A SMART MULTIMODAL INNOVATIVE MODEL FOR MARINE ENVIRONMENTAL MONITORING

Alessandro Tonacci
Clinical Physiology Institute – National Research Council of Italy (IFC – CNR)
Via Moruzzi 1, 56124 Pisa, Italy
atonacci@ifc.cnr.it

Marco Andrea Lippa
Istituto Nazionale di Geofisica e Vulcanologia (INGV)
Via Pezzino Basso 2, 19020 Fezzano, Italy
marco.lippa@edgelab.eu

Giovanni Pioggia
Clinical Physiology Institute – National Research Council of Italy (IFC – CNR), Messina Unit
Via Consolare Valeria SNC, 98125 Messina, Italy
gpioggia@ifc.cnr.it

Claudio Domenici
Clinical Physiology Institute – National Research Council of Italy (IFC – CNR)
Via Moruzzi 1, 56124 Pisa, Italy
domenici@ifc.cnr.it

Giovanni Lacava
Tuscia University
Via San Camillo de Lellis, 01100 Viterbo, Italy;
Edgelab s.r.l.
Via degli Altiforni 3, 57037 Portoferraio, Italy
giovanni.lacava@edgelab.eu

Lisa Lupi
Edgelab s.r.l.
Via degli Altiforni 3, 57037 Portoferraio, Italy
lisa.lupi@edgelab.eu

Lavinio Gualdesi
Edgelab s.r.l.
Via degli Altiforni 3, 57037 Portoferraio, Italy
lavinio.gualdesi@edgelab.eu

Michele Cocco
Edgelab s.r.l.
Via degli Altiforni 3, 57037 Portoferraio, Italy
michele.cocco@edgelab.eu

KEYWORDS

AUV, e-nose, environment, hydrocarbons, model, pollution

ABSTRACT

Hydrocarbon pollution represents one of the most serious issues for the health and entirety of the extremely fragile marine ecosystem, thus, the strategies for its monitoring have been grown in number and complexity in the last decades.

Therefore, the realization of systems able to detect the presence of pollutants in the marine environment has become extremely complex, involving different figures and integrated know-hows. This paper presents an innovative model for the real-time assessment of pollutants on sea surface based on a network of autonomous underwater vehicles (AUVs), also able to sail the sea surface, equipped with sensors, capable of detecting volatile organic compounds (VOCs) produced by hydrocarbons.

In particular, within this context, an AUV equipped with an E-Nose-like system is proposed, with the sensors employed that were characterized both on laboratory bench and at sea. The results obtained confirmed the feasibility of the approach proposed as well as a good reliability of the data acquired, confirming the likely employment of this system within an integrated marine monitoring tool.

INTRODUCTION

The Mediterranean Sea is almost completely surrounded by land, covering an approximate area of 2.5 million Km^2, connected to the Atlantic Ocean by the Strait of Gibraltar, and representing 1% of the world ocean surface. Its average depth is around 1,500 m, with the deepest point located in the Ionian Sea, between Greece and Italy, 5,267 m under the sea surface (Barale 2008). It represents an extremely fragile and vulnerable ecosystem, being its waters slowly renewable, thus making it rather sensitive to all kinds of pollutants, especially when coming from commercial traffic of the big tankers, industrial and tourism activities (Er-Raioui et al. 2009). Pollution is more intense in coastal areas, where highly anthropized urban settlements are mainly located and maritime traffic is more concentrated.

In order to preserve the integrity of this complex ecosystem, several protected areas have been created in the last decades. Such as the “Pelagos Sanctuary”, located in the Corso-Provencal Ligurian Basin, considered among the main feeding and reproductive areas for a number of cetaceans in the Mediterranean (Forcada et al. 1995; Notarbartolo di Sciara et al. 2003; Azzellino et al. 2012), and consistent with the EU Habitat Directive – Annex IV, having the aim to preserve, protect and improve the quality of the environment.

