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Call for proposal 2019 Strategic

MARLESS (MARine Litter cross-border awarenESS and innovation actions)

Priority Axis: Environment and cultural heritage; Specific objective: 3.3 - Improve the environmental quality conditions of the sea and coastal area by use of sustainable and innovative technologies and approaches

D.6.7.5 –Toolbox on drone technologies for plastic collection

AT 6.7

WP 6

Version: FINAL
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PROJECT MARLESS

Work Package:	**WP6**
Activity:	**AT 6.7 Toolbox**
WP Leader:	**PP6 University of Bologna**
Deliverable:	**D.6.7.5 –Toolbox on drone technologies for plastic collection**

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CONTENT:

ToolBox*:*
Pilot Actions to prevent, recover, process marine litter
-Activity 6.7-

WP6 aims to demonstrate the feasibility of several new technologies in the field of prevention, recovery and treatment of marine litter. The activity in question will produce Tool boxes for stakeholders aimed at boosting the transferability of WP main outputs.
This report describes two different robot action. One is a marine drone for microplastic collection, the other is an autonomous mobile net array for floating litter collection.
The toolbox will be split in two parts, each describing the specific robot.

Water drone for Microplastic Collection

1. **INTRODUCTION***:*

1.1 This activity was aimed at the design and protype of a marine drone for autonomous collection of microplastics at sea. At the moment, only few attempts have been made to collect microplastics from sea by innovative and self-guided mobile systems: microplastics are small bits of plastic, 5 millimeters or less, and either engineered for end-products, or the result of environmental degradation of polymer-based trash. Recent research estimates that there are 5,250 billion plastic particles floating on the surface on the world's seas and oceans: these fragments move with the currents before washing up on beaches. If the impact of this ever-growing pollution remains little understood in terms of biodiversity and human health, the economic costs are considerable. The negative impacts are felt by fishing industries and boaters as well as the islands and coastal towns. Today, faced with the enormity of the challenge, it is vital to support research designed to produce actionable results capable of driving transition to more environmentally friendly practices.

1.2 *Goals achieved*

As output of our tasks, we first designed and manufactured a scalable filtering system for microplastic collection, able to filter sea water and to catch particles of 5mm dimension and less; then we designed, realized and tested the full prototype of a drone equipped with the filtering system, an autonomous guidance system and a collision avoidance sensor.

2. **DELIVERABLE METHODOLOGY***:*

2.1 WHERE: The deliverable is usually located into the labs of CIRI FRAME in Ravenna, but is very easily transportable, due to limited dimension and friendly assembly-disassembly of parts. The drone wasn't tested at worst weather conditions, but under appreciable wind and current conditions it answered well to the autonomous control and guidance. Undoubtedly, the drone performances can be affected by the location and the seasonality and are higher under good sea conditions.

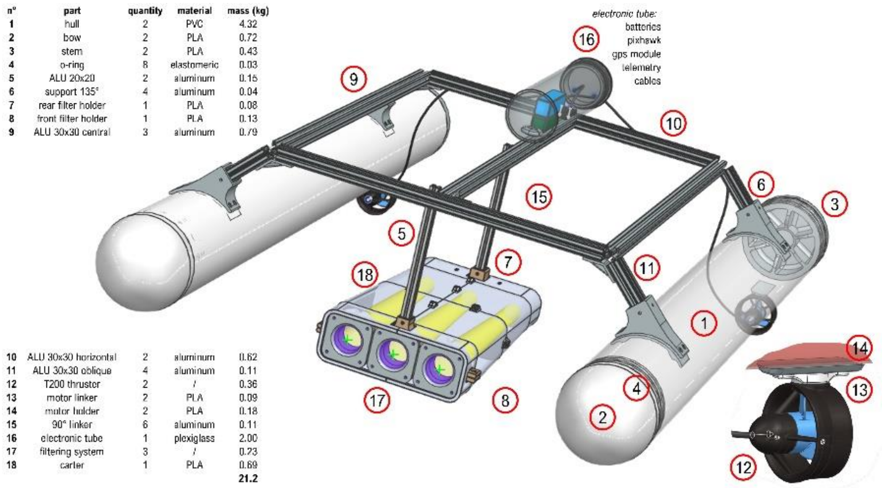
2.2 WHO: The design and prototyping phases of the work were performed by engineers, experts in electronics, control systems and mechanics, but, once the prototype was realized, its use, setting and whole management was also tested by students at our university, not necessarily experts. At least three people should be involved into the team in order to replicate drone, for its usage only two people would suffice.

