Ocean Engineering & Oceanography 6

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Quantitative Monitoring of the Underwater Environment

Results of the International Marine Science and Technology Event MOQESM´14 in Brest, France

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Kees de Jong *(1962–2014)*
This book is dedicated to the memory of Kees de Jong, Research and Development manager for Fugro Intersites BV.
The organizing committee of the conference MOQESM'14 is deeply saddened to learn the death of Kees de Jong, Visiting Professor in the session hydrography of MOQESM, tragically died afterwards the conference. Kees de Jong contributed to the development of Fugro Research activities since 2003, first as senior geodesian and then, from 2007, as Geodesy Department Manager in 2007. He formerly worked as Assistant Professor with Delft University in the high accuracy positioning domain. As an attempt to put industry closer to academics, he fostered much collaboration between some companies and some academic institutes as Newcastle University (UK) or ENSTA Bretagne (France) for instance.
All collaborators, whether colleagues or students gave him a deep respect as much due to for his scientific skills, his commitment to applied research and industry, as for his human quality. For all of us, Kees will remain a model both as human and as scientist.

Preface

Every 2 years, MOQESM is organized in Brest during the Sea Tech Week with the aim to focus on emergent techniques for quantitative monitoring of the underwater environment; MOQESM standing for MOnitoring Quantitatif de l'Environnement Sous-Marin. The 2014 edition of the conference, MOQESM'14, is the opportunity for people of the research and industry communities to meet, attend, and discuss with specialists of two research domains: marine robotics and coastal hydrography, with application to the coastal environment mapping and the survey of underwater infrastructures. The objective of the MOQESM'14 conference is to demonstrate that, though being very distinct, the two domains of marine robotics and coastal hydrography can take benefit from research progress in each other, in the future, in order to design new products and mapping methods combining them. The recent research and industrial achievements in these two domains are developed in the 11 papers gathered into the proceedings of MOQESM'14. The conference is organized in two plenary sessions headed with invited talks.

The first chapter of this book is dedicated to the improvements in hydrography. It begins with an invited talk given by Carole Nahum, from the Délégation Générale pour L'Armement (DGA), about defense needs and strategies in terms of environment monitoring. Techniques to acquire the underwater environment can be improved in many ways: from the positioning accuracy to the fusion of multiple sensors. Five scientific contributions constitute this first chapter. Precise mapping of the underwater environment requires accurate positioning of the acquired data. New approaches to obtain an accuracy of a few centimeters rely on Global Navigation Satellite Systems (GNSS). To reach such accurate positioning, Kees de Jong et al. propose an approach based on merging PPP techniques (use of precise satellite orbits and clocks) with Integer Ambiguity Resolution (IAR), known from GNSS Real-Time Kinematic (RTK) positioning techniques. As the accuracy of the acquired bathymetric data also depends on the motion of the sensors, Nicolas Seube, Sebastien Levilly, and Kees de Jong present an automatic method to estimate the angular alignment between the Inertial Measurement Unit (IMU) and the multibeam echo sounder. Acquiring the bathymetry can become a very difficult task when the environment is challenging and not cooperative: high-flowing rivers, confined zones and ultra-shallow waters. In such environment, unreachable with conventional survey launches, Mathieu Rondeau et al. proposed an autonomous drifting buoy equipped with a GNSS receiver, an IMU, and a single-beam echo sounder. The acquisition and the monitoring of the underwater environment can be improved by combining different sensors. Claire Noel et al. present new tools to produce operational seabed maps by fusing the information collected by several acoustic systems operating simultaneously or not. This session concludes with the higher level issue on how to efficiently make available the data from the marine environment to end-users like marine industries, decision-making bodies, or scientific research. As in Europe the marine data are stored in a wide range of national, regional, and international databases and repositories using different formats and standards, J.-B. Calewaert et al. present the European Marine Observation and Data Network (EMODnet). EMODnet is a network of organizations set up in 2007 by the European Commission in the framework of EU's Integrated Maritime policy to address the fragmented marine data collection, storage and access in Europe.

