Development of an Autonomous Robotic System for Monitoring of Surface Water Quality

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Motivations

• “Water resources, being one of the most important, face major threats due to contamination by pollutants of various types and origins.”

• The 2030 Agenda for Sustainable Development: Goal 14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development

• Widespread problem of water pollution through chemicals, waste and plastic
Related projects: Aquatropolis

• Development of technological frameworks to monitor and control Aquaculture Productions

• Autonomous Mobile Robots for fish inspection and water quality monitoring.
Related projects: LIBÉLULA

- This project aims to develop autonomous, mobile and robotic monitoring system units (LIBÉLULA) for the acquisition of water quality parameters, with a functional topology based on swarm robotics.
Field Requirements

Chemical and/or physical parameters:
• water temperature (correlation with other parameters);
• pH of the water, industrial pollution point (mineral acidity) or water eutrophication processes (relation between the oxidation of organic matter and the CO$_2$ content);
• others: dissolved oxygen, redox potential, conductivity, salinity and dissolved solids.

Data acquisition zone:
• Castelo do Bode reservoir in Portugal: main national water reservoir for public supply extension of 60 km, 3 300 ha, 1100. Greatest interest areas:
  (1) water catchment points for human consumption;
  (2) contributors with more domestic or industrial polluting load to the reservoir: confluences with the Zêzere river;
  (3) population clusters on the banks (in the summer the population significantly increases).
Solution Requirements

• **Collect data from water surface:**
  • Spatio-temporal measurements of large water surface areas;
  • Dispersion map of chemical concentrations on the water;

• **Operation Mode:**
  • Teleoperated mode through a set of waypoints or homing commands;
  • Autonomous supervised mode by defining an operation area that the system will autonomously monitor.

• **Data Communication and Processing:**
  • Long range radio communication for data exchanging between agents;
  • Cellular communication for data deployment to the cloud server.
Solution

• **Mobile Units for Water Monitoring:**
  • Autonomous Surface Vehicles (ASV);
  • Unmaned Air Vehicles (UAV).

• **Water monitoring:**
  • Water quality probes with digital communication;

• **Localization:**
  • RTK GNSS System with Base Station.

• **Communications:**
  • Lora communication for field data and commands;
  • WiFi/Ethernet/Radio for robot interface and configurations;
  • 4G for robot - server communication.

• **Data storage and processing:**
  • Non relational database;
  • Server on the "cloud";
Solution Design

- **ASV/UAV:**
  - Mobile Unit. Water quality monitoring and field data;

- **ROV BASE:**
  - Mobile Unit. Data Gateway between mobile units and Cloud;

- **Cloud Server:**
  - Storage, front-end and back-end processing;

- **LORA Network:**
  - Communication between mobile units and base station;

- **Internet Connection:**
  - Deployment of field data to the cloud;
Mobile Monitoring Unit Hardware Solution

• **MPU:**
  - Raspberry Pi 3 B+ or another Single Board Computer (SBC).

• **Lora Module:**
  - Lora communication interface.

• **Monitoring Module:**
  - Low level interface with Aqualabo probes;
  - Modbus/RS-485;
  - Altimeter ISA500 from Impact Subsea.

• **Navigation Module**
  - NAVIO2 from Emlid with Ardupilot software.

• **GPS Module:**
  - Emlid Reach M+ for localization and mapping purposes.

• **Radio RC receiver, module:**
  - RC receiver FrSky X8R.
Mobile Monitoring Unit Hardware Solution

Centro de Investigação em Cidades Inteligentes (UID 05567)
Mobile Monitoring Unit Software Solution

- Operating System: Ubuntu 18.04

- Software
  - ROS Melodic Software Framework:
    - Operation and interface algorithms;
    - Commands and Missions to ARDUPILOT
  - ARDUPILOT Software Framework:
    - Low level interface with actuators;
    - Control algorithms;
    - Localization and pose estimation;
    - Tele-operated and Waypoint navigation.
Mobile Base Unit
Hardware Solution

• MPU:
  • Raspberry Pi 3 B+ or another SBC board.

• Lora Module:
  • Lora communications Gateway.

• 4G Module
  • Cloud server and Internet communication.

• GPS Module:
  • Emlid Reach RS+.

• Navigation Module
  • NAVIO2 board with Ardupilot software.

• Radio RC receiver:
  • Rc receiver FrSky X8R.
Mobile Base Unit Hardware Solution
Mobile Base Unit Software Solution

- Operating System: Ubuntu 18.04
- Software
  - ROS Melodic Software Framework: Operation and interface Algorithms;
  - Missions/commands to ARDUPILOT.
  - ARDUPILOT Software Framework: Low level interface with actuators;
  - Control algorithms;
  - Tele-operated and waypoint navigation;
- NODEJS Application: Interface between field data and the Cloud.
Navigation Module

• Navio2 module from Emlid:
  • Low level interface with actuators generating PWM signals for electronic speed controllers (ESC’s);
  • Inertial Navigation System (INS);
  • Interface with GNSS module;
  • Interface with RC Radio receiver;
  • Possibility to interface telemetry modules;
  • Communication with SBC through Mavlink protocol.

• Ardupilot Software:
  • Localization and pose estimation algorithms through data fusion of GNSS and INS systems with Extended kalman Filter;
  • Navigation through motion commands or mission waypoints.
Monitoring Module

- Module for probes interface. Aqualabo/Ponsel digital probes;
- RS-485 Modbus protocol. Allow integration of adicional sensors;
- Module-SBC USB interface;
- Espressif ESP32 MCU running FREERTOS;
LORA Module

- Module for LORA communication between devices;
- Long range, low data rate communication technology;
- Communication of field data and operation commands;
- Espressif ESP32 MCU running FREERTOS;
- USB communication to allow a direct interface with SBC devices.
Cloud Server

- NodeJS Server

- Field data from Base Stations:
  - MQTT

- Storage:
  - MongoDB Database

- Frontend:
  - Bootstrap based Web Dashboard

- Backend:
  - NodeJS Server
THANK YOU!

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