2.3 HOW: Description of the activity realized (specific technology are needed? And the timing needed?)

The drone is essentially made of three main blocks:

- *The filtering system, with three nuts collecting plastics of 0.5 mm size and able to filter 200 l/hour of sea water.*
- *The main structure supporting the filtering, the motors and the electronics.*
- *Electronics and the autonomous guidance system, able to guide the drone for planned routes.*

Figure 1 shows the total assembly of the drone and a Bill of Material is provided, in ordert to make the action replicable at its best.



n°	part	quantity	material	mass (kg)
1	hull	2	PVC	4.32
2	bow	2	PLA	0.72
3	stem	2	PLA	0.43
4	o-ring	8	elastomeric	0.03
5	ALU 20x20	2	aluminum	0.15
6	support 135°	4	aluminum	0.04
7	rear filter holder	1	PLA	0.08
8	front filter holder	1	PLA	0.13
9	ALU 30x30 central	3	aluminum	0.79
10	ALU 30x30 horizontal	2	aluminum	0.62
11	ALU 30x30 oblique	4	aluminum	0.11
12	T200 thruster	2	/	0.36
13	motor linker	2	PLA	0.09
14	motor holder	2	PLA	0.18
15	90° linker	6	aluminum	0.11
16	electronic tube	1	plexiglass	2.00
17	filtering system	3	/	0.23
18	carter	1	PLA	0.69
				21.2

Figure 1: The assembly drawing of the marine drone. Each part composing the drone is described

For the prototype, different manufacturing techniques have been employed: the filtering system and the hull were completely realized by 3D printing (with FDM process). Other parts are almost standard parts. Figure 2 summarize the main steps of the 3D printing process, by showing, as example, a part of the drone's hull. Figure 3 shows the parameters that were set on the 3D printing for the hull bow. Figure 4 show the filtering system CAD model. Figure 5 shows an exploded view of *the drone, equipped with all the instruments required for its functioning. Finally, figure 6 shows the electronics, the motors and the guidance system, installed and set for optimal configuration. The drone is 1,8 by 1,2 metres long and is perfectly scalable for further and diversified applications.*

