An Autonomous Craft for the Study of Sea-Air Interactions

Sampling Sea Surfaces with SESAMO

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The sea surface autonomous modular unit (SESAMO) catamaran was satisfactorily exploited for sampling the sea-surface microlayer and immediate subsurface in the Terra Nova Bay area of the Ross Sea during the XIX Italian expedition to Antarctica in January–February 2004. The SESAMO prototype robot, designed to collect data and samples for the study of the sea-air interface, is the result of the synergy between the robotics group of Consiglio Nazionale delle Ricerche–Istituto di Studi sui Sistemi Intelligenti per l''Automazione (CNR-ISSIA), Genoa branch, and the scientific end users of Consiglio Nazionale delle Ricerche–Istituto per la Dinamica dei Processi Ambientali (CNR-IDPA, or Institute for the Dynamics of Environmental Processes) in the framework of a project of the Italian National Program of Research in Antarctica (PNRA). At sea, operations showed that a relatively simple robot could satisfactorily work in a natural, outdoor environment, dramatically facilitating the job of the human operator.

Research carried out in the last decade emphasized the role played by the physical and chemical interactions between the hydrosphere and atmosphere in the prediction of global-scale climatic circumstances. This gave a strong impulse to the study of the sea-surface microlayer (i.e., approximately the top 1 mm of open water bodies), as a modulator for the exchange of matter and energy between the atmosphere and aquatic ecosystems. In addition, the concentration in the microlayer of man-made compounds (such as pesticides, aromatic polycycled hydrocarbons, and oil combustion depositions) is hypothesized as increasing 2–1,000 times with respect to the bulk water, revealing the importance of the analysis of the sea surface for pollution evaluation. In addition, the surface microlayer emerged as an environmental portion with its own

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Operations showed that a relatively simple robot could satisfactorily work in a natural, outdoor environment.

Figure 1. *The SESAMO water sampling and distribution system: pumps and valves.*

properties, composition, and structural composition and even a unique community of life-forms named *neuston*. The analysis of chemical and/or biological constituents of the surface microlayer is usually executed on thin slices of water removed from the surface by conventional collectors such as metal screens, glass plates, polycarbonate membranes, teflon sheets, and rotating drums (i.e., a rotating hydrophilic cylinders that collect the adsorbed film). The last device, first proposed by Harvey in the mid-1960s [1], is usually mounted on small radio-controlled catamarans. The readers interested in aquatic microlayer research can find more detailed information in [2] and in the references therein. Currently, data and sample collection techniques are usually based on catamarans equipped with single microlayer samplers [3] or with a number of devices for the evaluation of the surface and the near atmosphere, as is done for WHOI LADAS [4].

As for technological background, in recent years, progress in the field of marine system automation and robotics led to the development of autonomous surface craft for water monitoring, such as the Measuring Dolphin [5], developed by the University of Rostock, Germany, for the collection of hydrographic and bathymetric data, as in the case of the Massachusetts Institute of Technology's Autonomous Coastal Exploration System (ACES) [6] and AutoCat [7]; and for the enhancement of the acoustic communication rates with a companion automated utility vehicle (AUV), as in the case of DELFIM, developed by Lisbon Instituto Superior Tecnico–Instituto de Sistemas e Robotica (IST-ISR)[8].

Based on the aforementioned technological background and the in-field experience gained by developing and operating the multiuse microlayer sampler (MUMS), a radio-controlled catamaran equipped with a rotating drum for microlayer sampling in the Tyrrhenian [9] and Antarctic coastal zones and in the Venice lagoon [10], the SESAMO project aimed to design, develop, and test an autonomous platform for data collection and the sampling of surface microlayer, water column, and near atmosphere in a scientific end-user predefined area.

The project was strongly interdisciplinary, concerning both the collection of water samples for the study of biochemical-physical interactions between ocean and atmosphere (and their relations to climatic and environmental change) and the design and development of an autonomous surface vessel. It is worth noting that marine scientists have been involved not only in the definition of the system specifications, but also in the design of the vessel and sampling system in order to better satisfy scientific requirements.

System Requirements

The main system goal is the collection of an integrated sample (i.e., a certain quantity of water in an area of interest) of the surface microlayer and immediate subsurface layer, with the monitoring of the air basic parameters just above the sea surface. In particular, scientists require two separate samples (organic and inorganic anolytes) for both layers. The collected water, 25–35 L for each layer (20–25 L of organic compounds and 5–10 L of inorganic ones), should be stocked in bottles of about 5 L in order to allow easy handling during in-field operations.

In addition, the possibility of executing on board in real-time a rough analysis of the sample could allow the scientific end users to evaluate the sampling performance and, if necessary, to replan the mission.

In any case, the quality of the sample must not be altered by the collector. This requirement imposes strong constraints on the choice of matter for constructing the sample collection, stocking devices, and vessel hull, and it also constrains the operation of the platform at field, maintaining the support vessel as far as possible from the interesting area, which must be reached by the catamaran autonomously. Thus, the robotic vessel should be able to both move at a relatively high cruising speed to go to and come back from the sampling area and to maneuver at an advance speed of a few centimeters per second with respect to the water while collecting samples.

From the point of view of vehicle maneuverability, the system is required to move in a user-defined area, maximizing the data collected and minimizing the consumed energy in order to perform an integrated sampling.

The extreme environmental operating conditions in Antarctica require the thermic isolation of some critical components of the sampling and stocking system as well as the possibility of the deployment or recovery of the platform by small support vessels.

