Scientific payload integration for an Autonomous Surface Vehicle

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April 3, 2019

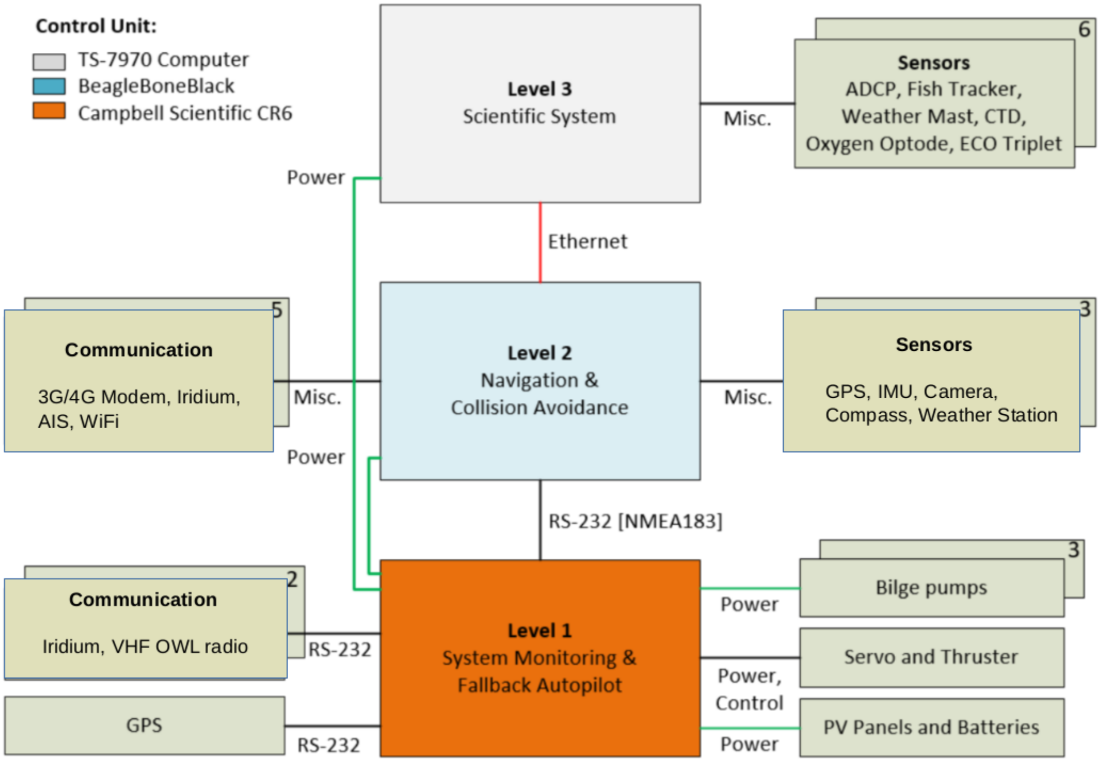
Introduction

AutoNaut is a self-powered Autonomous Surface Vehicle (ASV) developed by MOST (Autonomous Vessel) Ltd [1]. The ASV is designed to be a cost effective, low man-power data collection platform, with zero emission, extreme persistence and capability of surviving extreme weather conditions. Zero emission is achieved solely by wave and solar power. A patented Wave-propulsion Technology converts energy from the pitch and roll of the waves. AutoNaut is equipped with spring-loaded foils attached to the struts under the keel. These foils exploit the wave-induced vessel motion, caused by waves lifting the vessel up, out of the water and dropping it down again, to generate the forward propulsion. Under very calm weather conditions when the waves cannot alone propel the ASV, an electrical thruster on the stern strut can be used. This vehicle is the 5-meter version with max speed up to 3 knots, depending on the sea state.

The system presents a layered architecture composed by three main units dedicated to different functionalities. **Level 1** unit is the "heart" of the vehicle, in charge of the following:

- constant health monitoring of the whole system
- power management and distribution through solid-state relays
- sensors and onboard computer
- fallback behaviors (i.e. safety maneuvers, autopilot)
- periodic satellite communication with the operator via Irridium

Level 2 can be considered as the "brain" of the vehicle. It implements more abstract capabilities as a result of integration and processing of data provided by dedicated sensors (GPS, IMU, magnetic compass). As part of the navigation system, this unit constantly runs an AIS-based collision avoidance algorithm.



This document focuses on the integration of the scientific payload the vehicle is needed to be equipped with. With the aim of an autonomous monitoring and sampling of oceanic waters, the AutoNaut carries six relevant sensors able to process several physical and biological features related to the marine natural environment. Below is a brief overview of these[1]

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[1] More detailed description can be found at `http://autonaut.itk.ntnu.no/doku.php?id=sci_sens`.

