Compact Light-weight camera system for ARGO extension applications

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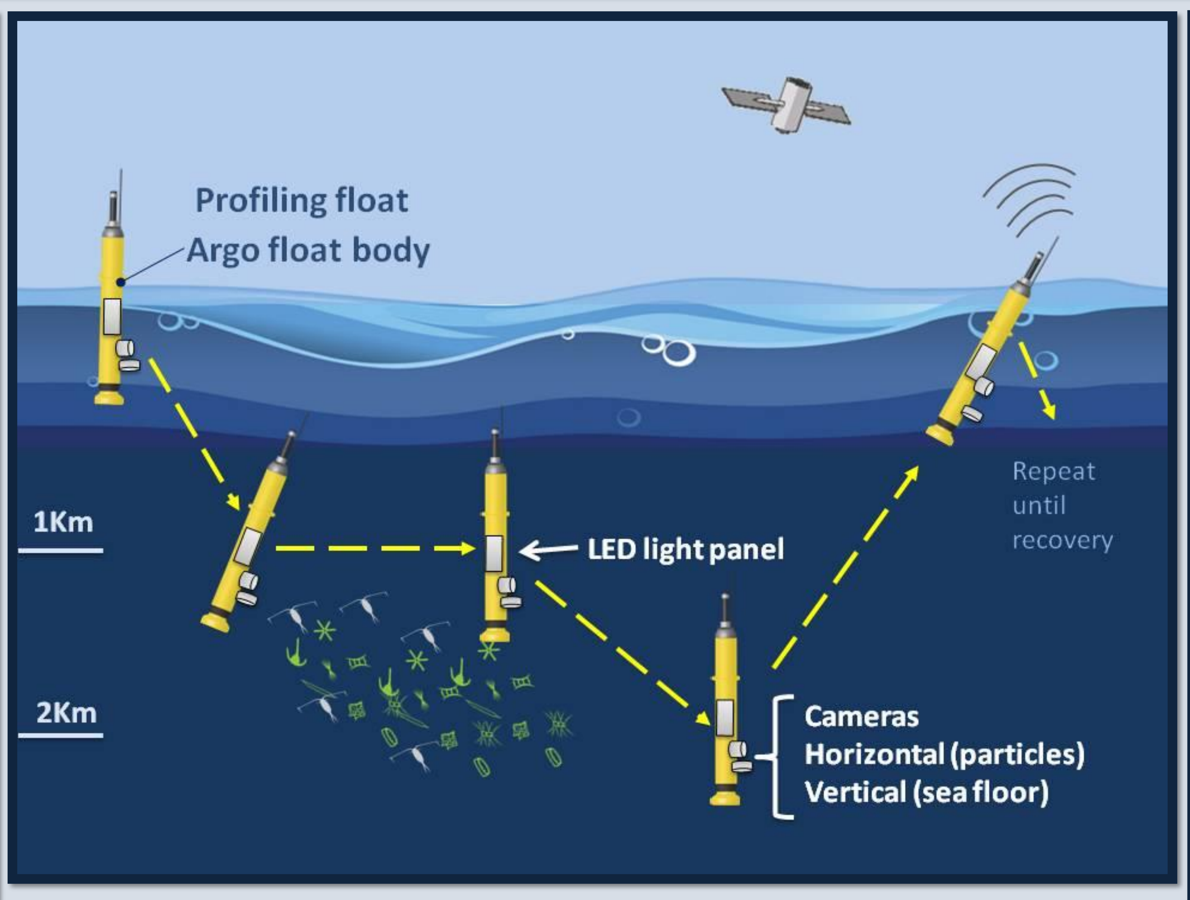
Abstract

To extend the capabilities of ARGO, the ability to acquire and record images is a major challenge that has the potential to provide information on biodiversity and the surrounding environment that is unobtainable in any other way. A prototype autonomous dual camera package, known as JELAB2, small enough to be carried on an ARGO float, has been developed. The system is based on two Raspberry Pi Camera Modules v2, with Sony IMX219 8-megapixel sensors which are capable of high definition video, still shots and time-lapse sequences. Embedded LED panels for each camera provide lighting when below the depth of maximum penetration of solar light. Camera 1 is oriented horizontally, designed for capturing images of particles in the water-column during descent or ascent. Camera 2 looks downwards obliquely to view an area of sea-floor when the float is parked on the bottom. The two Raspberry Pi boards are controlled by a low consumption Arduino Pro Mini microcontroller. The compact design is achieved by avoiding external instrument housings. The system is embedded in resin. In the prototype, inputs from pressure and temperature sensors are recorded and can be used to control image capture. JELAB2 is fully software programmable for a variety of missions.



