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CRUISE REPORT

GRASSMAP

RV SOCIB

14 – 20 September 2021,

Palma de Mallorca – Cabrera – Palma de Mallorca

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Contents

1 Summary

This project aims to demonstrate in situ capabilities for current state of the art platforms to enable remote awareness by removing common bottlenecks such as post-processing and classification of recorded underwater imagery. The methodology will be applied for the assessment of endemic seagrass species (*Posidonia oceanica*) in the Mediterranean using three different untethered platforms: an Autonomous Underwater Vehicle (AUV), an Autonomous Surface Vehicle (ASV) and a Lagrangian Drifter (LD).

2 Research Programme/Objectives

2.1 Programme

Posidonia oceanica (PO) is a seagrass with an extremely high ecosystemic value, as it provides shelter and oxygen to marine creatures, stabilizes the seabed, increases seafloor roughness breaking swell and wind-driven waves, encouraging the deposit of sedimentary particles [PI21]. It acts as a host to actual filterers such as sponges and provides the Balearic islands with their famous crystalline waters. Until recently, seagrass exploration has been carried out manually by divers. These dangerous, expensive and time-consuming tasks can be replaced with innovative underwater exploration approaches using Autonomous Underwater Vehicles (AUVs) and Artificial Intelligence (AI) guided image classification.

The main work area is at Cala Santa Maria (CSM), located in a Marine Protected Area (MPA) in the Cabrera Archipelago. The area was selected due to the low human impact, as anchoring is not permitted in the MPA waters, providing a representative baseline for an undisturbed location. Figure 1 shows where Cabrera Archipielago is located.

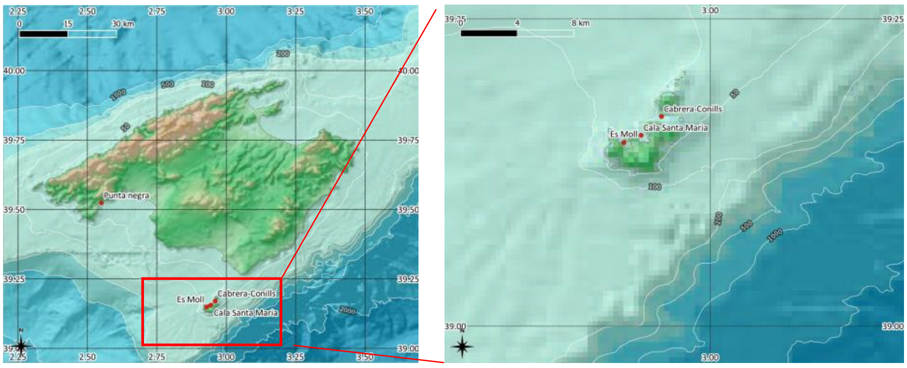


Figure 1: Working area - Marine Protected Area of Cabrera Archipielago

CSM has been previously studied by divers and surveyed using Uncrewed Aerial Vehicle (UAV) and its bionomy has been published [MA02]. Figure 2 shows the bionomy at CSM, where the PO is located in green, whereas sandy and rocky bottoms are shown in yellow and beige respectively.

In this cruise, two different underwater platforms are compared: a Lagrangian drifter “Floaty McFloatface” developed by the University of Southampton, and a Sparus II “Turbot” AUV manufactured by IQUA Robotics. Floaty LD equips two VRMagic VRmC-16 cameras and twelve Bridgelux Gen7 Vero 29 LEDs emitting a total of 200.000 lumens of warm hue white light. Turbot AUV is equipped with two AVT Manta G-283 cameras and two Aditech Mangrove AL-6V video lights. These platforms differ in the amount of required human support: the Lagrangian float drifts with sea currents whilst keeping at a constant altitude from the seafloor; whilst the AUV needs to have its trajectory pre-programmed and often relies on external localisation sensors to successfully achieve its mission with confidence. These external localisation sensors are often mounted on research vessels that become babysitting platforms for the AUVs, following them from the distance. The alternative presented by the University of the Balearic Islands to the use of research support vessels is an Autonomous Surface Vehicle (ASV) Xiroi, capable of following the AUV from the surface whilst carrying a USBL as a payload. This allows the distance between the AUV and the ASV to be minimal even in shallow waters to avoid common localisation problems with acoustics such as multipath [BA15] and frees the research vessel to perform other tasks.