System Design

The catamaran is—for stability with respect to roll, capability of payload transport with respect to the hydrodynamic drag, and redundancy in hull buoyancy—the kind of vessel usually employed in this type of application. Thus, taking into account the aforementioned operational needs, a catamaran was built with a length of 2.40 m, a width of 1.80 m, a hull height of about 0.60 m, and a space between the two hulls of 0.90 m. In particular, as far as the hull length is concerned, the resulting shape (rather short and wide) was constrained by the space available on the stern deck of the Antarctic support vessel and by the need to maximize the space for the scientific payload between the hulls. In order to avoid contamination for organic and inorganic analities, the hull was constructed in fiberglass covered with epoxide resin. The overall vehicle weighs about 360 kg (the payload weighs 55 kg) plus 60 kg of loaded water samples, with a resulting ratio between payload and carrier weights of 0.32.

The robot is powered by a set of four lead batteries, 12 V at 42 Ah, integrated with a set of solar panels to supply power peaks and to increase system autonomy.

In order to guarantee high performance during low-speed maneuvers, a propulsion system consisting of two propellers actuated by two electrical thrusters was designed. Steering is based on differential propeller revolution rates. Since commercially available electrical thrusters for small boats do not usually guarantee a fine velocity tuning at low speed, the choice was to use, at least for the first catamaran prototype, remotely operated vehicle (ROV) actuators specially designed for operating near bollard condition (that is, when the propeller is rotating with no speed of advance). Each thruster consists of a MAE M644-2530 dc motor (300 W at 60 V) with the corresponding tachometer and rotary joint and is coupled with a three-blade propeller. Each dc motor is controlled by a Mini Maestro DCD 60 V servo-amplifier, which performs a proportional-integral differential (PID) control of the thruster velocity on the basis of the error between the signal of the motor tachometer and the reference speed.

The robot navigation package consists of a global positioning system (GPS) Ashtech GG 24 C at 2 Hz integrated with a KVH Azimuth Gyrotrac able to compute the true north given the measured magnetic north and the GPS-supplied geographic coordinates. A TV camera allows a robot a subjective panoramic view of the operating environment. Wind direction and speed are measured by a weather station that can also supply the temperature of the atmosphere just above the sea surface.

Figure 2. *The SESAMO microlayer sampler during in-lab calibration.*

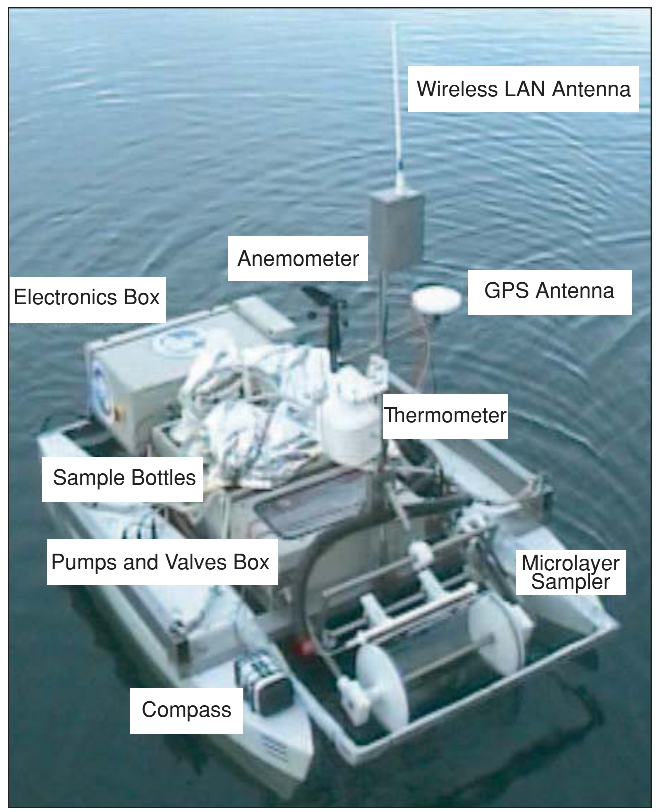

Figure 3. *The SESAMO platform.*

The onboard computing system, based on single board computers (SBC) and PC-104 I/O modules, consists of a SBC board (supporting an Intel Pentium III at 750 MHz CPU, 4 RS-232 serial ports, 1 CompactFlash slot, and Ethernet 100 Mps), and three PC 104 modules supporting digital input/output, analog input, and analog output respectively.

The onboard control system of the vehicle and scientific payload communicates through a radio wireless LAN at 1.9 Mbs, supporting robot telemetry, operator commands, and

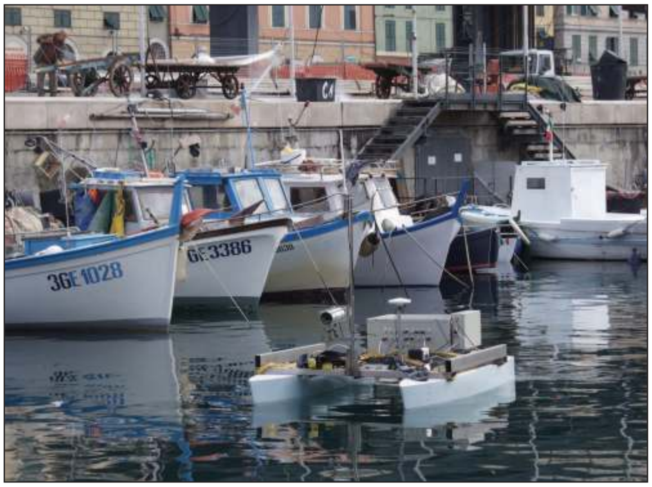

Figure 4. *Basic SESAMO tests in Genoa harbor wet dock on 22 October 2003.*

Figure 5. *The SESAMO catamaran on the* Malippo *stern deck (Terra Nova Bay, February 2004).*

Figure 6. *The SESAMO deployment from the* Malippo, *which is anchored to the ice pack (Terra Nova Bay, 20 January 2004).*

The robotic vessel should be able both to move at a relatively high cruising speed and to maneuver at an advance speed of a few centimeters per second.

video feedback from the onboard TV camera, with an operator station located on a supporting vessel for direct at-field mission control.

