019.

APPLICATION - COASTLINE

- Ship wake detection and ship traffic monitoring[1-3]
- Wave action monitoring[4]
- Surf zone bedload flow speed monitoring[4]
- Current monitoring[5]

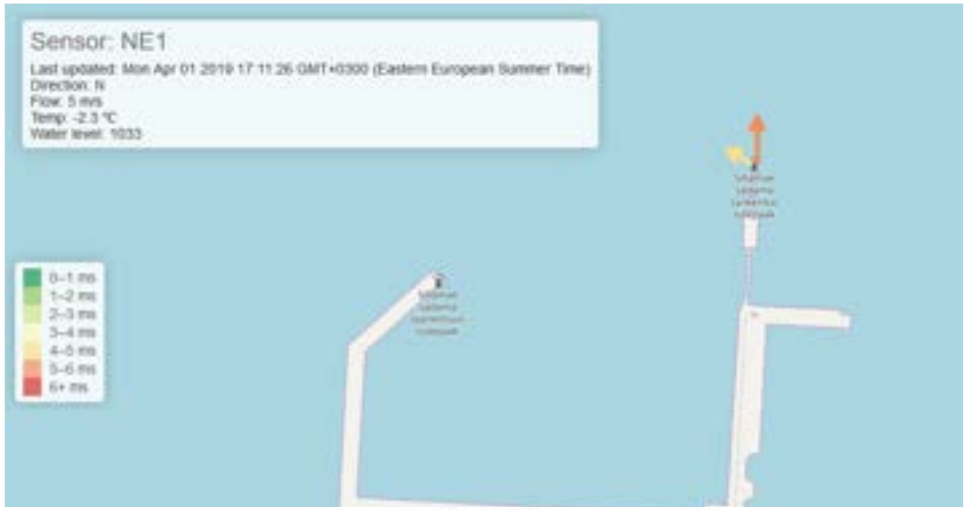


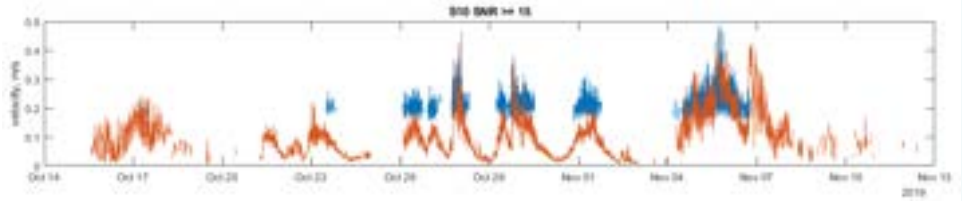


[1] M. Rätsep, K. E. Parnell, T. Soomere, M. Kruusmaa, A. Ristolainen, and J. A. Tuhtan, "Surface vessel localization from wake measurements using an array of pressure sensors in the littoral zone," *Ocean Eng.*, vol. 233, no. November 2020, 2021.
[2] M. Rätsep, K. E. Parnell, T. Soomere, M. Kruusmaa, A. Ristolainen, and J. A. Tuhtan, "Using Spectrograms from Underwater Total Pressure Sensors to Detect Passing Vessels in a Coastal Environment," *J. Atmos. Ocean. Technol.*, vol. 37, no. 8, pp. 1353–1363, Aug. 2020.
[3] M. Rätsep, K. E. Parnell, and T. Soomere, "Detecting Ship Wakes for the Study of Coastal Processes," *J. Coast. Res.*, vol. 95, no. sp1, p. 1258, May 2020.
[4] Ongoing project EMP480 "Solutions to current and future problems on natural and constructed shorelines, eastern Baltic Sea (1.06.2020−31.03.2024)", Tarmo Soomere, Tallinn University of Technology .
[5] Study near Port of Paldiski. ``Paldiski Lõunasadama hoovuste mõõtmine perioodil 15. märts kuni 4. aprill 2019``

APPLICATION - HARBOURS

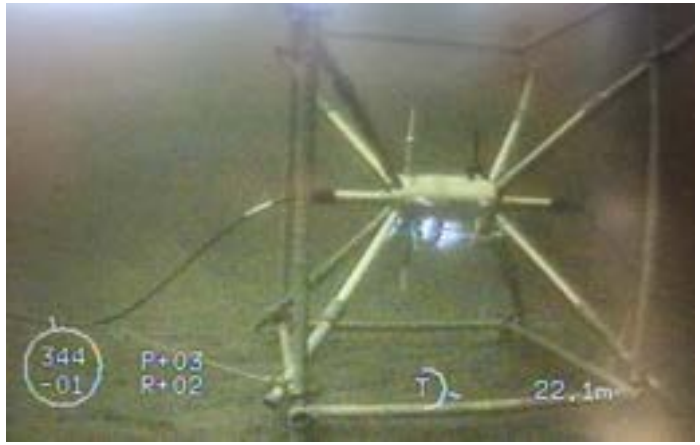
- Monitoring currents for harbour traffic safety
- Distributed sensing at different depths on pier posts





APPLICATION - SEABED

- Benthic process monitoring
  - thermocline in the Baltic sea
- Currents measurements for renewable energy sources
  - Tidal currents near Orkney islands

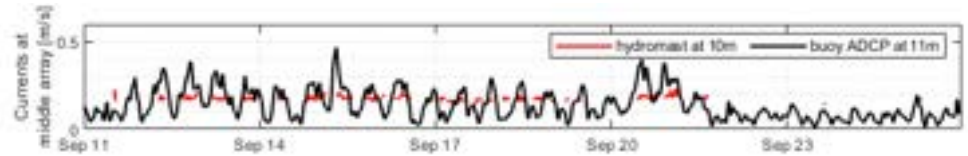


APPLICATION - SEABED

- Benthic process monitoring in Svalbard, Norway

APPLICATION – FISH FARMS

- Distribute flow sensing in aquaculture fish nets [1]
  - Pilot in Norway, Froya. At Sintef ACE facilities



[1] Ristolainen, Asko, Laura Piho, and Maarja Kruusmaa. "Feasibility study on distributed flow sensing with inertial sensors in aquaculture fish cages." *Aquacultural Engineering* 98 (2022): 102271.