This cruise objective is to answer the question of which intelligent sensing platform is better suited to replace divers at ecological monitoring for increased autonomy.

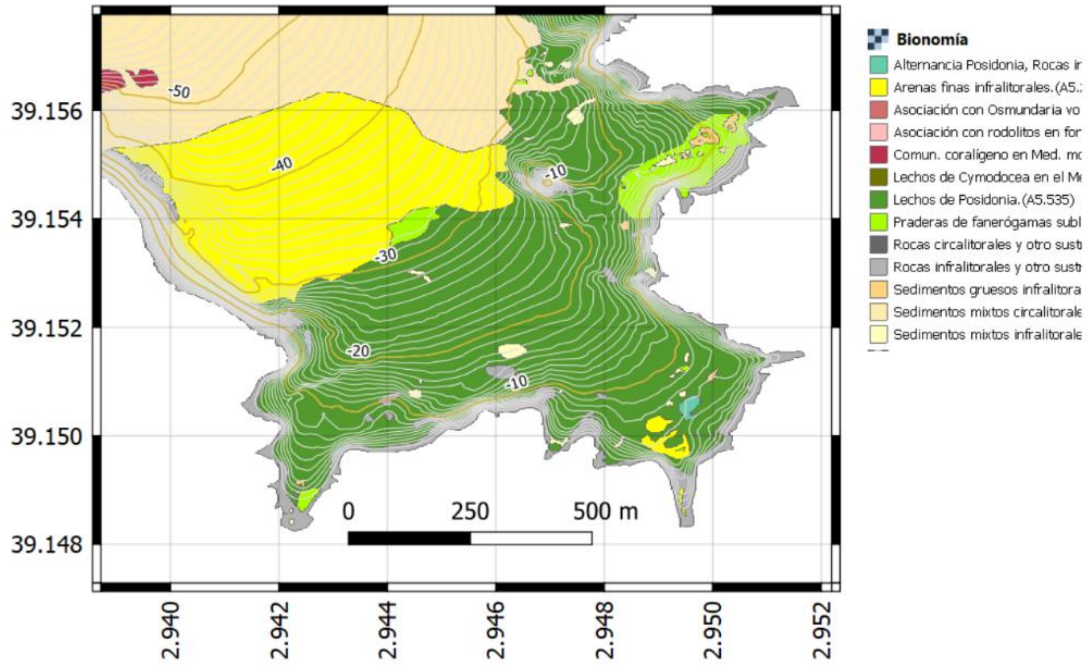


Figure 2: Bionomy of Cala Santa Maria in Cabrera. This cruise aims to assess the suitability of different platforms to detect Posidonia oceanica in their imagery data.

The traditional way in which targets visible in sub-sea images are characterised involves (1) field deployment of georeferenced imaging systems, (2) extraction of data through a physical connection (i.e. a tether or through the physical recovery of the system), (3) selection of a subsample of images for sparse description by human experts, and (4) use of aggregate statistics to represent the environment/region. This methodology limits the scale of interpretation to just a small fraction of the available data and introduces huge latency (months, years) when generating numerical summaries. Moreover, it needs dedicated research vessels or cabled infrastructure to support observations, which makes operation prohibitively expensive. To make imaging in marine applications scalable, there is a need to eliminate reliance on tethering and/or recovery for data extraction and develop end-to-end automated workflows (both training and analysis) for information extraction that is robust to different targets and instrument specifications.

This cruise will also address the above-mentioned bottlenecks to allow low latency, remote awareness of targets observed in benthic imagery using globally available satellite communication bandwidths. To achieve this, we will implement the framework presented in [YA20] for encoding and decoding images to send information through satellites and classify the underwater images looking for the coverage of the endemic seagrass *Posidonia oceanica*.

