

# The MetroSea Student Contest: An Amazing Educational Experience at 2019 IMEKO TC-19 International Workshop on Metrology for the Sea

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**Abstract**—The paper presents a new educational experience capable of merging different approaches such as project-based learning, inquiry-based learning and Science Technology Engineering and Mathematics (STEM) into a students competition to be held at the International Workshop on Metrology for the Sea. The contest is focused on the pollution control and removal by means of autonomous boats capable of achieving and reaching the position of floating rubbish (such as plastic). To accomplish the considered target, contest competitors have to take into account different problems, from boat assembly to autopilot implementation, from GPS positioning to navigation control. Despite of the competition results, the main goal of the contest is to motivate students to address the global challenge of sea pollution through a set of enabling technologies and soft skills. Students and teachers can therefore take advantage from an alternative solution to overcome typical drawbacks associated with traditional frontal learning practices, such as lack of motivation, insufficient practical laboratory experience, and inadequate collaborative team working practice.

**Index Terms**—monitoring, drone, Internet of Things (IoT), Artificial Intelligence (AI), Global Positioning System (GPS), Science Technology Engineering and Mathematics (STEM), Educational, self-driving, telemetry, measurement;

## I. INTRODUCTION

Globally, a rapid spread of new information communication technologies (ICTs), able to make smart the objects, the cars, the cities, the industries, is revolutionizing the world and to improve the quality life.

In this scenario, the ICT engineers need for high-technology know-how concerning the recent innovation trends (multidisciplinary) and soft skills, to make them-selves more and more self-employed.

These new skills cannot be adequately addressed by traditional teaching and therefore innovative didactic approaches, more suited to address this revolution, are coming up [3]-[5]. These new didactic methodologies intend to make students the major players of the learning process and no longer just the recipients, by spending less time for the frontal lectures in classroom to favour the active involvement of the students [6]. To this aim, scholastic and university institutions are working to carry out and plan new training paths focused more on vocational

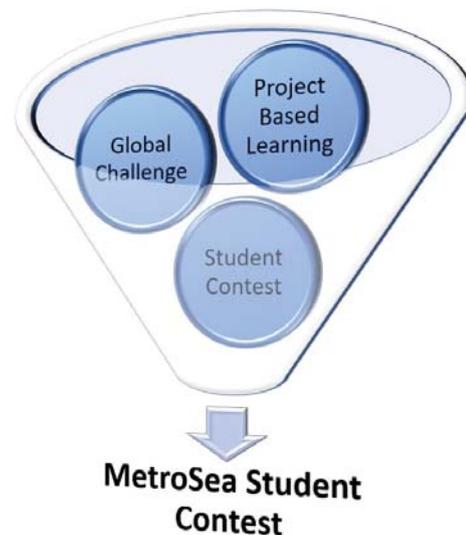


Fig. 1. MetroSea Student contest conceptual idea.

courses, informal and effective, allowing the students to get transversal skills, to work properly in teams, to solve problems, to do research and to communicate effectively.

In this paper the Authors describe the design of a new educational experience joining the project-based learning, inquiry-based learning and STEM into one activity: the "MetroSea Student Contest". It is an amazing competition having the protection of the marine environment as its theme. In particular, in the MetroSea Contest, the students are asked to assemble a self-driving marine drone and to program it to recover plastic objects dispersed in the sea (Fig. 1).

The contest is very challenging allowing the students to become familiar with the team working, synergy making, idea developing and working under strong stress conditions.

The paper is organized as follows. Section II deals with a short overview on the new frontiers in the engineering education field. In Section III the protection and preservation of the marine environment issues focusing in particular on the sea

plastic pollution, that has inspired the MetroSea Student Contest, is presented. The Section IV focuses on the description of the "LITTER HUNTER EDU", that is an innovative self-driving marine drone, in scale, used as the hardware tool for the MetroSea Student Contest and useful to teach principles and concepts of the new enabling technologies, too. Finally in the Section V details about the MetroSea Student Contest are provided.