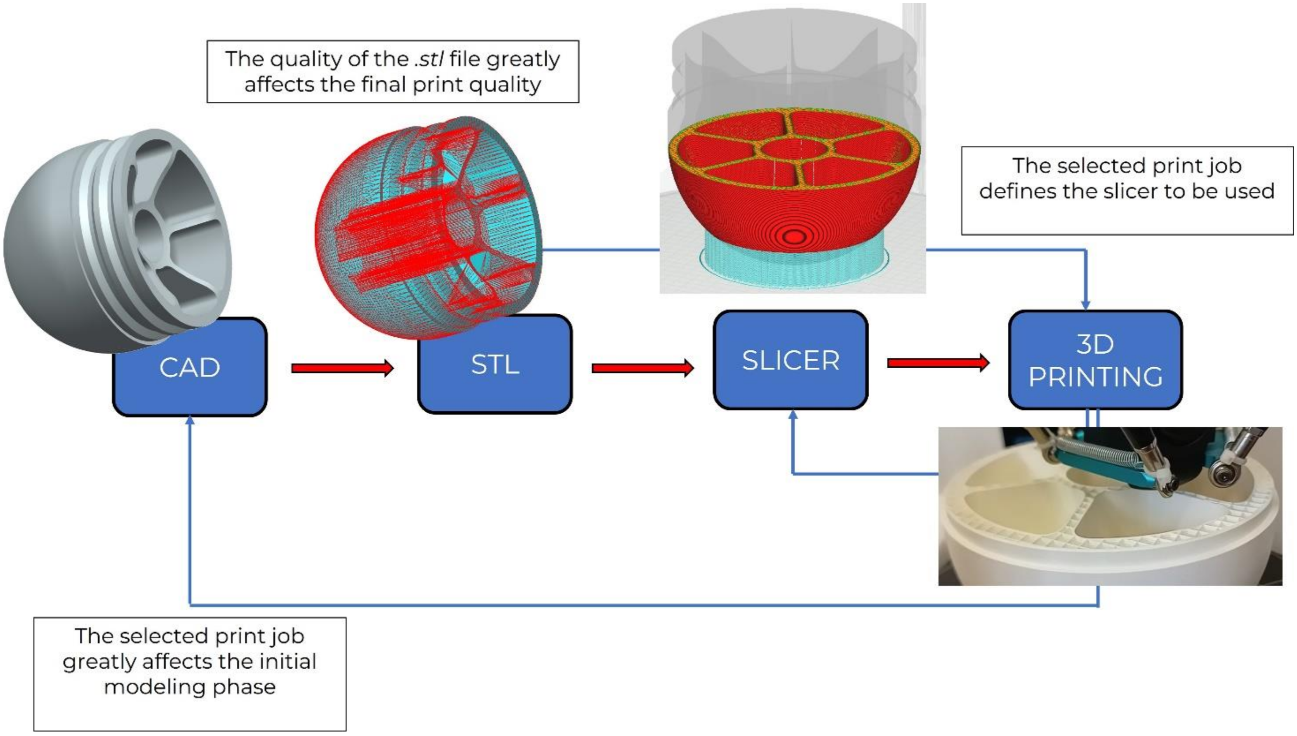


Figure 2: The sequence for 3D printing manufacturing

Layer height	0.4 mm	Infill density	15%	Print speed	120 mm/s	Skirt	3
Line width	0.4 mm	Infill pattern	grid	Infill speed	120 mm/s	Support	yes
Wall line count	3	Connect infill lines	yes	External Wall speed	70 mm/s	Overhang angle	45°
Top thickness	0.8	Printing t°	240	Internal wall speed	120 mm/s	Printing time	18 h
Bottom thickness	0.8	Build plate t°	65°	First layer speed	30 mm/s	*Weight*	716 g
Top layers	3	Bottom layers	3	Material	PLA	**Printer**	Anycubic Predator

Figure 3: The 3D printer's parameter setting for best performance of the manufacturing process.