The second chapter addresses new developments in marine robotics. The first invited speaker, Edson Prestes from Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil, proposes a new approach to the global positioning of underwater robots based on probability and interval analysis. The second invited speaker, Vincent Rigaud, IFREMER, France, introduces a new kind of underwater robots resulting from the hybridization of a Remotely Operated Vehicle (ROV) with an Autonomous Underwater Vehicle (AUV). Marine robotics has to operate in the very challenging oceanic environment. To design and build effective robots, a wide range of research topics must be addressed, e.g., underwater communication, obstacle avoidance, software design for embedded systems, control/command, sensor design and integration, algorithms for autonomous navigation, localization, and positioning. Below the sea surface high-frequency electromagnetic communication shows poor performance and acoustic waves are preferred. However, acoustic modems generally remains costly for small robots and Christian Renner et al. have studied a new acoustic modem design aimed at low power consumption, small form factor, and low unit cost. Before addressing the robot itself, it is important to improve the sensing devices. As for communications, the preferred technique for imaging the seabed is based on ultrasonic acoustic waves. New techniques based on synthetic aperture, multiple aspects and interferometry allow for both accurate measurement of the bathymetry and optics-like imaging of the sea floor. Myriam Chabah et al. present the design and discuss the first experimental results of the SAMDIS sonar system which first implements simultaneously these new techniques. Another scientific challenge is to efficiently design the code executing autonomous mission. Such code has several levels of abstraction from low-level control loops to high-level path planning. Goulven Guillou and Jean-Philippe Babau have developed IMOCA; a generic multi-platform model-based approach to code generation for embedded systems. At low level, the efficient control of a robot can be achieved by taking into account the hydrodynamics of the robot. Yang Rui et al. present this approach and apply it to the

Ciscrea AUV. At intermediate level, the AUV can be controlled using its vision sensor. Eduardo Tosa et al. show how visual servoing implemented in Coral-bot AUV solve the problem of detecting coral reef. At higher level, when navigating on the surface or underwater, autonomous robots have to find a safe path. For example, autonomous navigation of a surface vessel must take care of the shore line and the other vessels. To solve this problem Silke Schmitt et al. proposed a vector field approach.

The main conclusion of MOQESM'14 is that, although different and often separate, the domains of marine robotics and hydrographic measurements share some research topics like global positioning, acoustic sensing, data processing, or mission planning. The content of this book also demonstrates that marine robotics will play an increasing role in acquiring the marine environment.

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GDR Robotique

Vincent Creuze

CIDCO—Interdisciplinary Center for the Development of Ocean Mapping, Canada

Coralie Monpert, Nicolas Seube, Jean Laflamme

Invited Speakers

Pr Edson Prestes
Leader of Phi Robotics Research Group at UFRGS
Federal University of Rio Grande do Sul, Porto Alegre, Brésil

Carole Nahum
Manager Domain Environment and Géosciences of Directorate for the Armed Forces of the French MoD

Vincent Rigaud
Head of the Underwater Systems Unit, IFREMER Toulon

Chairmen

Benoît Zerr, ENSTA Bretagne
Hervé Bisquay, GENAVIR
Vincent Creuze, GDR Robotique

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Introduction

The French Directorate for the Armed Forces, commonly named DGA *Direction Générale pour l'Armement* belongs to the Ministry of Defense. It is in charge of equipping the navy, the army, or the air forces with devices such as sensors or weapons, new vehicles such as ships, aircraft carriers, underwater autonomous vehicles, or submarines, and of maintaining them in working order. When conducting operation, a precise positioning system, a navigation unit, data transmission or communication devices, sensors for detection, and tracking or recognition of targets are needed.

Furthermore, DGA is in charge of proposing software for decision-making or mission planning. Knowing the environment, which means the physical state of the atmosphere, the land, or the sea, and being able to forecast the changes and the dangerous events that could happen is a challenge and a prerequisite for these tools.