Introduction

The goal of JELAB2 is to add imaging capability to an ARGO float (e.g. Priede et al., 2019. A horizontal (profiling) camera is intended to image particles in the water-column and a vertical camera to image the sea floor. The concept of the mission is for a profiling float capable of descending to 2000m maximum depth, corresponding to the maximum depth of the Cretan Sea.

Scientific applications of the JELAB camera system include imaging of organisms in the water column such as macrozooplankton which may constitute major hidden pelagic biomass in the Eastern Mediterranean (e.g. Potiris et al., 2018), sea-floor inspection for vulnerable marine ecosystems (VME) geomorphology, and use in Baited remote underwater video (BRUV) non-extractive surveys of fishery resources.

The Technical Development of JELAB2

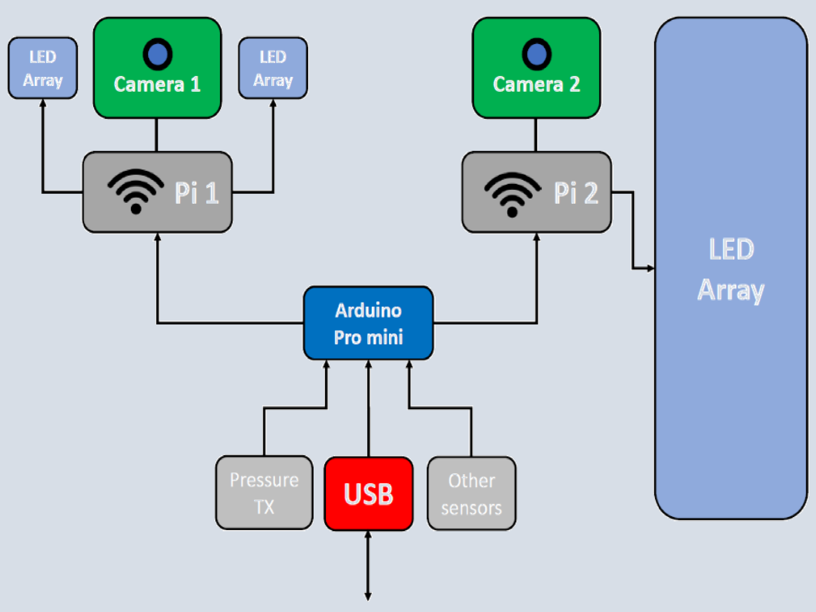


Figure 1. JELAB2 camera schematic.

The JELAB2 camera system (***Figure 1***) uses two independent cameras, each with its own LED lighting array:

- Camera 1 is a near-field (profiler) camera and has two small LED arrays
- Camera 2 is the far-field (benthic) camera with a single high-power LED array.

Each camera is controlled by Raspberry Pi Zero:

- Utilizes Camera Module v2: Sony IMX219 8-megapixel sensor, providing HD video, still shots and time-lapse sequences.
- Provides WLAN 802.11 b/g/n, for downloading images and reprogramming.
- Has an SD card slot with a 32 GB SD card for storing of images.
- LED light panels are activated in synchrony with the camera.

An Arduino Pro Mini:

- Controls the mission to avoid excessive quiescent power.
- Takes analogue and digital inputs from sensors such as pressure, temperature etc. In the prototype, a pressure sensor is used to trigger mission commencement (***Figure 2***).