As far as the scientific payload is concerned, each sampling line consists of a water collector (i.e., a rotating drum for microlayer and a simple seawater intake for immediate subsurface), from where the collected fluid is conveyed to the analysis or stocking bucket by a teflon-membrane pump. A three-way valve allows the deviation of the flux towards both the collecting buckets and a drain conduct, which is used to guarantee the washing of the lamina and the collection line. A kind of "dead volume," where probes for the onboard measuring of water temperature, salinity, and dissolved oxygen are located, is positioned along the drain conduct of the surface microlayer sample. A three-way valve deviates the flux of the stocked sample towards four 5-L metallic bottles for organic analities and one 10-L nalgene bottle for inorganic ones. The system can stock 20 L of organic analities and 10 L of inorganic ones, both for microlayer and immediate subsurface samples. In order to maintain the overall vehicle weight during sampling, ballast water tanks to be emptied over the course of the mission were positioned in the catamaran hulls. It is worth noting that all the line components are in Teflon, in order to avoid any contamination of the analities. A view of the SESAMO distribution system is shown in Figure 1.

The surface microlayer sampler, shown in Figure 2, is based on the adsorption of the water film. A rotating glass drum (33 cm in diameter, 50-cm long) collects the water film on its surface from where it is removed by a mylar lamina. The drum, actioned by an electrical thruster, can rotate at very low speed, i.e., 4–10 r/min.

A view of the resulting vessel is shown in Figure 3, where the dislocation from bow to stern of the sampling device, pump and valves box, sample bottles, and electronics is clearly visible.

Control Architecture

Control System

The control system is composed of the navigation, guidance, and control (NGC) system of the vessel, the data acquisition and control system (DACS) of the scientific payload, the human computer interface, and, in a second phase, the supervision module able to coordinate the NGC tasks with the sampling activities.

The vessel motion is controlled by the vehicle NGC system able to estimate the vehicle motion on the basis of GPS and compass measurements and to autonomously pilot it according to user requirements.

The scientific payload DACS handles the surface microlayer and subsurface sampling devices, controlling the pumps, valves, and drum actuation system and any additional sensors, such as probes for water analysis and the weather station.

The supervision module, not yet present in the first operating release, will coordinate the activities of the vehicle NGC system and scientific payload DACS, starting from simple actions, such as suspending water sampling during high-speed maneuvers or washing the collection line at fixed time intervals, to more complex ones, such as executing different maneuvers according to real-time measurements of the quality of the sample.

The ease of piloting the vehicle during operations led to the development of a human computer interface, enabling the user(s) to define the required mission and monitor its execution in real-time, comprising instances of two basic modules.

- *Pilot and system engineer interface*: Allowing full access to the vessel and payload control system, including the capability of setting and visualizing algorithm parameters and selecting control and estimation algorithms
- *Pilot and scientific end user*: Providing basic navigation data, accepting and sending basic guidance commands (i.e., heading, surge, and way-points) according to the selected working mode, and allowing full display and access to scientific payload data and control variables.

Basic Guidance and Control

In the first phase of the project, basic automatic guidance capabilities, i.e., auto-heading and line-of-sight (LOS) guidance, proved to be sufficient for the scientific end user to accomplish the main project goal of collecting surface microlayer and immediate subsurface water samples in an area of interest during the XIX Italian expedition to Antarctica. More sophisticated guidance techniques for path-following such as [11] will be evaluated in the future. Preliminary at-field trials for onboard identification of the hydrodynamic model of the robot revealed that the influence of the wind on the robot dynamics is not negligible, even when its speed is relatively low, i.e., lower than 5 kn. Conventional guidance and control algorithms implemented on the catamaran are summarized in the following for the sake of completeness.

Propulsion System Modeling

The thrust exerted by each propeller can be modeled as

$$\tau = a_n n|n| = a_V V|V|, \tag{1}$$

where V is the reference voltage applied to servo-amplifiers and n is the propeller revolution rate. $V \propto n$ due to servo-amplifiers action.

High quality sampling of surface microlayer requires a large amount of time leading to significant requests of the logistic resources.

Denoting with the subscripts L and R for the left and right actuators, respectively, the surge force f_u and yaw torque T_r assume the form

$$\begin{aligned} f_u &= \tau_L + \tau_R \\ T_r &= (\tau_L - \tau_R)\, d, \end{aligned} \tag{2}$$

where d is the half distance between the propellers, and the normalized control actions

$$\begin{aligned} \tilde{f}_u &= \frac{f_u}{2a_V} = \frac{V_L|V_L| + V_R|V_R|}{2} \\ \tilde{T}_r &= \frac{T_r}{2a_V d} = \frac{V_L|V_L| - V_R|V_R|}{2} \end{aligned} \tag{3}$$

can be defined.

Proportional-Derivative-Type Heading Control

A conventional proportional-derivative (PD) controller of the vehicle heading has been designed and implemented. The input variables are the reference and estimated heading, ψ^* and $\hat{\psi}$ respectively, while the output control signal is the normalized yaw torque $\tilde{T}_r^*$.

Introducing a saturation mechanism, the resulting algorithm is

$$\begin{aligned} \tilde{T}_{PD}^* &= k_P(\psi^* - \hat{\psi}) - k_D \dot{\hat{\psi}} \\ \tilde{T}_r^* &= sat\left(\tilde{T}_{PD}^*, -T_r^{MAX}, T_r^{MAX}\right), \end{aligned} \tag{4}$$

where sat denotes the saturation function.