2.2 Turbot AUV

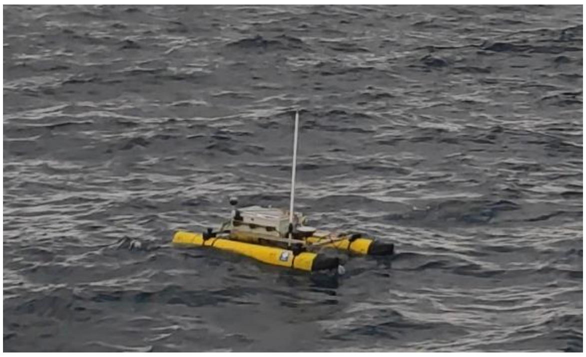
Turbot AUV [CA13] is an underwater platform manufactured by IQUA robotics and upgraded by the University of the Balearic Islands. The specifications of the platform are:

1.6 m torpedo-shape, 32 cm hull diameter
2 surge & 1 heave propeller
8 h autonomy, 60 kg, 200m rated
Navigation: DVL, IMU, pressure sensor, GPS, acoustic modem
Imaging payload: stereo camera, LED lights

2.3 Xiroi ASV

Xiroi ASV [MA15] is an autonomous surface vessel designed and built by UIB to follow Turbot AUV whilst carrying a USBL mounted on a pole underwater. The platform details are:

1.6 m long double hull catamaran
1.2 m distance between squids
2 surge propellers
12 h autonomy, 50 kg
Navigation: RTK GPS, IMU
Communications payload: USBL



2.4 Floaty LD

Floaty McFloatface [YA20] is a Lagrangian drifter designed and built by the University of Southampton to provide a sustainable and scalable alternative to underwater mapping. The platform can be deployed from a support vessel using winch or crane systems, and no human intervention is required during the mission duration. The specifications of the platform are:

1 x 0.85 x 0.34 m box-shaped Lagrangian drifter
2 heave propellers
1 week of autonomy, 70 kg, 200 m rated
Navigation: IMU, pressure sensor, altimeter
Imaging payload: stereo camera, LED strobes

3 Narrative of the Cruise

A summary of the activities aboard RV SOCIB is presented in Table 1. Briefly, the campaign start was delayed by one day due to equipment being delayed in customs for LD and the AUV missing its battery. It was recently changed for a new one and the shipment arrived on the day before. Both systems were assembled and tested at the docks in Palma in case any component failed or an unexpected item had to be purchased in the city of Palma. On the second day, we transited to CSM and started with the first mission.

Table 1: Activity summary for the GRASSMAP cruise on RV SOCIB. Mob. and Demob. stand for mobilisation and demobilisation respectively. GWD stands for Grey Water Discharge and CSJ stands for Colonia de Sant Jordi.

Time / Day	1 (14/09)	2 (15/09)	3 (16/09)	4 (17/09)	5 (18/09)	6 (19/09)	7 (20/09)
08:00	Mob.	Transit	Transit	GWD	GWD	GWD	GWD
08:30			LD				
09:00				Transit	LD	LD	AUV ASV
09:30			GWD	Crew shift			
10:00						AUV ASV	
10:30			LD	Transit			
11:00				AUV ASV LD	AUV watertight-ness tests		
11:30			AUV ASV				
12:00	AUV ASV LD testing						Transit
12:30		Prep					
13:00					GWD	GWD	
13:30				AUV flooded			
14:00		AUV		GWD	AUV ASV LD	Ship2shore	
14:30		LD	GWD				
15:00		Prep		LD		LD lost and recovered	
15:30		AUV ASV	LD				
16:00							
16:30			AUV ASV				Demob
17:00				Transit to CSJ and back		GWD	
17:30							
18:00						Medical Emergency	
18:30							
19:00						Camera calib.	
19:30		GWD	GWD		GWD		
20:00		Transit	Transit		Transit	Transit	

One issue that was communicated by the ship crew was the need to discharge grey waters three times a day. This requirement came from the low capacity of the water tanks in the ship combined with the impossibility of discharging these waters inside the MPA. To empty the grey water tanks we needed to transit 20 minutes out of the MPA and then transit back to the working area or the mooring site if it was in the afternoon. This issue affected our logistic planning and required us to replan the entire cruise on the site. The impact of this situation in terms of time can be seen in Figure 2

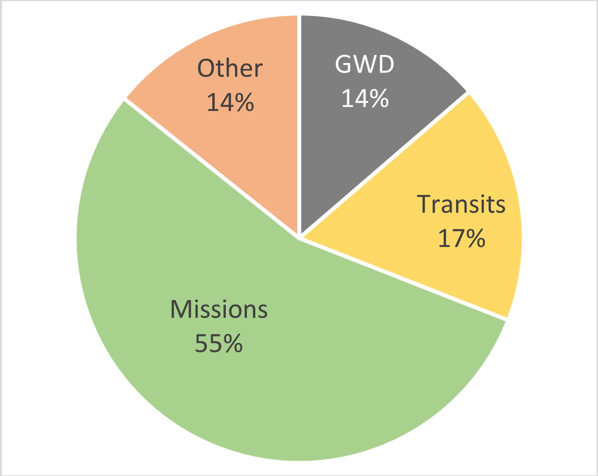


Figure 3: Pie chart of the average time utilisation for the allocated 12h/day.