In the last decades, in particular, petroleum pollution has become a matter of serious environmental concern

Proceedings 29th European Conference on Modelling and Simulation ©ECMS Valeri M. Mladenov, Petia Georgieva, Grisha Spasov, Galidiya Petrova (Editors)
ISBN: 978-0-9932440-0-1 / ISBN: 978-0-9932440-1-8 (CD)

in the Mediterranean Sea and all over the world, with petroleum hydrocarbons (gasoline, kerosene, fuel oil, etc.) known to enter the marine environment through spills or leaks, as well as accidents (Mille et al. 2007; Zrafi et al. 2013). Thus, in the above cited areas, the monitoring of such pollutants is extremely critical to properly preserve the environment and the safety of animal species.

To date, a number of different approaches have been employed to accomplish this difficult mission, including synthetic aperture radar (SAR) imaging and analysis (Alpers and Huhnerfuss 1989; Topouzelis et al. 2007), hyperspectral and thermal imaging (van der Meer and de Jong 2001), hydrodynamic mathematical modeling (Martins et al. 2001), and chemical sensors for electronic nose-like systems (Bourgeois and Stuetz 2002; Sobanski et al. 2006; Tonacci et al. 2015). Each of these approaches accounts for some relatively critical issues, including low detection capability during particular weather conditions (i.e. low and high wind speeds for SAR), or during particular parts of the day (i.e. at night). Thus, the employment of an innovative approach, based on the signals produced by electrochemical sensors in presence of hydrocarbons or other potentially dangerous pollutants, could represent an important development and/or a useful complement to the traditional monitoring methods, in order to improve their performances in such key-tasks for marine environment preservation.

In order to perform a proper analysis of the environmental pollution state, the electrochemical sensors system, whose functioning is based on the Electronic Nose technologies, has been placed into an Autonomous Underwater Vehicle (AUV), sailing on the water's surface, and able to ride out customized or pre-loaded missions depending on the user's needs.

Thus, the aim of this paper is to display a smart system, based on the technologies of Electronic Nose, able to dynamically monitor the presence of pollutants (particularly hydrocarbons) on the sea surface. The system proposed could be employed, together with traditional methods, for a complete and exhaustive analysis of the marine pollution caused by hydrocarbons.

MATERIALS AND METHODS

The main part of the smart system based on the E-Nose technology has been composed by an array of sensors, placed with a radial symmetry into a cylindrical flow chamber manufactured in polymeric material. The sensors employed for this application have been photo-ionization detectors, whose driving force relies on a vacuum ultra-violet radiation capable of ionizing volatile organic compounds (VOCs) contained in the air overhanging seawater. Such ionized particles were then detected by a proper electronics, placed inside (a pair of electrodes) and outside (electronic board) the sensor and producing an output signal somehow proportional to the concentration of VOCs present in the air. One of the main advantages of this system lied in the fact that such sensors were not responsive to major air components, thus not producing spurious signals possibly due to such a similar contamination of the sample drawn.

The air inlet and outlet have been represented by a smart system of tubes, micropumps and valves, able to sample a given amount of air through an aspiration cone within a single analysis cycle, normally lasting 6 minutes overall (1 minute of air intake and 5 minutes for purging the system), and then releasing the air analyzed by an air outlet conceived to be connected to a hose external to the AUV.

The integration within the AUV was another pivotal step that was performed in the design phase of the system described. The choice made was in favor of the modularity of the system, and the "E-Nose" payload was designed in the way it could be integrated but also to be detached from the remainder of the AUV when not necessary. Thus, all the cables and electronic components were connected with the remaining section of the vehicle, in order to ensure the possibility to be externally supplied and to reduce as much as possible the eventual inconvenience due to the displacement of the internal parts of the payload.

The AUV (Figure 1) is composed of a central body, with an area reserved for a payload (320 mm in length, 110 mm in diameter) – the E-Nose for this purpose – with the possibility to be integrated with the external module when needed. The present system was reduced in dimensions and weight when compared to a similar system previously described (Tonacci et al. 2015).