Sensor	**Features**
Nortek Signature500 ADCP	Measures current profiles at up to 8 Hz sampling frequency, direct vertical velocity profiles, wave height and direction, and ice thickness and drift.
Seabird CTD SBE 49	Conductivity, Temperature, and Pressure at 16 Hz (16 samples/second) or polled sample acquisition.
ThelmaBiotel TBR 700	Live data feed for fish tracking for aquaculture applications
Aanderaa Oxygen Optode 4835	Measures absolute oxygen concentration and %-age saturation
WET Labs ECO Puck Triplet	Biogeochemical measurements of chlorophyll and CDOM fluorescence and red backscattering and remote Sensing and Particle Dynamics Measurementsblue, green and red backscattering
Airmar 120WX Weather Station (right now in L2)	Ultrasonic wind measurements, apparent wind speed & angle, barometric pressure, air temperature, wind chill

Project workflow

Selected student(s) will first become acquainted with the operational modes of the sensors, after detailed study of their manuals and datasheets. Such a study would aim at familiarization with the principles of operations of each sensor, helping the candidate(s) to outline possible scenarios and missions they will be part of. A technical report is expected at the end of this first phase. At a subsequent stage, the sensors are to be integrated in the ASV; the physical placement of the sensors on the skeleton of the vessel, with related communication and power cables, has already been performed. However, an overall review and potential adjustments will likely be needed.

Software toolchain and processing unit

TS-7970 is the processing unit (CPU) selected for this application [2]. The choice is mainly due to its robustness, computational power and GPIO variety.

- CPU: ARM COrtex, 1GHz, GPU and FPU
- RAM: 2GB
- ROM: 4GB
- Ext storage: 1 microSD slot, 1 SATA port
- Interfaces: 2x Gigabit Ethernet, 1 USB host (4 ports), 4x Serial/COM ports (3x RS-232, 1x TTL add 3x w/o RS-485/Bluetooth), 2x RS-485 ports, 1x SPI bus, 1x I2C bus, 2x CAN bus, 1x ModBus, 1x bluetooth, 1x cellular modem, 1x WiFi radio, 1x HDMI port.

Based on the software implementation of Level 2 unit [3], this computer will host one of the following OS:

- GLUED: minimal Linux distribution targeted at embedded systems [4].
- Yocto [5].
- Ubuntu 16.04 [6].

The software running on the TS-7970 will be Dune [7].

Master-slave cooperation

Dune already runs in Level 2 providing advanced navigation and collision avoidance capabilities. Level 3 acts as a secondary instance, receiving plans from Level 2. A possible master-slave (where Level 2 is the master and Level 3 the slave) configuration works as follow:

- the master computes servo inputs that allow the vessel to reach the area of interest embedded by the operator in a plan - the slave unit is turned off.
- once the target area is reached, the slave is turned on and a plan is communicated by the master to the slave (more details about what a plan could be are described later).
- the slave executes the plan, locally stores data and communicates the results to the master unit.
- the master unit sends acknowledge to the operator and turns off the slave.

Candidate responsibilities

The selected student(s) will be responsible for the integration and implementation of the necessary drivers that allow the sensors to transmit data to the unit. The integration of the sensors has to be aligned with the design philosophy of the architecture. Some of the drivers are already available, however adaptations will likely be needed to accommodate the sensors and the processing unit within the system already tested. After a first round of integration, the student is expected to engage in the the task of dry-testing the sensors on land. Once all of them are proven to work as expected, sea trials can be organized in Trondheimsfjorden. The student will have the chance to actively participate to the trials, monitoring and evaluating the sensors data flow and likely go to sea. The project/thesis is concluded once a stable implementation is achieved and the scientific payload works as planned, documentation of the code is done and delivered, via a code repository.

Required skills

- active interest ub robotics and autonomous systems,
- must have familiarity with UNIX-based systems (CLI operations and usage as basic requirement)
- intermediate to advanced knowledge of C++, Python and Matlab
- basic bash programming is a plus!
- appreciation and interest in marine science and oceanography is a plus

We encourage students with *strong* programming skills coming from any discipline with a keen desire to make an impact and publish results to apply. Depending on the performance, the evaluating professor could help in offering advice in joining well known companies in the United States.

More information concerning the toolchain (GLUED, Dune, Neptus, IMC) are available in [8]. More detailed description of the AutoNaut architecture is found at [1].

References

[1] “Autonaut itk webpage.” `http://autonaut.itk.ntnu.no`.

[2] “Ts-7970 sbc powered by arm cortex-a9.” `https://www.embeddedarm.com/products/TS-7970`.

[3] “Toolchain - lsts.” `https://lsts.fe.up.pt/toolchain`.

[4] “Glued - lsts.” `https://lsts.fe.up.pt/toolchain/glued`.

[5] “Yocto project.” `https://www.yoctoproject.org/`.

[6] “Ubuntu 16.04.” `http://releases.ubuntu.com/16.04/`.

[7] “Dune - lsts.” `https://lsts.fe.up.pt/toolchain/dune`.

[8] J. Pinto, P. Calado, J. Braga, P. Dias, R. Martins, E. Marques, and J. Sousa, “Implementation of a control architecture for networked vehicle systems,” *IFAC Proceedings Volumes*, vol. 45, no. 5, pp. 100 – 105, 2012. 3rd IFAC Workshop on Navigation, Guidance and Control of Underwater Vehicles.