Line-Of-Sight Guidance

A LOS algorithm, generating the reference heading, has been implemented for basic way-point guidance:

$$\psi^* = atan2(y^* - \hat{y}, x^* - \hat{x}), \tag{5}$$

where $(x^*\ y^*)$ and $(\hat{x}\ \hat{y})$ are the reference and measured coordinates of the vessel.

Sea Trials

After the SESAMO catamaran launch and basic buoyancy and maneuverability tests, extended navigation, guidance, and control trials were performed in the Genoa harbor at the end of October 2003 [12]; see Figure 4. Basic PD-type

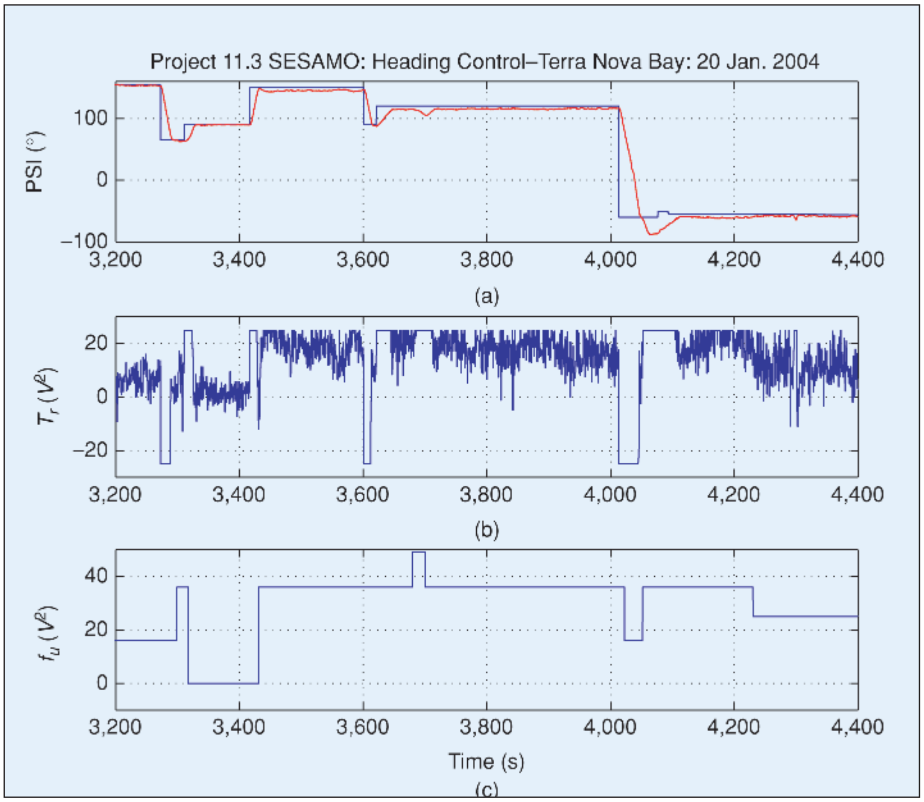

Figure 7. *PD-type auto-heading: (a) reference (blue) and measured (red) headings; (b) normalized control torque; and (c) normalized surge force (Terra Nova Bay, 20 January 2004).*

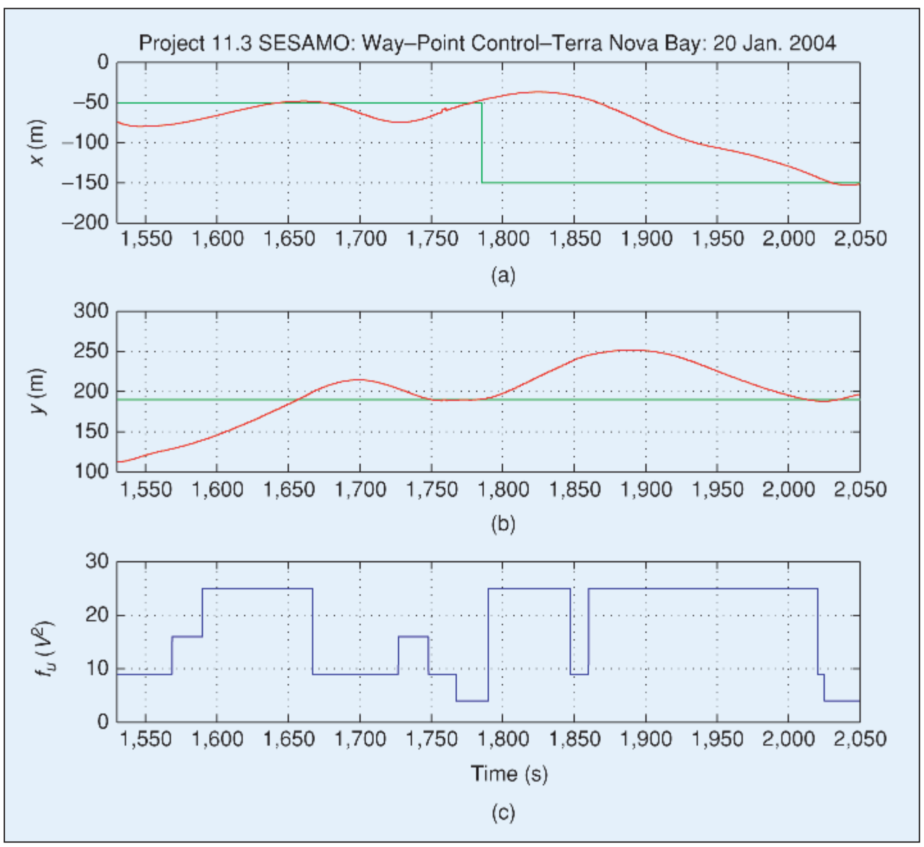

Figure 8. *Line-of-sight waypoint guidance: reference and estimated x-y coordinates and applied surge force (Terra Nova Bay, 20 January 2004).*

auto-heading was tuned and showed satisfactory performance as well as LOS guidance. Thus, the system was ready for the XIX Italian expedition to Antarctica, where sea trials of the robotic catamaran and scientific payload were completed in January 2004.