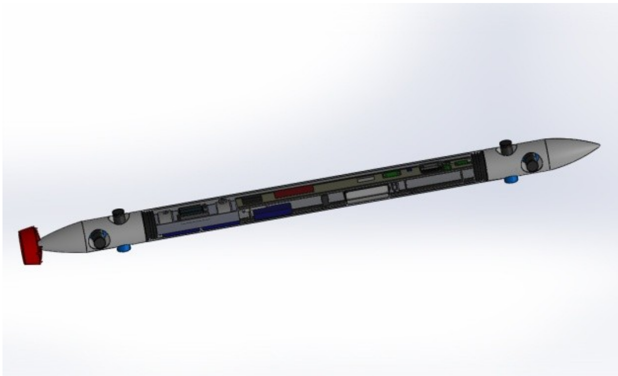

Figure 1: 3D rendering of the AUV with the Electronic Nose system

The sampling and sensor chamber were resized in order to be placed into the payload compartment (113.6 mm^3 of volume for the sampling chamber, 127.2 mm^3 for the sensor chamber), while the pumps were dimensioned to be able to carry on the minimum air flow necessary for the VOCs analysis (the diameters of the hoses were 4 mm) (Figure 2).

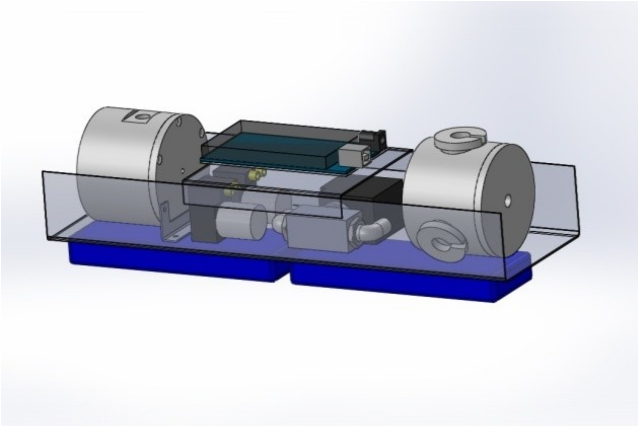

Figure 2: 3D rendering of the Electronic Nose system payload

The control, sampling and analysis sections were placed within the payload compartment, together with the battery pack (14.4 V @ 5000 mAh), while the only part interfaced with the exterior was represented by the two tubes for air inlet and outlet, linked to a pillar able to keep them high enough to detect VOCs produced by hydrocarbons and, in the same time, to prevent the water from entering the sampler and damaging the overall system. The overall Electronic Nose system layout is displayed in Figure 3, with the electric and fluid dynamic connections between its different parts (sampling chamber, sensorized chamber, electrovalve and pumps).

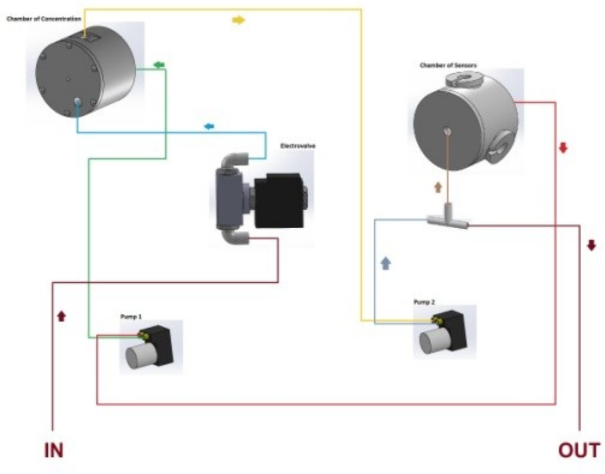

Figure 3: Layout of the Electronic Nose system

Within the AUV, the engines were placed afore and astern.