On the fourth day, we exchanged two members of the scientific party. The specific reason for this was a misunderstanding between the ship crew and the vessel operators in the available number of scientific berths at the time of signature. In order not to leave someone who was already in the signed cruise proposal, we decided to transit to the Cabrera harbour, disembark one person and embark on a new one, with the corresponding COVID-19 controls in place.

In terms of non-planned events, on the 4th day, the AUV had flooded one housing, which involved going to Colonia de Sant Jordi (CSJ) to collect spare o-rings to replace the damaged ones. The next day, we tested the watertightness of the AUV housing by lowering it to 40m for 20 minutes and checking that there was no water inside after resurfacing.

On the 6th day, LD deployment and unexpectedly surfaced back 2h later than the expected time, and on that same day, a member of the scientific crew hurt himself and needed medical evaluation. Hopefully, there was an infirmary on the island of Cabrera and they recommended we go to the hospital in the next 24h, which was done by the next day.

Data gathering missions of the AUV, LD and ASV are summarized in Table 2, Table 3 and Table 4 respectively. Collectively, there are more than 20 hours worth of data and more than 60.000 images over the six days where platforms were deployed for data collection.

Table 2: Turbot AUV mission times and descriptions. Successful data commissions are indicated by an asterisk and in bold.

Date	*UTC Hour*	*Duration (s)*	*# Images*	*Mission target*
15/09/2021	14:29:05	209	0	Robot check
	15:52:46	238	505	Camera Check
	16:11:22	239	506	Dense survey (aborted)
	16:32:19	1944	3516	Dense survey (aborted)
	18:18:30	2047	4121	Dense survey
16/09/2021	12:24:14	404	0	Robot Check
	12:36:07	1247	0	Robot Check
	13:55:39	1141	0	Antenna range test
	14:14:46	726	0	Acoustic communications check
	17:06:37	1069	1684	Dense survey (aborted)
	17:27:07	2947	5132	**Dense survey***
	19:03:43	187	422	Robot Check
17/09/2021	11:14:26	644	994	Navigation params. check
	11:28:39	3529	6953	**Dense survey***
	12:34:37	2765	5230	Sparse survey (aborted)

18/09/2021	15:54:05	800	1583	Camera check
	16:42:06	1107	0	USBL and acoustic comms. check
	17:02:49	1022	0	USBL and acoustic comms. check
	17:25:06	3767	7560	Sparse survey (aborted)
19/09/2021	10:58:38	288	0	Watchdog test on surface
20/09/2021	09:36:15	877	1622	Camera and acoustics check
	10:14:08	882	1737	Test to check replanning.
	10:41:53	4295	8627	**Sparse survey***

Table 3: Floaty LD mission times and descriptions. Successful data collection missions are indicated by an asterisk and in bold.

Date	*UTC Hour*	*Duration (s)*	*# Images*	*Mission target*
16/09/2021	13:28:31	600	0	System check. Adjust PID gains
	15:53:09	600	800	System check. Adjust PID gains
17/09/2021	09:23:22	1200	807	System check, timekeeping
	13:05:53	3600	1206	**Drift. Blurry images***
	14:11:19	3600	1151	**Drift. Blurry images***
18/09/2021	06:37:50	4200	3677	**Drift. Blurry images***
	11:44:58	1200	793	Testing camera gains
	12:36:51	3600	0	Testing camera gains (overexp.)
	13:07:44	3600	1268	Testing camera gains
	14:45:02	3600	2358	Testing camera gains
19/09/2021	06:50:58	850	192	**System check. Short drift***
	09:24:07	850	192	**System check. Short drift***
		7200	0	Long drift. Corrupt hard drive.

Table 4: Xiroi ASV mission times and descriptions.