The SESAMO platform was operated according to weather conditions in the proximity of the Italian station of Terra Nova Bay ($74^\circ\,41'\,S$, $164^\circ 03'\,29\,E$), Ross Sea, in the Gerlache Inlet and Tethys Bay area. During operations, the catamaran was deployed and recovered by the *Malippo*, a 16-m support vessel hosting the human operator surface station, in the proximity of the sampling area. A view of the SESAMO catamaran on the *Malippo* stern deck is shown in Figure 5. When possible, operations were carried out with the *Malippo* anchored to the ice pack (Figure 6). The wireless communication system allowed control of the vehicle up to a 550-m range, avoiding pollution of the sampling area with the support vessel.

The behavior of the PD-type heading controller is shown in Figure 7, where the reference and measured headings, normalized control torque, and surge force are plotted. The controller gains had the values tuned in Genoa harbor trials, i.e., $k_P = 4.0$, $k_D = 6.0$ and $T_r^{MAX} = 25.0$, with the angles expressed in degrees. With incremental applied surge force, the steady-state error increases, pointing out the presence of a torque induced by the vehicle surge. In any case, the performance of the PD heading controller is satisfactory for the needs of the scientific end user (who must smoothly pilot the vehicle inside an interesting area), for the fine approach of the support vessel for platform recovery, and for a guaranteed satisfactory performance of the automatic LOS guidance system.

As far as LOS guidance is concerned, the vessel navigated through a sequence of waypoints manually set by the human operator as soon as the current one was reached by the vehicle. The applied surge force was also set by the human operator, basically according to the distance from the target point. The reference and GPS-measured coordinates of the vehicle are plotted in Figure 8, together with the normalized surge force, while the vessel path is shown in Figure 9. It is worth noting the classic behavior of the LOS algorithm when the final waypoint is not moved and a constant non-null surge force is applied: the vehicle continues to bend in the proximity of the desired waypoint.

The application goal, i.e., collecting samples inside an area of a few square kilometers, did not motivate the use of a differential GPS.

As far as the surface microlayer sampling system is concerned, the optimization of the orientation and position of the mylar lamina with respect to the cylinder led to a flux of collected water of about 6 L/h, with the drum rotating at 7 r/min.

Robot trials and operations were always carried out in relatively smooth sea and wind conditions (during Genoa harbor tests there were gusts of up to 30 kn); according to system requirements, the vessel was designed to work in calm waters, satisfying shape and size constraints given by logistic and operational needs (see "System Design").

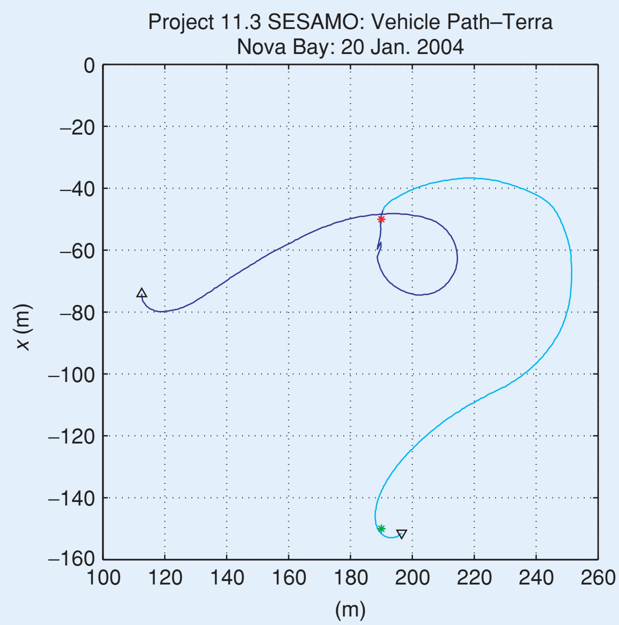

Figure 9. *Line-of-sight waypoint guidance: the catamaran path. Asterisks denote waypoints; triangles denote the initial and final position of the vessel (Terra Nova Bay, 20 January 2004).*

Table 1. SESAMO Mission Summary.

Date	Length	Goal	μl O	μl I	ss O	ss I
20 Jan.	1h15′	NGC-comms tests	—	—	—	—
26 Jan.	3h30′	Water sampling system trials	20 l	—	20 l	10 l
31 Jan.	4h00′	Exploitation	9 l	10 l	20 l	10 l
4 Feb.	1h15′	NGC tests	—	—	—	—
5 Feb.	4h50′	Exploitation	20 l	6 l	—	6 l
9 Feb.	5h15′	Exploitation	20 l	11.8 l	20 l	10.7 l

(a)

(b)

Figure 10. *The SESAMO platform maneuvers to avoid a block of ice (Terra Nova Bay, 9 February 2004).*