Data acquired by the E-Nose system were analyzed through two Artificial Neural Networks (ANNs) relying on Kohonen Self Organizing Map (KSOM) structure, based on clustering upon centroid distance (distance for each point and maximum distance from each cluster's ellipse centroid).

RESULTS

The system proposed was at first bench-tested in order to assess the responses provided by the sensors and to evaluate the optimal air flow to maximize the signal-to-noise ratio produced by the detectors employed. This latter analysis produced a clear result that confirmed the 2 l/min of air flow as the optimal air flow rate for the present application. The responses of the sensors in presence of hydrocarbons' dilutions was evaluated in terms of minimum detectable quantity of the various substances analyzed. In particular, a concentration of 100 ppm of the different hydrocarbons employed (gasoline, kerosene, diesel fuel and crude oil, often considered as the most frequently present compounds in polluted sea, according to Mille et al. 2007 and Zrafi et al. 2013) was clearly detected by the system.

After this initial characterization, the system, integrated into the AUV, was deployed into seawater and used for marine monitoring purposes. The data gathered during these missions, together with the ones at bench, were employed to train two ANNs. The first of these ANNs aimed to classify the stimuli detected according to three different levels of warning ('low', 'medium' and 'high', depending on the intensity of the stimulus concentration, corresponding to different amounts of hydrocarbons' VOCs present in the air). The ANN designed for this purpose was of the type KSOM, and was composed of 100 neurons (10 x 10) (Figure 4).

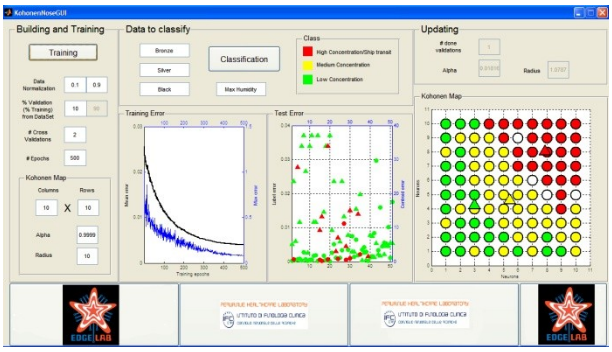

Figure 4: The first ANN realized to discriminate stimuli depending on pollutants concentration

This ANN had three inputs, corresponding to the maximum output of each of the three piD sensors (Bronze, Silver and Black piD), determined to be the most relevant features among all the data extracted from the E-Nose system after a Principal Component Analysis (PCA).

The performances of this network were satisfying, with a good 80.76% of correct classification of the stimuli into the three classes above stated, against only 9.62% of misclassification (Figure 5). The most common misclassification was related to the difference between category 1 and 2 (low vs. medium concentration) minimally affecting, therefore, high concentrations that were the most important category of stimuli to be correctly detected in our purpose.

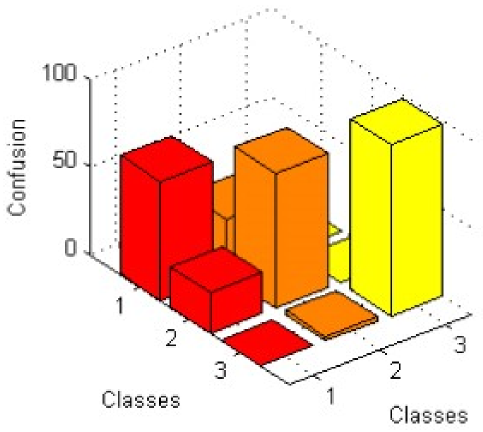

Figure 5: Confusion matrix of the first ANN

Similarly, a second ANN was designed and implemented, with somewhat comparable characteristics in terms of overall number of neurons. In this case, anyway, the outputs of the network were four, corresponding to the four types of hydrocarbons employed for the sensors' characterization (gasoline, kerosene, diesel fuel and crude oil, as above stated).
The aim of this second ANN was to correctly identify the hydrocarbon detected based on the output signal features of the sensor network. In this case, after a PCA, three inputs were identified as the most significant, represented by the outputs of each of the three piDs in terms of peak time (t_{up}).
The task was correctly accomplished in 66.67% of cases, with 11.11% of misclassification, a slightly higher value when compared to the first task due to the different, and undoubtedly more complicated, analysis required in this latter case, thus resulting, anyway, in a satisfying overall outcome. Indeed, in this case, no common misclassifications were identified, probably because of the high complexity of the task required to the network.