## II. NEW FRONTIERS IN ENGINEERING EDUCATION

The need to keep academic training in step with digital innovation is leading to experimentation and adoption of amazing teaching models, in which students and practical activities become central compared to traditional approaches based essentially on frontal lectures [7]. F. Corno et al. in [8] describe a study carried out over two academic years, in a course in Ambient Intelligence at Politecnico di Torino, Italy. In the course, a Project-based learning (PBL) approach was adopted, in which students design and prototype an Aml system, and the learning outcomes show that the adopted course strategy is able to deliver the needed hard and soft skills. At the same time, students are satisfied with the course organization, although they feel it to be very demanding. I. Calvo et al. in [9] describes the design of an industrial informatics course, following the PBL methodology, where students became aware of their learning needs and had to work proactively, both autonomously and in teams to develop an embedded controller for a 2DoF SCARA robot that drew a specific trajectory. Others teachers are exploiting several variant of PLB, such as collaborative-PBL (CPBL) and scenario-PBL (SPBL) to improve courses and bring learning content close to job market requirements [10]. However, the experiences reported show that the strong impulse towards the innovative teaching methods has been also influenced by the availability of low-cost tool designed for learning of new technological progress in the ICT engineering field. Open-source electronics platform based on easy-to-use hardware and software as ARDUINO [11] or NUCLEO board by STMicroelectronics [12] are an example. To support educators in the teaching of self-driving technologies, researchers have been developed Roobopoli [13]. It is a tiny smart city, a miniature city, where the life of the inhabitants called Roobo, is assisted by modern technologies, the same available in real cities, but reproduced in scale for educational, testing and simulation purposes. As part of the Roobopoli project, one of the main activities consists in the construction and programming of vehicles called Roobokart, which will have to move independently on the roads of Roobopoli. The project ensures an educational experience for learning about robotics and the programming of new-generation microcontrollers, which will be included in the context of the Science Technology Engineering Art and Mathematics (STEAM) disciplines, addressing a current theme, that of autonomous driving vehicles and smart cities.

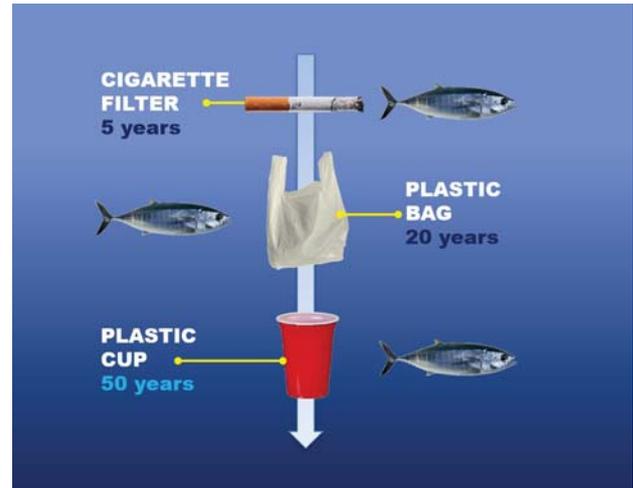


Fig. 2. Number of years in which plastic remains at sea.

## III. PROTECTION AND PRESERVATION OF THE MARINE ENVIRONMENT

Today, the plastic is the first cause of marine pollution, being the 95% of waste dumped at sea. Large pieces of plastic injure and often cause the death of animals, including both protected and endangered species such as the sea marine turtles. Smaller fragments enter, instead, through the fish in the food chain, putting at risk also the human health. Plastic is practical and indestructible. Even though this feature has favored its widespread use, it is worth knowing that it remains in the environment for hundreds of years once dispersed (Fig. 2).

Beside causing damages to the environment and human health, plastic puts also at risk the economic activity linked to the sea exploitation, since polluted seas and dirty beaches discourage tourism. The world is facing a declared "Global Emergency"; in fact, in 2018 the United Nations Environment Program (UNEP) [14] placed the problem of plastic in the oceans among the six most serious environmental emergencies. Without an effective turnaround, by 2025 the oceans will contain 1 ton of plastic every 3 tons of fish, and by 2050 there will be more plastic than fish by weight [15].

However, the good news is that cleaning and protecting the sea is possible, first, by reducing the daily consumption of plastic; the European Union has banned disposable plastic by 2021. A second solution concerns the exploitation of the new technological progress in the ICT and robotics field, such as Drones, Computer Vision and AI. With reference to this last issue, the Greentech Solution [16], an innovative start-up from Campania Region operating in the environmental protection sector, has designed and developed the "LITTER HUNTER", a system involving drones and self-driving catamarans capable of detecting and recovering waste and floating plastic near the coast [17].