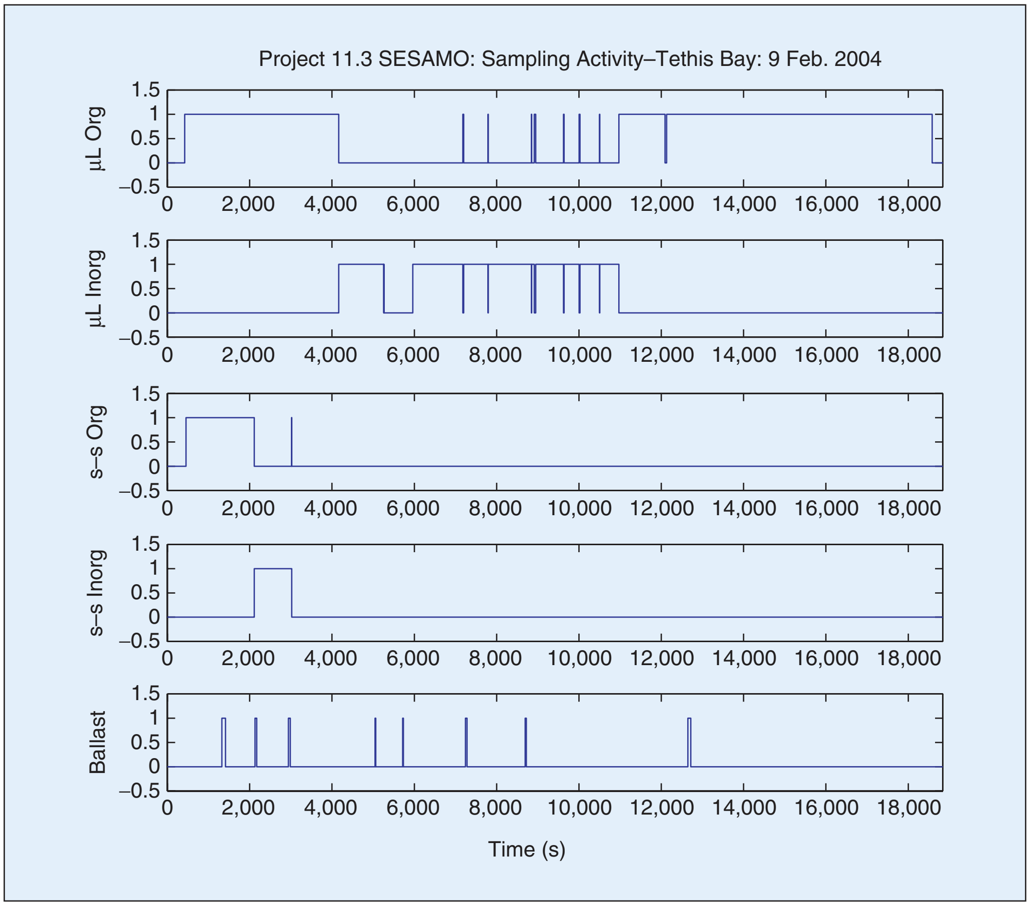

Figure 11. *The microlayer and subsurface sampling and ballast release time sequence (Terra Nova Bay, 9 February 2004).*

Exploitation

As a result of satisfactory performance at sea, after basic scientific end-user training, the SESAMO platform was exploited to collect surface microlayer and immediate subsurface water samples in the framework of the PNRA project chemical contamination.

Unfortunately, bad weather conditions in February limited the number of the executed missions, which are reported in Table 1. The robot worked for more than 20 h, collecting almost 100 L of surface microlayer sample. A view of the catamaran maneuvering to avoid an adrift ice block in ideal operating conditions is shown in Figure 10. Regarding the sampling strategy, initial priority was given to the slower microlayer sampling; the sampling of the immediate subsurface was executed at the end of the mission. When the temperature fell in February, in order to minimize the risk of the collecting tubes icing, as happened to the subsurface organic line on 4 February, the subsurface sampling was performed at the beginning of the mission, and the collection of organic and inorganic compounds of the microlayer was alternated during the time. An example of the sampling and ballast releasing time sequence is given in Figure 11, while the sampling activity along the vehicle's path is shown in Figure 12. The green and red lines denote the sampling of organic and inorganic analities, respectively, while no sampling activity is indicated by the blue lines.

Conclusion

System design, sea trials, and Antarctic exploitation of the SESAMO platform have been presented in this article. The main observation is that high-quality sampling of the surface microlayer requires a large amount of time, leading to significant demands on logistic resources, mainly in terms of operating time of the support vessel *Malippo*, which was made available by the Italian Station of Terra Nova Bay.

The quantity of the collected water cannot be increased by an incremental increase of the revolution rate of the glass drum, because this dramatically affects the quality of the sample. The vehicle and payload mechanical frames have been designed and built to support a cylinder length of 70 cm, with respect to the 50 cm of the current version (used to maintain a compatibility with the MUMS). This upgrade of the cylinder capability in collecting water should be used to compensate for a reduction of the cylinder revolution rate in order to increase the quality of the sample.