DISCUSSION

The monitoring of environmental pollution, focused in particular on marine environment, has been becoming more and more critical in our present days. Indeed, several national and international policies aiming at preserving the ecosystem's health have been outlined during the last decades, highlighting the importance of taking care about these aspects in today's society.
The institution of marine protected areas, where ship transits and/or oil spills are partially or, in most cases completely forbidden, has gone in this direction, therefore environmental monitoring in such areas could be considered more critical again with respect to other marine regions.
Moreover, the recent accidents occurred in various parts of the world, including the Mediterranean Sea area, such as the collision between Moby Prince and Agip Abruzzo near Leghorn, the explosion of M/C Haven near Genoa, both in 1991, as well as the Costa Concordia wreck near Giglio Island in 2012, with massive oil and pollutant spills, displayed how fragile this particular ecosystem is to such events, proving the importance of an accurate and proper monitoring of pollution in such cases, as well as the need for massive and immediate interventions after a similar accident or after an abuse concerning illegal ship transits in a given area.
In order to successfully accomplish this aim, an overall monitoring and intervention strategy, based on the data gathered from different sensors, should be adopted, also preventing as much as possible eventual spurious responses produced by some kinds of survey means normally adopted – often as a standalone methods – in this context.
With an accurate and reliable approach, it is possible to model the behavior of the pollutants in a given area, in order to better understand the main features of the interaction between water mass and pollutant.
In particular, to accomplish this aim, multimodal data gathered from different sensors are required, including output from buoys, satellite images or other AUVs equipped with diverse detectors (i.e.: Conductivity-Temperature-Depth (CTD) sensors).
A network composed of AUVs and a single buoy allows to recreate in real-time a map of the marine area under control. The network could be formed of a "Master", consisting of the buoy, with a Wireless link towards the AUVs and a satellite communication to an inshore station, and some "Slaves" of the network, represented by the AUVs. Each AUV could be linked through Wireless connection to the Master and to the other Slaves, in order to be able to raise warning signals to the station as well as to check the phenomenon evolution in real-time (Figure 6).

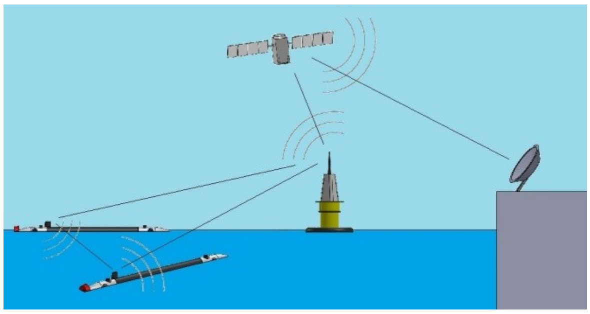

Figure 6: Layout of the real-time marine monitoring multimodal scenario

The system proposed could allow for an early intervention strategy from the designated entities as well as from the AUVs themselves, when equipped for such a similar circumstance.
One of the most important features of the system is, as stated above, its multimodality, being based on the integration of several different monitoring tools, one of the most promising of which is represented by

electrochemical sensors composing E-Nose-like systems.