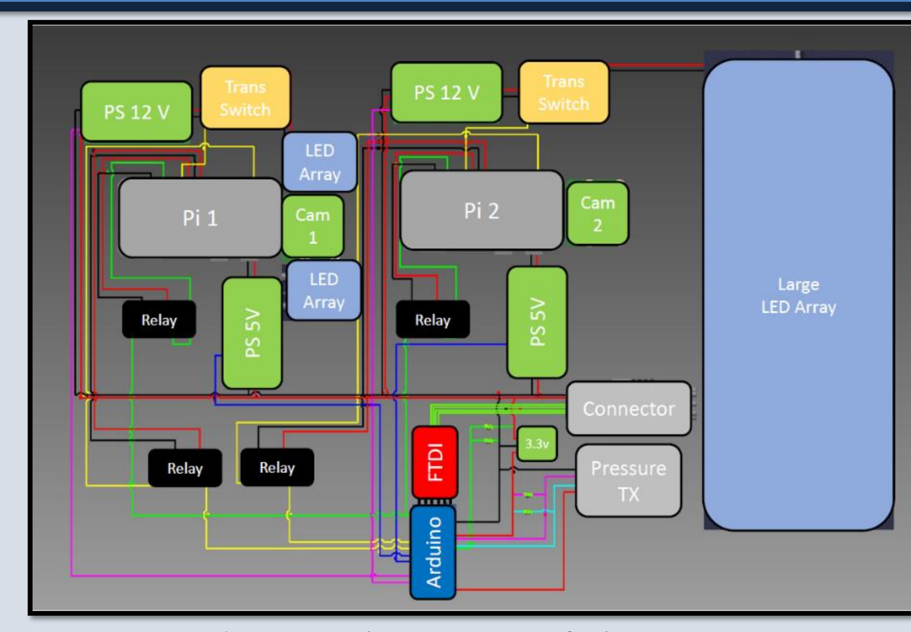
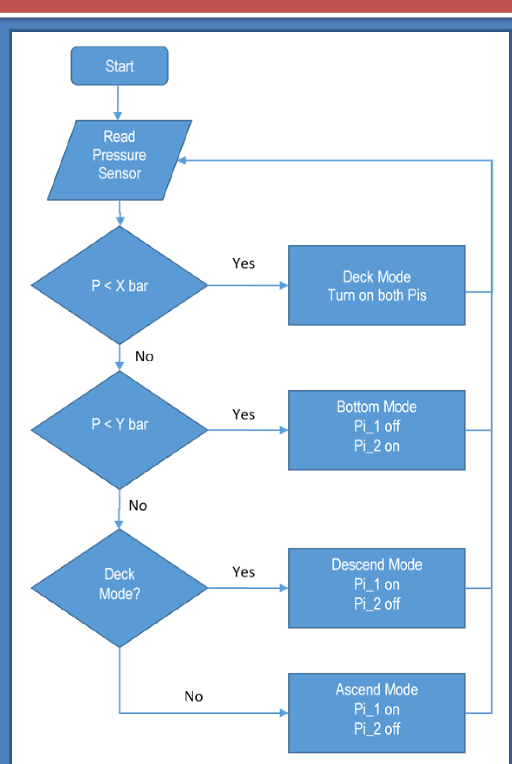
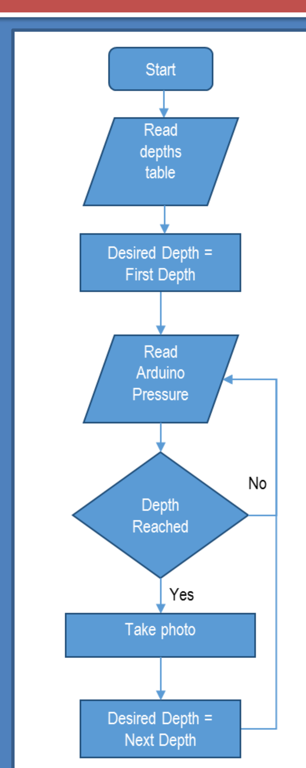


Figure 2. Hardware implementation of the JELAB2 system. An external battery provides 14.8 V nominal via the connector.

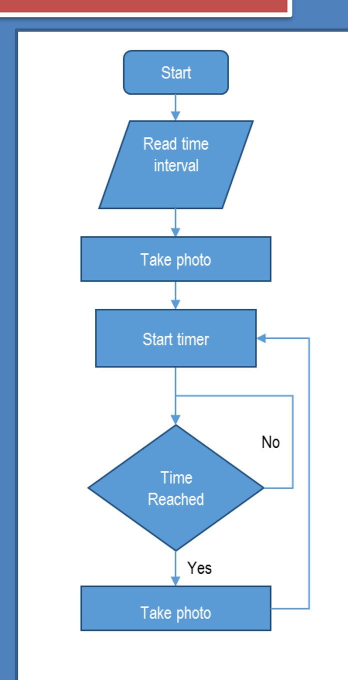
Software



Flowchart 1. The operation of the Arduino controlling the two Raspberry Pi.