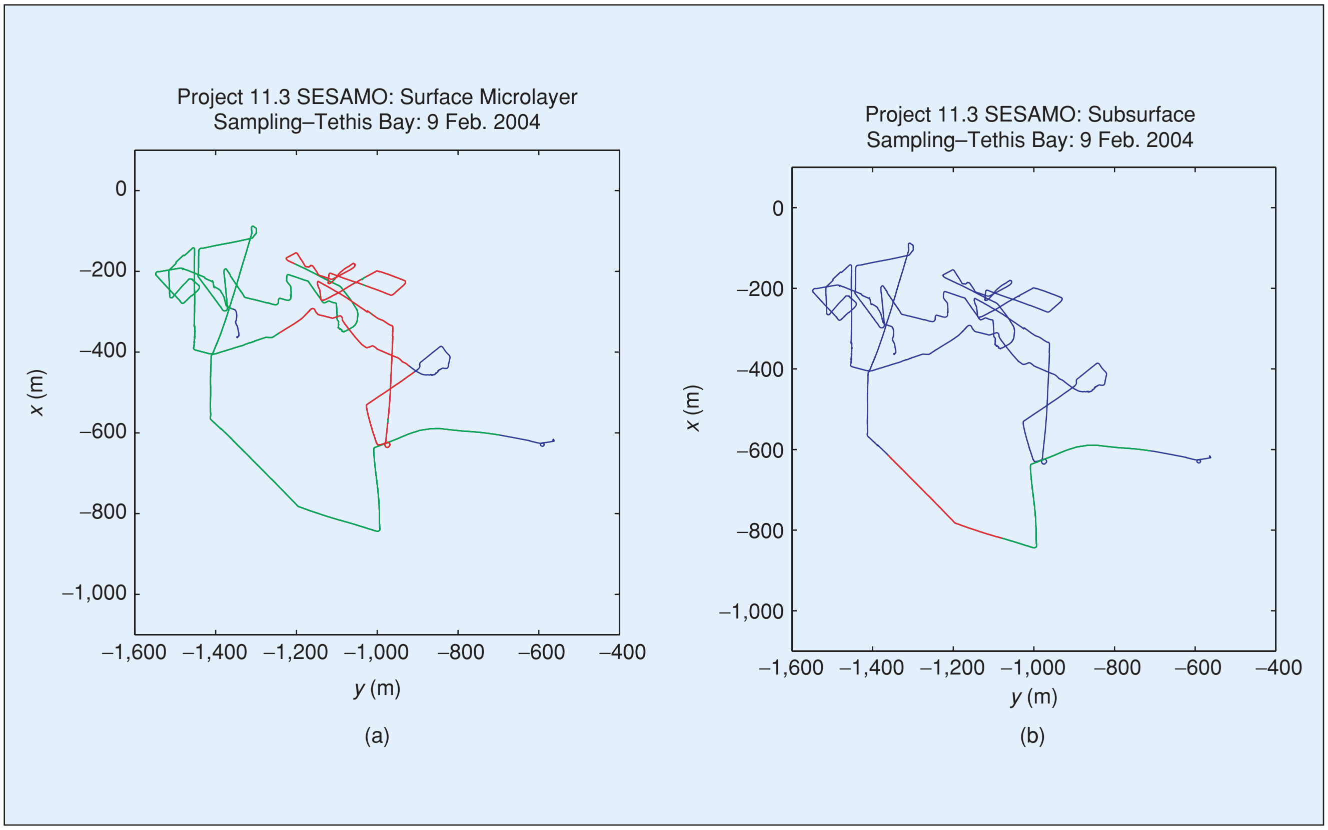

Figure 12. *Surface microlayer and subsurface sampling activity along the catamaran path (Terra Nova Bay, 9 February 2004).*

On the other hand, the vehicle seems able to execute 4–6 h missions without any power supply problem (if necessary, the power supply system could be immediately enhanced by mounting the solar panels on the vessel). The navigation sensors, i.e., GPS and compass, are quite reliable and precise, and the automatic guidance system guarantees accurate maneuverability of the vehicle.

These observations suggest the possibility of increasing the vehicle autonomy, basically in terms of automatic guidance capabilities in the presence of adrift ice blocks (i.e., developing an obstacle detection and avoidance system focused on sea ice targets), in order to use the support vessel only for safe deployment and recovery of the platform, which should be operated by the end user from a surface station located on the ground (in sight of the operating area for communication needs). The operator ground station, comprising the human computer interface notebook and the wireless communication system, can be made fully portable and powered by batteries and solar panels. During the sampling, the vehicle should navigate through waypoints specified by the end user, avoiding obstacles on its path.

The aforementioned operating scenario would require a working range of the wireless communication system of quite a few kilometers, with respect to approximately 500 m of the current one, but this requirement could be satisfied by increasing the transmission power and improving the antennas.

Acknowledgments

The authors would like to thank all of the personnel of Terra Nova Bay station for their help and support during operations and the whole expedition. A particular mention goes to the *Malippo* crew, G. Alessandro and P. Leone from the Reggimento Lagunari "Serenissima," for their very kind and highly professional support during at-sea trials.

Keywords

Autonomous surface vessels, marine science applications, marine robotics.

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Massimo Caccia received the Laurea in electronic engineering from Genoa University, Italy, in 1991. In 1993, he joined the Consiglio Nazionale delle Ricerche (CNR) Istituto Automazione Navale (IAN) in Genoa, as a research scientist. His research at CNR has encompassed numerous subjects, notably, software architectures for intelligent underwater vehicles; sensor-based navigation, guidance, and control; modeling, identification, and simulation of unmanned underwater vehicles; and execution control of robotic tasks in-water testing. He was the task leader in the European Commission MAST project for an advanced manipulator for deep underwater systems (AMADEUS 2) and the advanced remotely operated vehicle (ROV) package for automatic mobile investigation of sediments (ARAMIS). He participated in the XIII Italian expedition to Antarctica in 1997–1998, working on the under-ice performance evaluation of acoustic devices for underwater vehicles. In the XIX Italian expedition to Antarctica in 2003–2004, he was a member of the Antarctic Benthic Shuttle team and the principal investigator of the SESAMO project.