In general, an E-Nose-like system could bring many advantages with respect to traditional monitoring methods, including its operability both in the daylight and at night, the possibility to be integrated into dynamic and static structures to accomplish different kinds of monitoring strategies and, in particular concerning the integration into the AUV, allowing for the implementation of customized missions, based on the data gathered by the sensors, that could nail down – by georeferentiation – maps of the pollution state of a given area. Thus the AUV, properly programmed and equipped with the E-Nose-like system, could be able to "follow" the oil slicks performing a real-time analysis extremely useful in a context of prevention and very early intervention of such potential environmental disasters.

This approach was followed in the work described here. In particular, the results obtained during the bench-testing as well as at sea demonstrated the feasibility of the solution proposed in such a difficult task as marine environmental monitoring is. Only a few drawbacks were noticed in the sea-testing, in particular occurring in presence of high values of humidity ratio (above 70% RH), due to drift in sensors output signals. Indeed, RH > 70% caused the sensors to decrease their reliability, especially in terms of repeatability of the measurements, accounting for a limitation of this tool. In such cases, the merger with other monitoring systems could be recommended in order to avoid spurious values, possibly causing false warning signs to be raised.

The response obtained by the sensor array, both on bench and at sea, was compliant with what we expected, thus quite similar to the performances displayed in the datasheet of the components chosen for this purpose.

The system proposed in this work, together with traditional monitoring methods (i.e.: satellite images, drifting buoys, etc.), could form the basis for the realization of an innovative integrated multimodal tool for environmental monitoring, operating 24/7. The main features of this innovative system could rely on the customization of the analysis as well as on the extreme rapidity in intervention policies suddenly after the accident or adverse event.

CONCLUSIONS

In this work, we presented the basis for the design and realization of an innovative system for marine environmental monitoring, whose main features could be represented by the employment of the technologies of Electronic Nose. The E-Nose-like tool could be integrated into an Autonomous Underwater Vehicle in order to perform a dynamic check of the pollution status of a given area. The system, composed of an array of sensors, a flow chamber and electronics, was tested at first at laboratory bench and then directly at sea, demonstrating its efficiency and reliability in the detection of hydrocarbon pollutants present on the sea surface. Its programming, specifically conceived to build up a georeferentiated map of polluted areas, has aimed to make the integrated system able to follow the oil slicks and/or the contaminated sites, also possibly represented by ships performing illegal transits in some particular protected regions. This specific extension to the basic functions already performed by earlier prototypes (Tonacci et al. 2015) could embody an invaluable innovative contribution to the prevention strategies already adopted throughout the world in this field, possibly forming the basis for future multimodal tools for marine monitoring. Obviously, the tool proposed should be integrated with the other traditional methods for marine monitoring commonly used, in order to improve their reliability but, in conclusion, it demonstrated its reliability and ease to use. Both on laboratory bench and during testing at sea.

REFERENCES

Alpers, W., and H. Huhnerfuss. 1989. "The Damping of Ocean Waves by Surface Films: A New Look at an Old Problem". *Journal of Geophysical Research* 94, 6251-6265.

Azzellino, A., Panigada, S., Lanfredi, C., Zanardelli, M., Airoldi, S. and G. Notarbartolo di Sciara. 2012. "Predictive habitat models for managing marine areas: Spatial and temporal distribution of marine mammals within the Pelagos Sanctuary (Northwestern Mediterranean sea)". *Ocean & Coastal Management* 67, 63-74.

Barale V. 2008. "The European Marginal and Enclosed Seas: An Overview". In *Remote Sensing of the European Seas,* V. Barale and M. Gade (Eds.). Springer, London, 3-22.

Bourgeois, W., and R.M. Stuetz. 2002. "Use of a Chemical Sensor Array for Detecting Pollutants in Domestic Wastewater". *Water Research* 36, 4505–4512.

Er-Raioui, H., Bouzid, S., Marhraoui, M. and A. Saliot. 2009. "Hydrocarbon pollution of the Mediterranean coastline of Morocco". *Ocean & Coastal Management* 52, 124-129.