Flowchart 2. Function of the cast Pi (Pi_1).



Flowchart 3. Function of the benthic Pi (Pi_2).

Flowchart 1: the operation of the Arduino microcontroller, responsible for:

- Reading the pressure sensor,
- Turning on and off the Raspberry Pi boards, depending on which phase of the dive the system is in.

Flowchart 2: operation of Pi_1 Pressure from Arduino board is compared with table of depths where photos are to be taken

Flowchart 3: Function of the Benthic Pi: Using a delay loop, a photo is taken after a pre-determined time interval.

Led panels (***Figure 4***)

Based on commercial off the shelf (COTS) LED strip lighting (SMD 3014 V-TAC), each LED produces light over a 120° arc in air. Two types of LED arrays were used:

- Small one for near field use, with two near field panels used in parallel, giving a total of ca. 300 lm. (dimensions 22x52mm each) has 18 LEDs which consume 1.6W at 12V producing *ca*. 150 lm at a colour temperature of 6400°K.
- Large one for far field illumination (dimensions 94x110x10mm) with 270 LEDS consuming 24W at 12V producing *ca*. 2300 lm.

Resin embedding

The main issue with resin embedding the camera is that an air space must be maintained for the optical system. In the case of the Sony IMX219 camera the air space is small so that a thin walled housing can resist the surrounding pressure. The window in front of the lens is only 2 mm diameter (***Figure 3***) which using 1 mm thick optical slide glass exceeds the 2000 m depth specification for JELAB2.

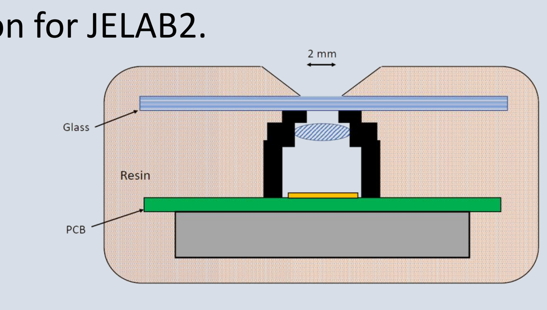


Figure 3. Schematic section of a Raspberry Pi camera module complete with circuit board embedded in resin.

Epoxy resin RX771C/NC with hardener HX771C/NC from Robnor Resin Lab Ltd, Swindon UK was used. A plug of the required shape was prepared and used to cast a flexible mould of ZA 50 LT bi-component (base and catalyst) RTV silicon rubber.

Underwater trials

The first underwater trials of the JELAB2 were performed in HCMR's Thalassocosmos facilities in Crete. The system was deployed in a four-meter depth aquaculture tank (***Figure 5***) and in the small harbour nearby (***Figure 6***). Sea trials were performed in the Heraklion gulf onboard the HCMR rib ***"IOLKOS"*** using a small manual winch able to lower the system to 100 meters below the surface (***Figure 7***).

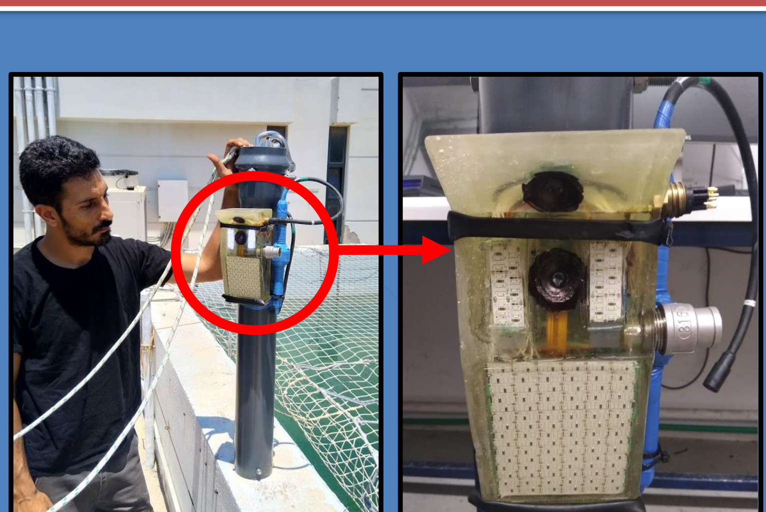


Figure 4. The JELAB2 test configuration with battery pack and ballast module.