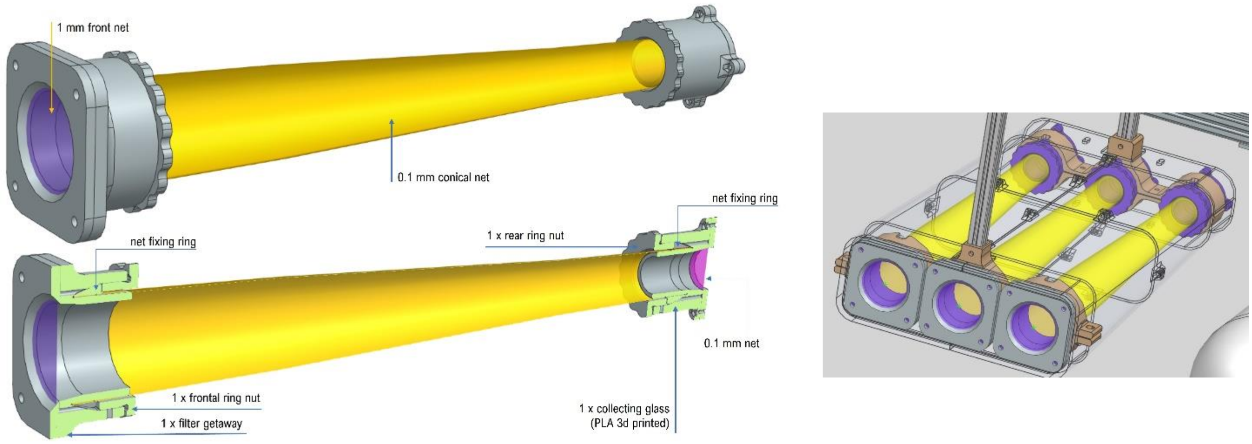


Figure 4: The filtering system of the single net and of the whole system.

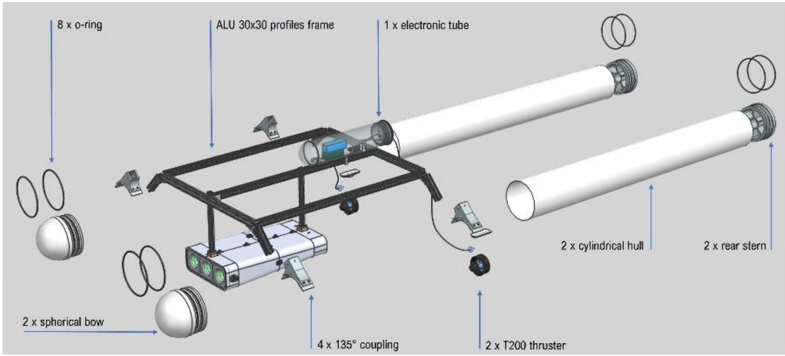


Figure 5: an exploded view of drone assembly and of all the parts installed on it.

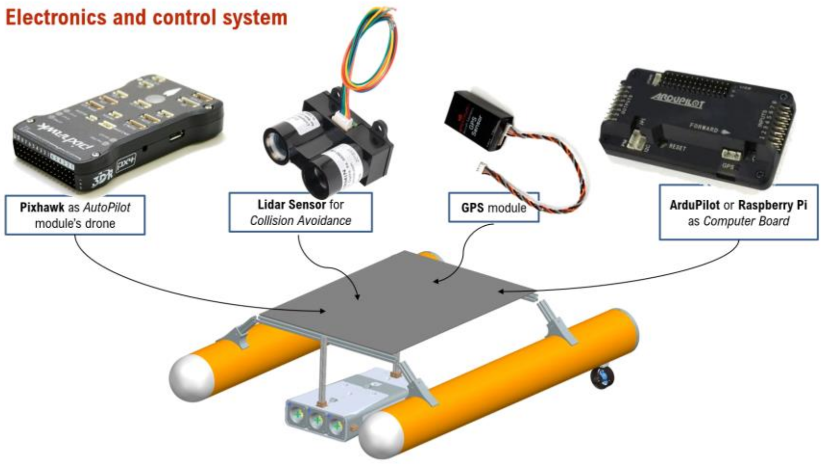


Figure 6: The electronics modules equipped on the drone for its control and the autonomous guidance system.

2.4 Outputs achieved were fully in line with those expected as the prototype realized was really faithful to the model designed; only minor adjustments were made during the prototype's construction, more related to the optimal arrangement of the components on board. The target specifications were largely achieved.

2.5 ***SWOT ANALYSIS***

Describe, with the support of the SWOT analysis scheme, how the performed action can be improved