Forcada, J., Notarbartolo di Sciara, G. and F. Fabbri. 1995. "Abundance of fin whales and striped dolphins summering in the Corso-Ligurian Basin (*Balaenoptera physalus, Stenella coeruleoalba*)". *Mammalia* 59, No.1, 127-140.

Martins, F., Leitão, P., Silva, A., and R. Neves. 2001. "3D Modelling in the Sado Estuary Using a New Generic Vertical Discretization Approach". *Oceanologica Acta* 24, S51-S62.

Mille, G., Asia, L., Guiliano, M., Malleret, L., and P. Doumenq. 2007. "Hydrocarbons in coastal sediments from the Mediterranean sea (Gulf of Fos area, France)". *Marine Pollution Bulletin* 54, 566-575.

Notarbartolo di Sciara, G., Zanardelli, M., Jahoda, M., Panigada, S. and S. Airoldi. 2003. "The fin whale (L. 1758), in the Mediterranean Sea". *Mammal Review* 33, No.2, 105-150.

Sobanski, T., Szczurek, A., Nitsch, K., Licznerski, B.W., and W. Radwan. 2006. "Electronic Nose Applied to Automotive Fuel Qualification". *Sensors & Actuators B* 116, 207–212.

Tonacci, A., Corda, D., Tartarisco, G., Pioggia, G., and C. Domenici. 2015. "A smart sensor system for detecting hydrocarbon Volatile Organic Compounds in sea water". *CLEAN - Soil, Air, Water* 43(1), 147-152.

Topouzelis, K., Karathanassi, V., Pavlakis, P., and D. Rokos. 2007. "Detection and Discrimination between Oil Spills and Look-alike Phenomena through Neural Networks". *ISPRS Journal of Photogrammetry and Remote Sensing* 62, No.4, 264–270.

van der Meer F.D. and S.M. de Jong. 2001. "Introduction". In *Imaging Spectrometry: Basic Principles and Prospective Applications,* F.D. van der Meer and S.M. de Jong (Eds.). Kluwer Academic Publishers, Dordrecht, 21-23.

Zrafi, I., Bakhrouf, A., Mahmoud, R., and S.D. Dalila. 2013. "Aliphatic and aromatic biomarkers for petroleum hydrocarbon monitoring in Khniss Tunisian-Coast, (Mediterranean Sea)". *Procedia Environmental Sciences* 18, 211-220.

AUTHOR BIOGRAPHIES

ALESSANDRO TONACCI was born in 1986 in Massa, Italy and went to the University of Pisa, where he studied biomedical engineering and obtained his master degree in 2010. He is currently PhD candidate in Automation, Robotics and Bioengineering at the University of Pisa, and research fellow at the National Research Council of Italy – Clinical Physiology Institute (IFC-CNR), in Pisa. His main research activities are focused on the study of the neurophysiological basis of the sense of smell and on the development and testing of Electronic Nose-like systems for diagnostics and environmental purposes. From 2011 to 2012, he was involved in the EU funded 7th Framework's Project ARGOMARINE (Automatic Oil-Spill Recognition and Geopositioning integrated in a Marine Monitoring Network) in the development of an E-Nose system for marine pollution monitoring. His email address is: atonacci@ifc.cnr.it

GIOVANNI LACAVA was born in 1984 in Grottaglie, Italy and went to the University of Pisa, where he studied Biomedical Engineering/Automation Engineering and obtained his master degree in 2011. He is currently PhD student in Ecology and Biological Resources Management at the University of Tuscia, and Ocean Engineer (junior experience) in Edgelab s.r.l. , in La Spezia. His email address is: giovanni.lacava@edgelab.eu

MARCO ANDREA LIPPA was born in 1986 in Avezzano, Italy. He studied Mechanical Engineering at "La Sapienza" University of Rome, and obtained his master degree in 2011. He is currently a researcher for INGV (Istituto Nazionale di Geofisica e Vulcanologia) in the field of underwater robotics, and collaborates with EdgeLab S.r.l. in La Spezia as a mechanical designer. His email address is marco.lippa@edgelab.eu