APPLICATION – SEDIMENT TRANSPORTATION

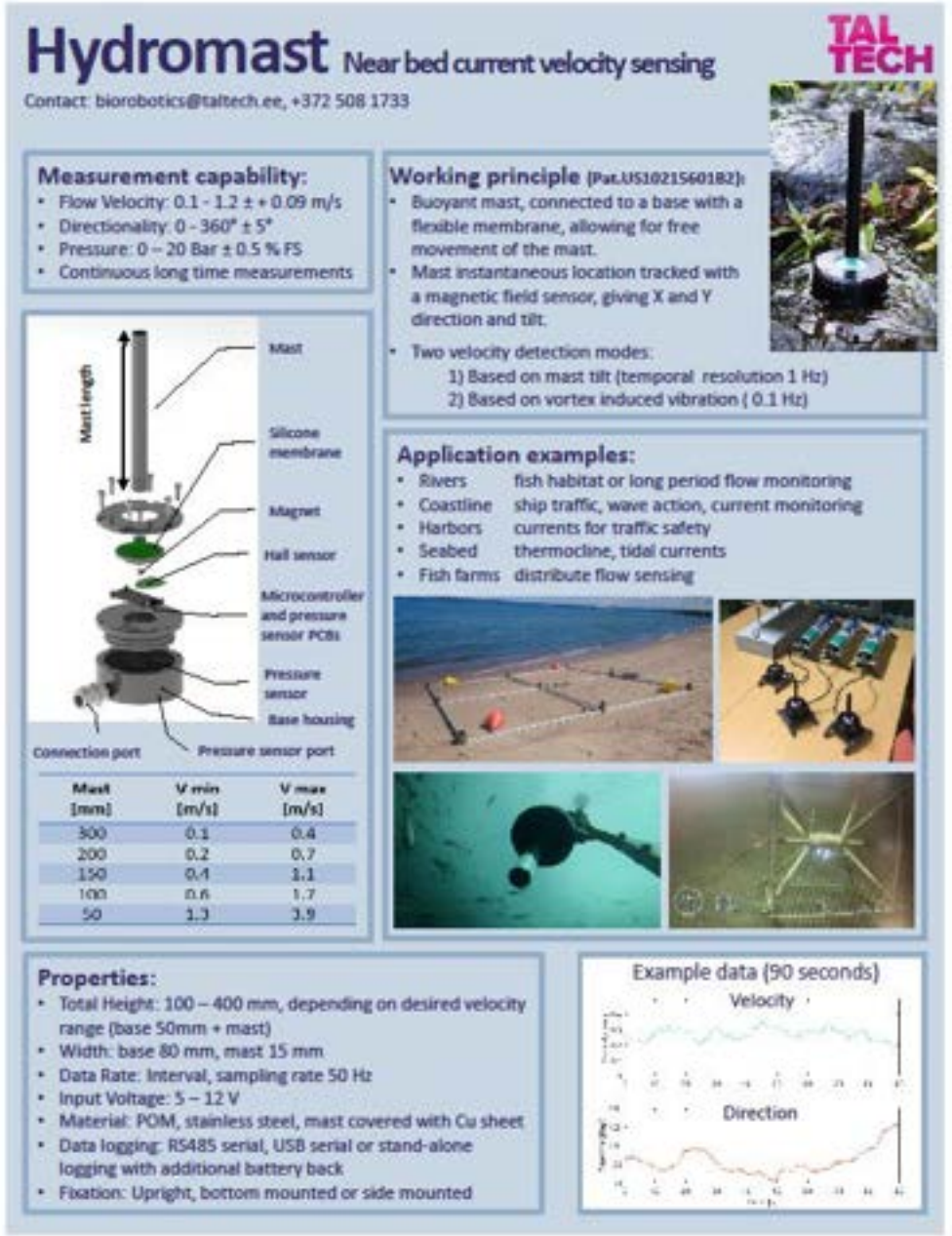
- Distribute flow sensing near shore at the seabed
  - Pilot grid tested in the Bay of Riga, Baltic Sea (August 2022)
  - Sediment model in development

ALTERNATIVE APPLICATIONS

- Possible applications
  - Online ship wake detection
  - Coastline long term monitoring
  - Seabed flow condition monitoring
  - Aquaculture site investigations
  - Fish passage monitoring
  - Sensing flows in extreme places
  - Ship hull biofouling

FUTURE PLANS

- Develop and test telemetry solutions for live data monitoring
- Integrate live sensor streams to ILIAD pilots
- Embedded software implementation
- Longevity tests
- …



TAL TECH

THANK YOU

- Contact:
  - asko.ristolainen@taltech.ee
  - Centre for Biorobotics
  - Tallinn University of Technology
  - Akadeemia tee 15a-111
  - 12618, Tallinn
  - Estonia

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