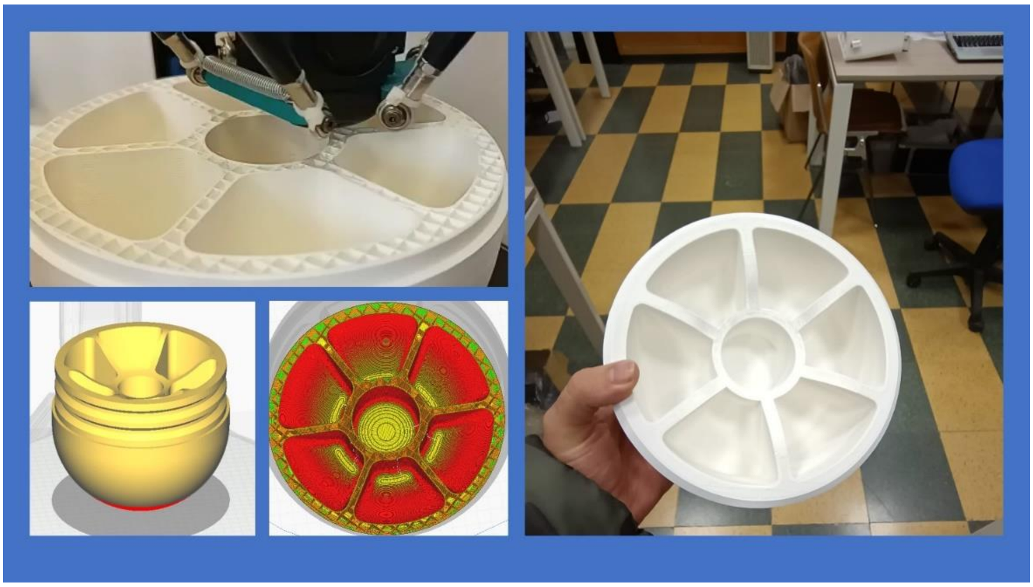
	Helpful	***Harmful***
Internal Origin	*STRENGHT:* *The design and prototype of the drone was completely done internally at university labs, also for the handcrafted parts (by 3D printing) up to the assembly and the testing together with the electronics setting and its management.*	*WEAKNESS:* *The collision avoidance system should be improved to achieve high accuracy even in rough seas.*
External Origin	*OPPORTUNITIES:* *The scalability of the prototype should be tested for grater dimensions. The system could be further developed for an optimal configuration aimed at continuative using.*	*THREATS:* *The use of the drone in dangerous conditions should be tested, checked and optimized*