Thinking about the future (within 10–20 years), one must take into account not only political and strategic changes over the world but also progress of scientific research or technologic improvements. It is our responsibility to incorporate them into the devices. Therefore, DGA supports scientific studies and technological projects proposed by laboratories or SMEs respectively, connected to the needs of the forces. But on the other hand, researchers and designers must cope with some constraints such as integration of sensors on small platforms (constraints of weight, size, energy supply, etc). Robust hardware, especially in hostile areas, must be designed since electronic devices may be damaged by particular environmental conditions or their performances drastically reduced. The algorithms must also fulfill several requirements such as real-time running. This is particularly challenging when conducting or planning activities in the ocean. The underwater environment is not accessible via satellite or airborne sensors (optical, infra-red, or RADAR) and specific technics must be addressed.

For these reasons, the International Conference on Quantitative Monitoring of Underwater Environment (MOQESM) which gathers researchers and SME's designers offers a wide range of topics of great interest for DGA. In particular, the session "Hydrography: from sensors to products" presents smart devices, new methods, and algorithms.

The military in operation needs up-to-date and precise information. For example, positioning in the underwater is crucial. As for land operations, a map of the bottom of the ocean is the basic tool. How to get it? Bathymetry is usually deduced from measurements of gravity and its derivatives. So even if we develop small gravimeters, this would require the visit of an area and would take time to draw the map. Unfortunately, we often have to manage in some unknown regions. Among military activities, one must not forget survey for which several types of sensors may be used in order to retrieve bathymetry but also the nature of the seabed. It is very relevant for us to propose some real-time technics.

Interferometric sonars are powerful tools for shallow water survey. Unfortunately they suffer uncertainties which may degrade bathymetry quality. The paper "Real-time sounding uncertainty estimation in phase measuring bathymetric sonars" presented by Kongsberg GeoAcoustics Ltd. develops a method for calculating in real time the uncertainties of a commercial PMBS.

In every activity, the military, as anybody, has to keep safe and to care about their impacts on ecosystems. Mapping is also used for finding mines which can be dangerous or putting small devices for survey. In order to draw a map of the seabed, SEMANTIC (France) proposes to integrate several types of acoustic sensors on a small ship and to develop a new data fusion method in "New tools for seabed monitoring using multi-sensors data fusion." This is particularly relevant for us since this can be performed with very low-cost sensors and nearly in real-time.

Improving offshore positioning in real time using Global Navigation Satellite System (GNSS), in particular for tidal applications, may be challenging. The usual accuracy is 3–5 cm horizontally and 6–10 cm vertically. The problem is addressed in the paper "New developments in precise offshore GNSS positioning" proposed by Fugro Intersite. Merging PPP technics (precise satellite orbits and clocks) with Integer Ambiguity Resolution (IAR) allows a better accuracy.

Accuracy relies on a boresight calibration between IMU and Multibeam Echo Sounder (MBES). ENSTA Bretagne (France) and CIDCO (Canada) propose in their paper "Automatic boresight calibration of hydrographic survey systems," a multi-dimensional optimization concept which should provide statistical analysis to be integrated in every calibration report

Deployment of AUVs equipped with several types of sensors such as DVL, pressure sensor, sound velocity sensor, long base line systems, and Inertial Navigation System (INS) in order to collect information is a challenge since the autonomous retrieval of the position may be erroneous. XBLUE (France) proposes in "Optimizing survey deployment and processing times using sparse LBL positioning," a new concept of sparse array navigation and prove that an optimized coupling between inertial unit and the acoustic positioning system may result in a decimetric positioning precision.

CIDCO (Canada) introduces the Hydroball system which is an autonomous drifting buoy equipped with a GNSS receiver, an IMU and a single-beam echo sounder, for surveying hostile and non-accessible areas, in particular ultra-shallow waters. This system is shown to meet industrial international hydrographic standards.