Figure 6. The JELAB2 Benthic camera pictures taken during night in the Thalassocosmos harbour.

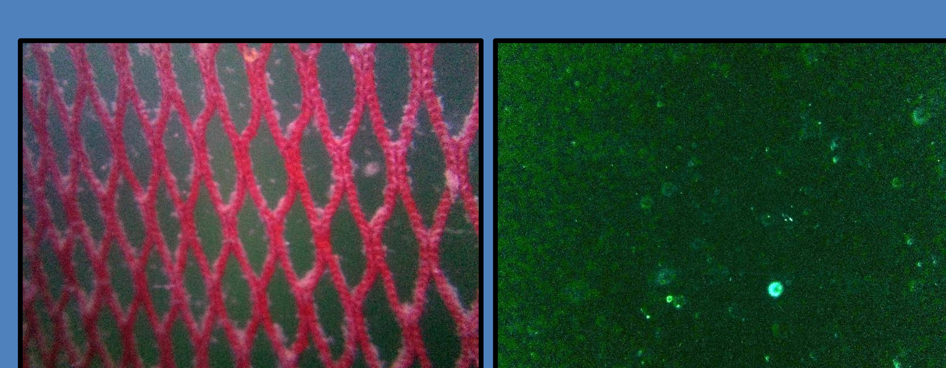


Figure 5. The JELAB2 Profiler camera pictures taken during the tests in the Thalassocosmos aquaculture tank. The left panel picture is an unprocessed picture targeting the nets inside the tank. The right panel picture is processed.

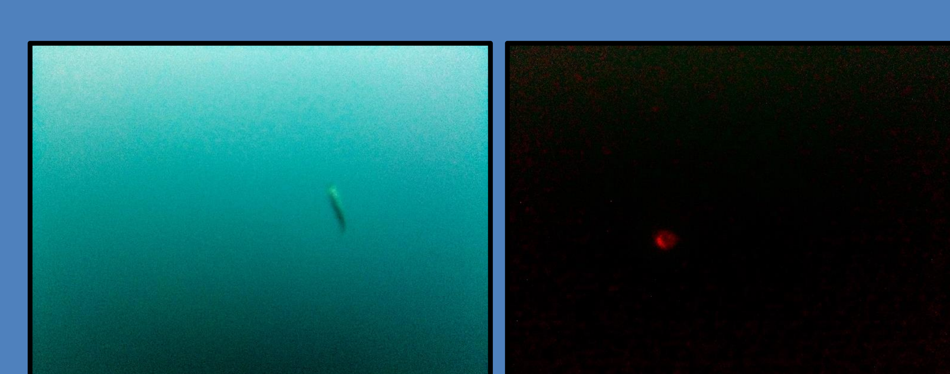


Figure 7. The JELAB2 Profiler camera pictures taken during the sea trials in the Heraklion Gulf. Left and right processed pictures captured respectively in 33 and 55 meters (as recorded by the pressure sensor).

Conclusions/Perspectives

The main conclusions are:

- An autonomous programmable dual camera system with LED lighting panels rated to 2000 m depth has been developed to meet the JELAB specification for a light-weight module capable of being carried on board an ARGO profiler float.
- The final prototype has dimensions 240x145x105 mm (connector included) and weights 0.375 kg (immersed in sea-water) which is comparable to the dimensions and payload of scientific sensors that have been successfully integrated in the ARGO floats (e.g. Wet labs Fluorometers, SUNA Nitrate sensor).
- The JELAB2 system is based on low cost commercial hardware (Arduino and Raspberry boards) and modules and can be expanded with the addition of more components and sensors.
- The software controlling the system, based on C/C++ and Python can be also modified in order to meet the demands of different user or scientific missions.

The future steps of the JELAB2 system:

- Further development and testing in the field aiming to improve the system operational capabilities.
- Data analysis will be continued to figure out the optimum sampling scheme (camera settings) for different deployment scenarios.
- Before the integration in a float the JELAB2 will be exposed to greater water depths for a longer period in order to verify the requirements of the ARGO systems.
- Although the main limitation of the system is the large size of the collected data (pictures, video) that can not be transmitted using satellite connections, the metadata can be integrated in the ARGO transmissions.
- Apart from the ARGO floats JELAB2 can be used on a wide variety of platforms like: Profiling CTD, Benthic Landers, Fixed point mooring lines, Surface buoys, Gliders

Acknowledgment

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