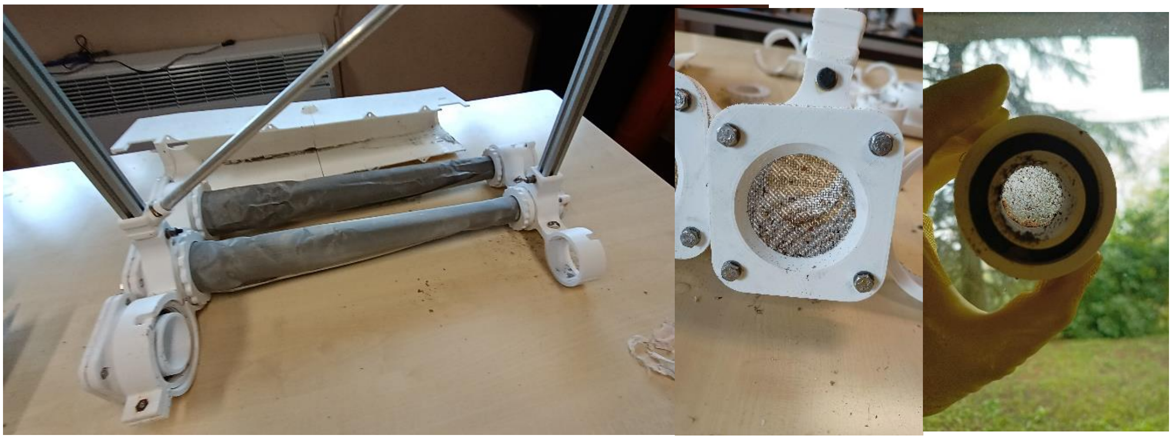
3. **CONCLUSION / SUMMARY***:*

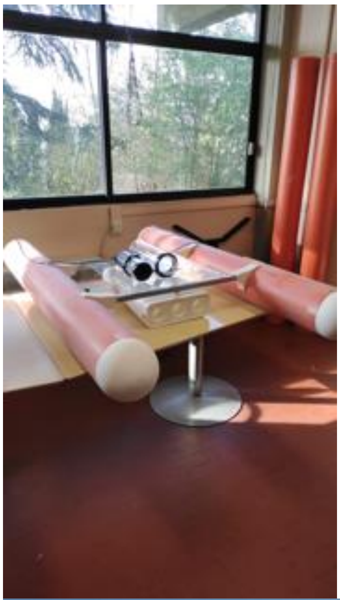
University of Bologna designed, prototyped and tested a marine drone for microplastic collection at sea. The drone is essentially made of a filtering system, with three nuts collecting plastics of 0.5 mm size and able to filter 200 l/hour of sea water, a main structure supporting the filtering, the motors and the electronics, an autonomous guidance system, able to guide the drone for planned routes. It was manufactured by 3D printed parts (as for the hull and the filtering system) and by standard parts. The motors and the guidance system were installed and set for optimal configuration. The drone is 1,8 by 1,2 metres long and is perfectly scalable for further and diversified applications. It is an agile vehicle of such dimensions that it can be used in a variety of capacities. It was tested first in a test tank, for best setting of control and guidance parameters, then was tested directly at sea. All the tests were successful and at sea the filtering system was able to catch different items of plastics.
Further studies may be addressed to replicate the model at higher scales and to test the best settings for control, autonomous guidance and collision avoidance, also in rough sea conditions. The optimization of this innovative system could attract the interest of parties willing to finance design optimization and development of greater autonomous drones.

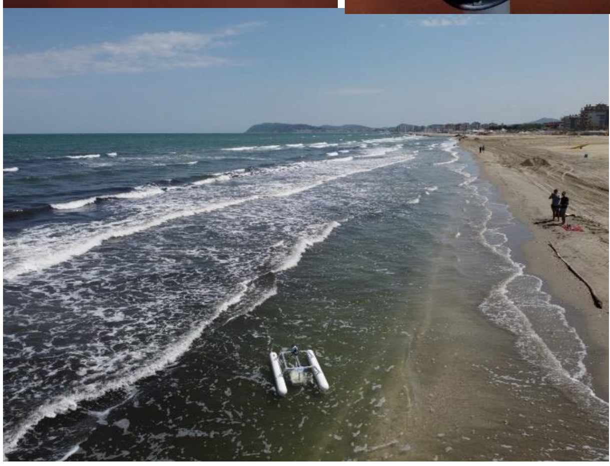
4. **TRANSFERABILITY***: The drone can be used by local authorities and interested organizations for demonstration purposes, training, testing of new systems for collecting microplastics, which can complement or even replace traditional water sampling techniques.*

5. **MEDIA:** *As follows, some images, photos and video of the design, manufacturing and realization of the drone. The videos show its testing in the test tank and at sea.*









Video_tank_drone.mp4
Video_drone_at_sea.MP4

Autonomous Mobile Net Array for Floating Litter Collection

1. **INTRODUCTION***:*

1.1 Brief description of the activity performed

Researchers from the University of Dubrovnik, Laboratory for Intelligent Autonomous Systems (LARIAT) designed and implemented the autonomous mobile net array for floating litter collection. After agreeing on the dimensions and mobility and control mode of the net array, the equipment needed for the assembly was purchased. Control algorithms for coordination and efficient litter collection were also developed and the prototype of the autonomous mobile net array was custom made. The net array was successfully tested by the researchers from LARIAT with the guidance and useful inputs from the researchers from the Department for Applied Ecology for collection of various types of common floating litter and it was presented at to different target groups (general public, local, regional and national public authorities, regional and local development agencies, education and training organizations as well as universities and research institutes).