Date	*UTC Hour*	*Duration (s)*	*Mission target*
15/09/2021	17:14:50	183	Robot check
	18:18:28	2420	Turbot AUV following
16/09/2021	12:26:09	256	Navigation and sensors check
	13:09:42	805	Robot check
	13:55:50	630	Antenna range test
	17:06:30	786	Turbot AUV following
	17:34:09	2700	Turbot AUV following
17/09/2021	11:01:24	157	Turbot AUV following
	11:09:24	130	Turbot AUV following
	11:28:49	1360	Turbot AUV following
	12:32:28	365	Turbot AUV following

4 Preliminary Results

4.1 Missions

Turbot AUV performed two dense missions and one sparse. The trajectories of Figure 4 correspond to two datasets collected by the robot during two different missions navigating at a constant depth of 40 meters, performed in Cala Santa Maria, the 16/09/2021 (a), and the 17/09/2021 (b), covering an approximate area of 800 squared meters each one. Vehicle trajectories are estimated by the vehicle navigation module which consists of an EKF (Extended Kalman Filter) that integrates the velocity and altitude given by a DVL, inertial velocity and acceleration from an IMU, a visual altimeter, the altitude from an echosounder pointing downwards and a pressure sensor to estimate depth. These navigation data are included in the bag files recorded online, during each mission. The location of the initial point in the mission date on 16/09, in decimal degrees, is (39.1533, 2.9446), and the initial location of the mission dated 17/09 is (39.1535,2.9443). Missions are programed in Turbot and Xiroi using the HMI IquaView. [IQUAVIEW]

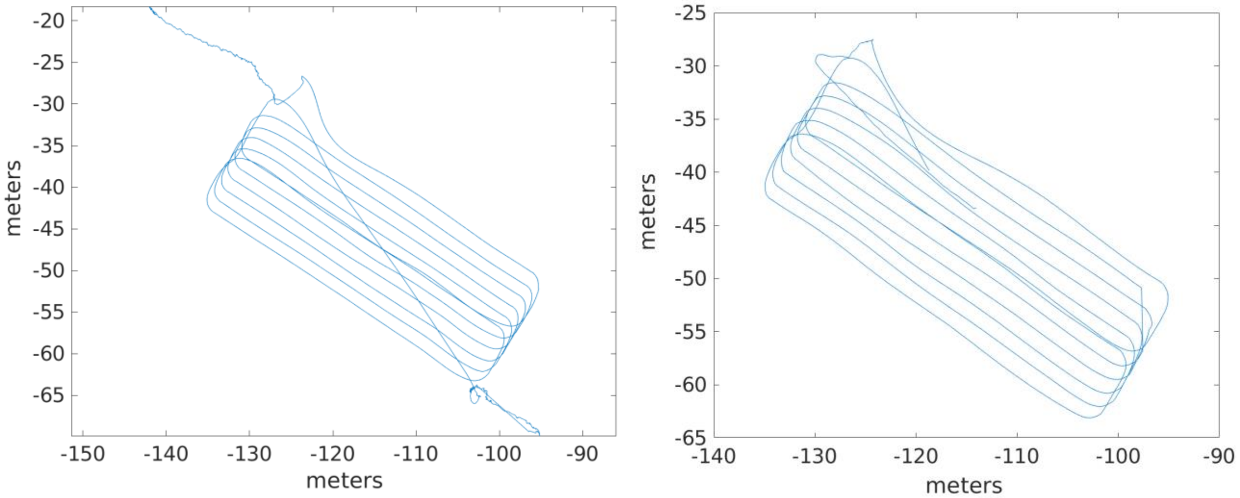


Figure 4: Sparse missions performed on the 16th (a) and 17th (b) of September 2021 by Turbot AUV.

Floaty LD performed 5 successful drifts, where on 3 of them the images were not fully in focus. This issue was solved by manually focusing the cameras on the deck, which involved modifying the acquisition parameters and adjusting them to the strobe light. The last two missions were scheduled as overall system checks before a long drift to collect more data. Unfortunately, the last long drift was unsuccessful. The platform surfaced back with an empty battery and a corrupt hard drive. No data could be recovered from that last mission.