LISA LUPI was born in 1983 in Portoferraio, Italy and went to the University of Pisa, where she studied biology and obtained her PhD in Biology in 2012. Currently she works as scientific adviser for EdgeLab s.r.l.. Her email address is: lisa.lupi@edgelab.eu

GIOVANNI PIOGGIA was born in 1972 in Messina, Italy and went to the University of Pisa, where he studied electronic engineering and obtained his master degree in 1997. He obtained his PhD in Robotics from University of Genova in 2002 and is currently researcher at the National Research Council of Italy – Clinical Physiology Institute (IFC-CNR), in Messina. His email address is: gpioggia@ifc.cnr.it

LAVINIO GUALDESI, Dott. Ing., graduated from the Naval Academy, Livorno as Officer of the Italian Navy and was then awarded the Naval Architecture Master Degree at the University of Trieste. As Technical Director of Intermarine Shipyard in Sarzana, Italy, he contributed to the design of various fiberglass mine-countermeasure vessels. As Head of Ocean Engineering Branch of the Nato Research Centre in La Spezia he has worked on buoy technology, towed body and underwater structure prototypes and their construction for 26 years. He contributed to the diffusion of ocean engineering technologies as consultant in various international institutions. Among the most important: IMEDEA (Balearic Islands) to initiate the spin-off firm "Albatros"; University of Las Palmas de Gran Canaria: Master in Esperto de Puertos; INFN (Istituto Nazionale Fisica Nucleare, Italy): sea station for the neutrino underwater telescope; University of Genova and Pisa: Master in Ocean Engineering; MDS (Marine Desalination Systems) St. Petersburg Florida: chief engineer during the construction of a novel desalination pilot plant to sequester CO2. Mr. Gualdesi, as Member of the MTS (Marine Technology Society, US), is author of numerous publications and he is presently active in European Programs for marine archeology and to preserve Marine Parks from pollution activities.

CLAUDIO DOMENICI received the Laurea degree in physics from the University of Pisa, Italy, in 1977. In 1980 he received the D.E.A. degree from the University of Grenoble, France. He also holds an Italian Research Doctorate degree (PhD) in material engineering, awarded in 1987.

From 1977 to 1979 he worked at the Institute of Physics, University of Pisa. From 1979 to 1981 he was a Research Fellow at L.E.T.I.-C.E.A. in Grenoble. Since 1981 he has been involved in the research activities of Centro "E. Piaggio", University of Pisa, and at the Institute of Clinical Physiology, Pisa, where he is currently a staff member of the Italian National Research Council.

His main research interest and scientific activity, devoted for many years to the development of sensors and transducers and their application in the biomedical and environmental fields, are at present focused on gene specific biosensors. He is also engaged in research on physico-chemical properties of polymeric materials and their interaction with biological systems. Within this topic, he was involved in the EU funded 7th Framework's Project ARGOMARINE (Automatic Oil-Spill Recognition and Geopositioning integrated in a Marine Monitoring Network), where he coordinated the IFC-CNR group in the development of an E-Nose system for marine pollution monitoring. His email address is: domenici@ifc.cnr.it

MICHELE COCCO was born in 1962 in Foggia, Italy and graduated in Physics at the University of Pisa. He then earned a Ph.D. in Microsystem Engineering at the Scuola Superiore S.Anna, Pisa. He has been working for universities, research centers and companies as a Scientific Advisor for drawing up, organization and management of basic and applied research projects, at both National and international level. From Sept. 2009 to 2012 he coordinated the EU funded 7th Framework's Project ARGOMARINE (Automatic Oil-Spill Recognition and Geopositioning integrated in a Marine Monitoring Network) on behalf of the National Park of the Tuscany Archipelago, at Isle of Elba, Italy. His email address is: michele.cocco@edgelab.eu