The LITTER HUNTER system operates as follows. A drone flies on the surface of water to be checked for waste floating such as plastic bags, plastic cups, etc. The polluting objects are therefore identified through recognition algorithms



Fig. 3. LITTER HUNTER in action this summer on the beaches of the Amalfi Coast.



Fig. 4. Plastic recovered by LITTER HUNTER during a mission.

when they enter in the camera view or in the range of other sensors mounted on the drone. When a target is identified, the drone communicates its coordinates to the ground control station, that plans a recovery mission and transfers the proper information to the marine drone, which can then leave for the recovery of the object of interest. LITTER HUNTER has already been used in different contexts and has proved to be a valid tool to tackle marine pollution. To raise awareness about the considered problem, LITTER HUNTER was used this summer on the beaches of the Amalfi Coast, (Italy), allowing to remove several tens of kilograms of plastic from sea and arousing great interest among the bathers (Fig. 4).

#### IV. LITTER HUNTER EDU

Starting from this background in Engineering Education and following the success of its system, Authors launched the "LITTER HUNTER Edu", a kit made up of a mini-vessel with autopilot that allows the students, technicians, and engineers to develop skills in the design and implementation of marine drones, through the emulation of a waste recovery mission,



Fig. 5. LITTER HUNTER Edu.

with an experimental, entertaining and at the same time useful approach to the environment.

The open architecture of the LITTLE HUNTER Edu allows the development and testing of innovative technological solutions at different abstraction layer, thus it can be effectively used to carry out several learning objectives. Even if it can be seen as a low-cost version of the "LITTER HUNTER", the good level of the adopted hardware and software offers to students the possibility to discover potential and limits of the self-driving technologies when applied in the marine contest.

The LITTER HUNTER EDU is provided in kit easy to assemble.

The kit includes:

- **Radio Controlled (RC) Boat (Fig. 5):**

- Deep V-hull in PVC, 66 cm long;
- Water-cooled brushless motor 2000 RPM/V;
- Waterproof Servo Steering for RC boat;
- Electronic Speed Controller (ESC);
- Spectrum radio remote control;
- 2.4 GHz Receiver.

- **Autopilot (Fig. 6):**

- Flight Control Board based on 32 bit ARM Micro-controller 168 MHz/256 KB RAM/2 MB Flash;
- Inertial Measurement Unit (IMU);
- GPS module and antenna;
- 433 MHz Telemetry Radio System;
- Power Module XT60
- Cables and connectors for wiring.

- **Lipo Battery 3300 mAh.**

With the main components, other accessories needed to assemble the RC boat and autopilot, such as plywood board, sponge, rubberized thickness, waterproof sea, etc., are provided.

A detailed instruction manual, slides and video tutorials, online available, ensure that all the assembly operations can be carried out correctly.

A PC and a mission planner software (both not provided), compatible with the telemetry radio system, realize the Ground



Fig. 6. LITTER HUNTER Edu Autopilot in kit.

Control Station (GCS) that provides all facilities to plan auto missions [18].

In the following more details on the sensors and instrumentation used are provided.

#### A. Inertial Measurement Unit

The most basic instrumentation needed is an Inertial Measurement Unit (IMU). The IMU typically includes a 3-axis rate gyroscope, 3-axis accelerometer and 3-axis magnetometer, whose outputs are usually converted from analog to digital information through an analog-to-digital converter (ADC) [19]. The ADC resolution will determine the accuracy of the instrument (the higher, the more accurate the measurement). In addition, some vehicles include a barometric sensor for determining the relative height, a Global Positioning System (GPS) as an extra sensor to measure the absolute position. Sonar, laser-ranging or infrared sensors can also be implemented.