4.2 Underwater image colour correction

Raw images gathered have been post-processed with the suite *oplab_pipeline* developed by UoS and publicly available, to recover colour information from the underwater images. Figure 5 shows two raw images from Floaty LD, where the red spectrum is almost missing from the colour image. After applying correction algorithms, we can retrieve colour-corrected images such as the ones in Figure 6.

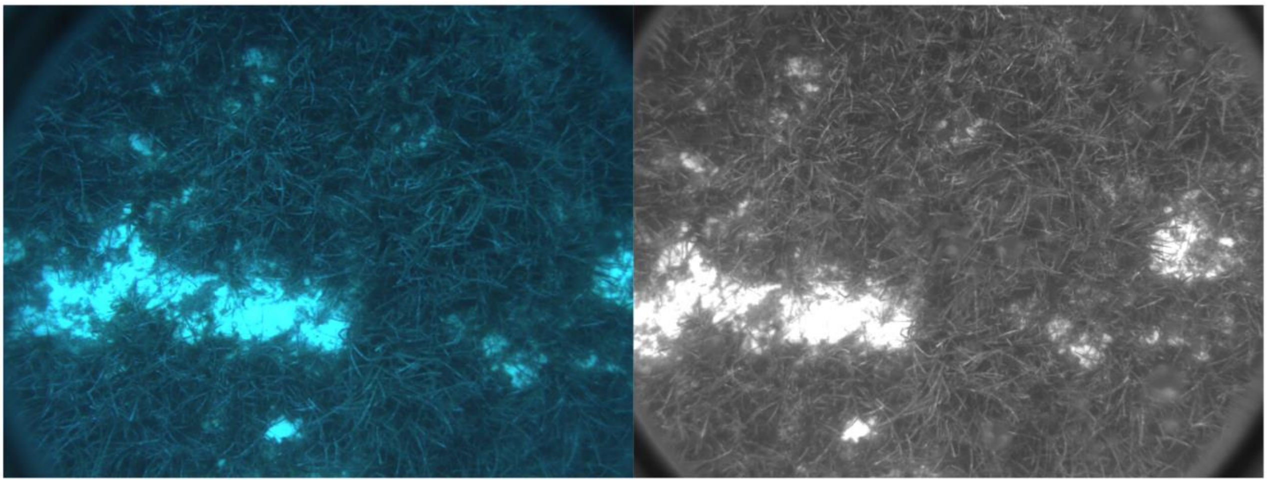


Figure 5: Left (colour) and right (grayscale) raw images of the seafloor from Floaty LD. A *Posidonia oceanica* continuous patch can be observed in both pictures.

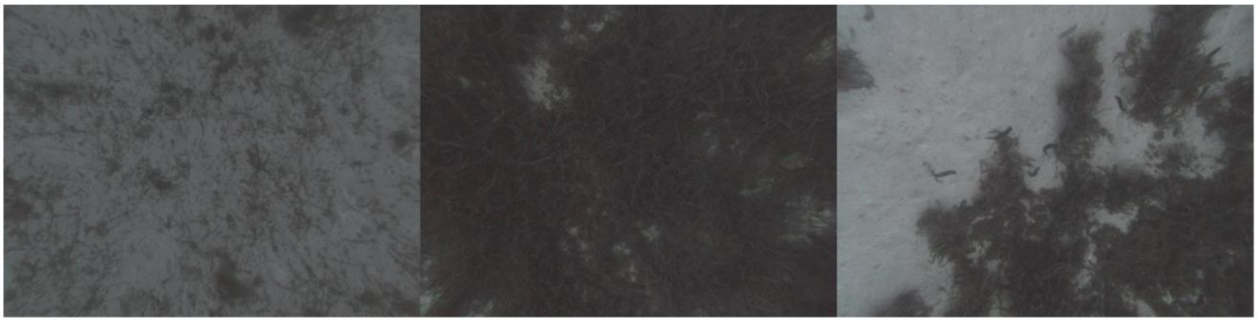


Figure 6: Example colour corrected images gathered using Turbot AUV.

4.3 Habitat classification

Keyframes used to build the mosaics are extracted from the ROS bag files recorded during each mission covered with Turbot and played at the lab on a PC. The original resolution of keyframes was decimated by 4, and images were debayered and rectified using the calibration camera parameters and stored in the hard drive.

Keyframes were extracted for every 0.35 meters of camera displacement. The camera displacement is estimated as the robot motion, which is obtained from the navigation data detailed previously.