Riccardo Bono received his degree in electronic engineering in 1980, and in 1984, he joined the Consiglio Nazionale delle Ricerche (CNR) as a research scientist. He operated in the field of computer-generated imagery applied to training simulators. He was involved in research projects in the field of vessel traffic services and regional vessel traffic service (acquisition and processing of maritime traffic data in the Mediterranean area during COST301 trials). He is a member of Robotlab, developing software architectures for the control of remotely operated vehicles and for human computer interfaces. He was a task leader for the European Commission MAST projects AMADEUS (advanced manipulator for deep underwater systems) 1 and 2 and ARAMIS (automatic mobile investigation of sediments). He participated in the XIII Italian Expedition in Antarctica and was responsible for the ROV Romeo software. He also participated in the XVII, XVIII, and XIX Expeditions, and was responsible for the O.U. ABS and Tele-ABS. In the XVIII and XIX Expeditions, he was responsible for the technology sector.

Gabriele Bruzzone obtained his degree in electronic engineering at the Genoa University, Italy, in 1993. He joined Consiglio Nazionale delle Ricerche (CNR) as a research engineer in 1996. His research activity focuses on the study, design, and development of real-time hardware and software control architectures and the simulation of complex robotic systems, in particular, manipulators and teleoperated underwater vehicles, and on the development of methodologies allowing access and availability to robotics resources via the Internet. He contributed to the design and development of the ROV's Roby2 and Romeo. He was task leader in European Commission MAST projects AMADEUS (advanced manipulator for deep underwater systems) and ARAMIS (automatic mobile investigation of sediments). He was the person in charge of the e-Robot1 and e-Robot2 project experiments. In 2003–2004, he was responsible for the design, implementation, and integration of the software for SESAMO.

Giorgio Bruzzone obtained his high school certificate in telecommunications in 1980. In 1982, he joined the Consiglio Nazionale delle Ricerche–Istituto per l'Automazione Navale (CNR-IAN) as a technician and has since been involved in a number of projects, including the operation and maintenance of meteo-oceanographic buoys, oceanographic campaigns for instrument testing and data collection, and the design and construction of systems for data collection and signal conditioning. He is responsible for the Robotic Laboratory, where he works for the development of many electronic and mechanical devices for underwater applications and vehicle testing. Since 1987, he has participated in seven Italian expeditions to Antarctica. In 1994–2000, he took part in EC MASTII project AMADEUS (advanced manipulator for deep underwater systems) and MASTIII project ARAMIS (automatic mobile investigation of sediments). SESAMO and ABS were the last Antarctic projects developed.

Edoardo Spirandelli received his high school certificate in industrial electronics in 1987. In 1988 he completed a specialization course in electronics and attended a course in English and computers at Berkeley University Extension College of San Francisco, California. In 1989, he joined the Consiglio Nazionale delle Ricerche–Istituto per l'Automazione Navale (CNR-IAN) as a technician. He worked on the development of various hardware and software underwater robotics systems. He has participated in several oceanographic campaigns for instrument testing, and in late 1994 was made assistant systems administrator. In 1994–2000, he participated in the European Commission projects AMADEUS (advanced manipulator for deep underwater systems) and ARAMIS (automatic mobile investigation of sediments). Between 1995 and 2004 he participated in four Italian expeditions to Antarctica.

Gianmarco Veruggio graduated with a degree in electronic engineering, from the University of Genoa, Italy, in 1980. He has been a senior researcher at the Consiglio Nazionale delle Ricerche–Istituto per l'Automazione Navale (CNR-IAN) since 1983 and founded the CNR-IAN Robotics Department in 1989. He was responsible for several projects, including European Commission projects AMADEUS (advanced manipulator for deep underwater systems) in 1993–1996, AMADEUS2 in 1996–1999, and ARAMIS (automatic mobile investigation of sediments) in 1997–2000; he was also involved in the Bilateral Italy-USA project "Autonomous Underwater Vehicles: fault diagnosis and recovery," in 1997–1999. He was responsible for Project 4a, robotics and telescience in extreme environment at TNB in the IX Expedition 1993–1994. He was the scientific coordinator of the thematic area 5a "Robotics and Telescience" in the XIII Expedition 1997–1998, the ABS-Antarctic Benthic shuttle project of the PNRA 199-01 program, the E-Robot project in the XVII Expedition in Antarctica 2001–2002, the E-Robot2 project in the 2002 campaign at Svalbard Islands, and the MIUR RoboCare project unit (multiagent system for human assistance). He is the president of the School of Robotics.

Angela Maria Stortini received a degree in biological sciences in 1990 and a Ph.D. in environmental sciences-marine ecology in 1995. She received grants from the Marine Biology Interuniversitary Centre of Leghorn, Italy, the Italian Antarctic Research National Program, the University of Florence, Italy. She has also been a contractor at the University of Florence. She participated in five Italian Antarctic expeditions (sector-project N.9-Chemical Pollution) and was an invited scientific personnel at an intercalibration session in the European Commission project AIRWIN (the structure and role of biological communities involved in the transport and transformation of persistent pollutants at the marine AIR-Water Interphases). She is now a contractor at the Institute for the Dynamics of Environmental Processes at the National Research Council of Venice, Italy.

Gabriele Capodaglio is a full professor of analytical chemistry in the Faculty of Mathematics, Physics, and Natural Sciences at the University Ca' Foscari of Venice, Italy. His scientific research involves many aspects of analytical chemistry, such as the study of processes that control the distribution and transport of pollutants in the environment, the development of analytical methodologies for the study of real matrices, and the analytical determination of complex real matrices and the chemometric elaboration of their analytical data. Particular emphasis is given to the study of the biogeochemical cycles that regulate the distribution of the metals in polluted and unpolluted marine waters. He is a scientific coordinator of two oceanographic campaigns in the Italian National Research Program for Antartic Research (PNRA), for the Chemical Pollution Project—Chemical Methodologies topic. In the same program, he has scientific responsiblity for the input and distribution of metallic species in the Ross Sea (Antarctica) operational unit. His studies are also in the evolution of sulphured species in seawater.

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