1.2 Goals achieved

UNIDU designed and implemented autonomous mobile net array along with the control algorithms for coordination and efficient litter collection using autonomous mobile net array achieving in that way the activity deliverables.

2. **DELIVERABLE METHODOLOGY***: (first briefly describe what was done, then some tips for the replication of the action – suggestions are reported below)*

2.1 WHERE: Deliverable location description (the location can affect the effectiveness of the action? What about the seasonality?)

The autonomous mobile net array was used in the Bistrina Bay (Southern Adriatic), 55 km southern from Dubrovnik at the Laboratory for mariculture of the University of Dubrovnik. There, UNIDU has

a research concession on sea area with floating longlines for suspended bivalve culture that was used to test the net array.
The effectiveness of the action can be affected by the location and the seasonality by means of the hydrometeorological conditions, especially in the case of the strong wind and the sea currents.

2.2 WHO: Experts Involved (Which background do you need to perform well the action? What's the minimum team?)
The research team that designed the autonomous net array are members of LARIAT with background in robotics, control systems and computer science. During the design process the useful input was added by researchers from the Department for Applied Ecology with background in marine science and ecology. Thus the minimum team to perform well the action would be two to three experts in robotics, control systems and computer science and one experts in ecology and marine protection.

2.3 HOW: Description of the activity realized (specific technology are needed? And the timing needed?)

For the development of the autonomous net array the UNIDU research team spent in total around two years. The technologies used for design and development are sensors for autonomous navigation and localization, autonomous nonholonomic surface vehicles serving as actuators for the net array, path planning algorithms and machine learning algorithms. The first version of the system was ready 17 months after the beginning of the activity and the first public demonstration including all the stakeholders was performed in May 2022. Until the end of the project the system was constantly updated, tested, and validated in real filed experiment, with the last demonstration performed in April 2023.

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2.4 Outputs achieved vs Outputs expected

The plan of the UNIDU pilot action included a demonstration of a sustainable collection activity on two sites in Dubrovnik area, but we performed it one location, Bistrina Bay, several times. The other planned location was the Dubrovnik Old Town Port which occasionally gets hit by a huge amount of the floating litter, usually after a series of storms in the Southern Adriatc, and that (luckily) didn't happen during the project implementation.
A system prototype consists of a mobile net array capable of collecting surface marine litter. The array uses a combination of active and passive collection mechanism to capture the floating waste which can be collected from the shore.

2.5 ***SWOT ANALYSIS***

Describe, with the support of the SWOT analysis scheme, how the performed action can be improved

	Helpful	***Harmful***
Internal Origin	*STRENGHT:* *The developed system can be used for collection of surface litter in confined environments such as ports or marinas.*	*WEAKNESS:* *The current prototype is still in the early technology stage and can only be operated by expert personnel*
External Origin	*OPPORTUNITIES:* *The developed system has the ability to be further developed into a fully autonomous system is the research and development continues to be funded.*	*THREATS:* *The current prototype is not suitable to be used in harsh weather conditions, i.e. high waves, strong wind and heavy rain*

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3. **CONCLUSION / SUMMARY***:*

main achievement of the pilot action (after this pilot, can be set a new baseline for new studies? What can be done to continue this pilot actions?

UNIDU designed and demonstrated the autonomous mobile net array for floating litter collection. The net array was successfully tested for collection of various types of common floating litter and it was presented at to different target groups (general public, local, regional and national public authorities, regional and local development agencies, education and training organizations as well as universities and research institutes). Interested parties can invest in supporting this kind of research with special focus on robotics design, development of control systems algorithm and artificial intelligence.

4. **TRANSFERABILITY***:*

After the project, the prototype of the mobile net array will be available to the local authorities, interested public and non-governmental organizations in a case they show interest in using it, especially in a case that Dubrovnik Old Town Port gets hit by a huge amount of the floating litter.

6. MEDIA

The functioning of the autonomous mobile net array for floating litter collection developed by the University of Dubrovnik can be seen here: [UNIDU MARLESS mobile net array]

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