Stored keyframes are colour corrected and contrast-enhanced using a CLAHE (Contrast Limited Adaptive Histogram Equalization) algorithm, and afterwards, images are segmented using the Convolutional Neural Network presented at [MA18], to discriminate the Posidonia from the background. Segmented images are in a grey-scale format, where the grey level of each pixel indicates the probability of being Posidonia, being white the colour that indicates the maximum probability of being Posidonia and black, the minimum.

Once the images have been extracted and segmented, two mosaics are built, one with the original colour images and another one with the segmented images. Keyframes are placed at a position (x,y) and orientation (yaw) equal to the camera pose registered at frame grabbing but scaled from meters to pixels using the vehicle navigation altitude. Areas with overlaps between keyframes blended with a multi-band blending technique, in both, the colour and the grey-scale mosaic. Figure 7 shows the two mosaics, colour and segmented, corresponding to the dense trajectory performed by Turbot the 16/09/2021, corresponding to figure 4 (a)

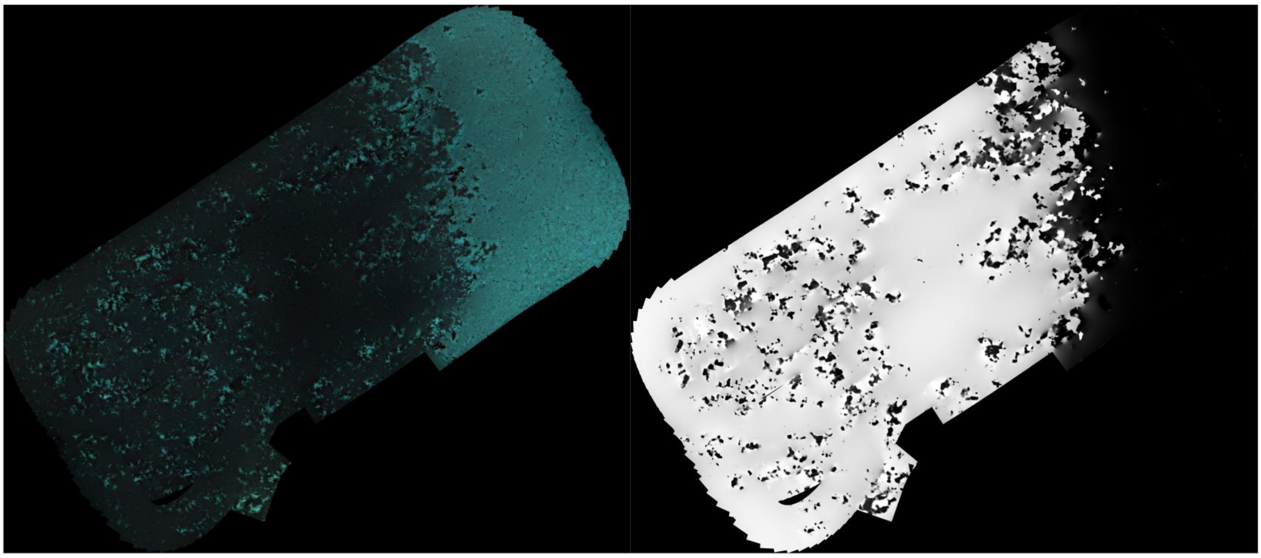


Figure 7: Mosaic of the dense survey (16th Sept) and the corresponding PO cover.

As a second habitat classification method, we present the outputs of a Location-Guided Autoencoder (LGA) [YA21]. LGA is an unsupervised convolutional neural network net that can be trained with no human input. Then, its latent space has been clustered without supervision and 100 most representative images labelled manually to be either sand or PO. This information is fed to LGA, where a Support Vector Machine extends the labels to the rest of the latent space. The results of this step can be seen in Figure 6.