#### B. Flight Control Board

The flight control board (FCB) is essentially the brain of the Unmanned Systems and takes into account all the equations of flight dynamics (installed as firmware in dependence of the vehicle class and type of frame) necessary in order to control the body of the drone itself. It receives information about the position, acceleration and space orientation respectively from the GPS, accelerometer and magnetometer and transmits them to the Ground Control Station through a telemetry; as well known, the main problems with MEMS inertial sensor are the associated bias and drift to be compensated [20]-[23]. The FCB used, characterized from a certain number of ports that allows the communication with sensors and the eventual actuators and obviously the alimentation of the FCB itself. In particular, the outputs of the FCB are divided into the main output and aux output, the former is dedicated to the rotors and the latter to the auxiliary actuators such as cameras. The FCB chosen for the educational project includes the IMU platform. It mounts:

- ST Micro L3GD20 3-axis 16-bit gyroscope;
- ST Micro LSM303D 3-axis 14-bit accelerometer/ magnetometer;
- Invensense MPU 6000 3-axis accelerometer/gyroscope;
- MEAS MS5611 barometer;

#### C. Telemetry Radio System

Telemetry is an automated communications process by which measurements and other data are collected at remote or inaccessible points and transmitted to the receiving equipment for monitoring. It is the primary source of the real-time measurement and status information (processed by FCB) transmitted during the testing of the unmanned vehicles from an on-board flight test instrumentation system. The hardware used is composed by two different radio modules for air and ground: (i) the ground module has a USB connector making it easy to connect directly to the ground station; (ii) the on board module has a FTDI six pin header that allows it to be directly connected to the Flight Controller telemetry port. It also allows to establish a connection between GCS and autopilot to transfer programmed mission made up of navigation commands (i.e. waypoints) and do commands.

#### D. Radio Control Transmitter and Receiver

A radio transmitter is a device that allows pilots to control the vehicle by means of a wireless link. The signal/commands sent are then received by a radio receiver (RX) which is connected to the flight controller. The 2.4 GHz system is the standard for radio control, after new protocols were created that introduced frequency hopping technology [24]. It basically looks for the available channel automatically to avoid interfering with other pilots, allowing multiple pilots controlling at the same time. RX is the device that receive commands from the radio transmitter and pass them to the FCB [25]. During autonomous missions, the RC control is important to take manually the USV control in case of unexpected events. During the phase of component integration, its fundamental to place Telemetry, GPS and RC receiver as far as possible from each other in order to avoid interference problems.

#### E. Ground Control Station

A GCS is a land- or sea-based control centre that provides the facilities for the human control of USV. Smaller USVs can be operated with a traditional "twin-stick" style transmitter, as used for radio-controlled model. Extending this setup with a laptop or tablet computer, data and video telemetry, and aerials, creates what is effectively a GCS. The GCS is provided of a software used for planning and flying a mission. It provides a map screen where the user can define waypoints and see the progress of the mission. It also serves as a virtual cockpit, showing many of the same instruments as in a manned vehicle. The LITTER HUNTER EDU GCS software could be the open source Mission Planner (MP) [26], which can be used as a configuration utility or as a dynamic control supplement for autonomous vehicles.

Inside the 2019 IMEKO TC-19 International Workshop on Metrology for the Sea, Greentech Solution promotes the Global Challenge KEEP THE SEA PLASTIC FREE. It is opened to teams of student from all over the world, who will compete with the LITTER HUNTER Edu. The challenge consists of:

- assembling the marine drone, by using the LITTER HUNTER Edu kit provided to each team;
- completing parts of the code and programming the mission planner to allow the self-driving boat to reach one or more fixed targets (which emulate dispersed plastic objects at sea) and return to the starting point;

The team able to collect more plastic objects in the shortest time will win the challenge. The competition field will be a bordered stretch of water within the ancient port of Genoa, near the submarine Nazario Sauro. Near the competition area, a stand will be set up to hold event of awareness and discussion on the use of the innovative technologies for the environmental protection issues. At the end of the challenge, the winners will be rewarded by the participating authorities.

#### A. Learning Objective

The learning objective of the proposed Challenge is to empower students to address a global Challenge, such as the sea pollution, while acquiring content knowledge in the new engineering ICT technologies and soft skills. Through challenges, teachers and student are experiencing that learning can be deep, engaging, meaningful and purposeful. Challenge as the MetroSea Student Contest provides teachers an alternative solution to overcome many of student's deficiencies associated with the traditional frontal learning practices; such as lack of motivation, insufficient practical laboratory experience, and inadequate collaborative team working practice [27].

#### VI. ONGOING ACTIVITIES

Ongoing activities concern the promotion and organization of the event, which will be held in Genoa (Italy) on October 4, 2019. There are already several teams of students who have joined the initiative so far. At the end of the competition, students will be requested to complete a survey to assess by means of an 5-point Likert-type scale the effectiveness of the action carried out. Materials and technical support are both provided for the registered teams.

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