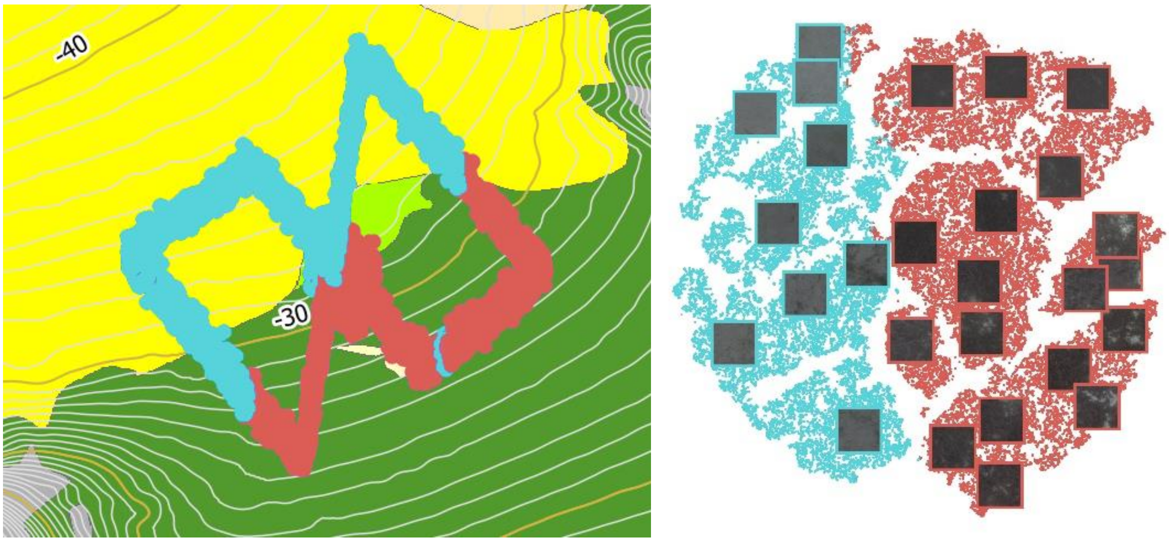


Figure 8: Location-guided autoencoder classification outputs. Sand is classified in light blue whereas PO is classified in red colour. On the left, the location of the images is drawn on top of the known bionomy, and on the right-hand side, the TSNE space is shown.

5 Data and Sample Storage / Availability

Data is to be uploaded to Squidle+ (http://soi.squidle.org) and made public under the user group EF+GRASSMAP.

6 Participants

Table 5: GRASSMAP participants that embarked onboard R/V SOCIB. Participants funded by EUROFLEETS+ are indicated with an asterisk.

No.	Name	Early career (Y/N)	Gender	Affiliation	On-board tasks
1	Miguel Massot Campos*	Y	M	UoS	PI, Drifter operator
2	Jose Cappelleto*, Student		M	UoS	Drifter operator
3	Eric Guerrero, Student		M	UIB	AUV operator
4	Antoni Martorell	Y	M	UIB	ASV operator and technician
5	Caterina Muntaner, Student		F	UIB	AUV operator
6	Bo Miquel Nordfelt, Student		F	UIB	Camera operator
7	Miquel Martin Abadal		M	UIB	AUV operator
8	Francisco Bonin	N	M	UIB	AUV team coordinator

Affiliations:

UoS	Dept. of Civil, Maritime and Environmental Engineering. University of Southampton. United Kingdom
UIB	Systems, Robotics and Vision. Dept. of Mathematics and Computer Science. University of the Balearic Islands. Spain
USyd	Australian Centre of Field Robotics. University of Sydney. Sydney. Australia

Table 6: GRASSMAP remote participants.

No.	Name	Early career (Y/N)	Gender	Affiliation	Remote tasks
9	Gabriel Oliver	N	M	UIB	Remote support & coordination
10	Yolanda Gonzalez	N	F	UIB	Image classification
11	Blair Thornton	N	M	UoS	Image classification
12	Oscar Pizarro	N	M	USyd	Trajectory optimisation, image classification
13	Jackson Shields, Student		M	USyd	Trajectory optimisation, image classification

7 Station List

- Palma harbour (Ship berth)
  - Location: 39.563195, 2.636231
  - Description: Used for testing and trimming of platforms
- Cabrera harbour
  - Location: 39.151014, 2.933625
  - Description: Used for calibrating Turbot AUV cameras
- Cala Santa Maria
  - Location: 39.152745, 2.944927
  - Description: Main site

8 Acknowledgements

RV SOCIB ship-time was provided free of charge for the GRASSMAP survey, as part of the Eurofleets+ project which received funding from the European Union’s H2020 Research & Innovation Programme (grant agreement No. 824077).

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