UNMANNED VEHICLES SYSTEM UTILIZING WASTE TRACKING DATA TO TACKLE PLASTIC MARINE LITTERING ON TOURIST ISLANDS

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ABSTRACT

Marine pollution is undoubtedly a global, serious and rapidly increasing problem, as millions of tons of waste end up in the marine environment annually, causing multiple negative environmental, economic, health and aesthetic impacts, which are even more damaging for islands that base their economy on the tourism industry. The majority of marine pollution comes from anthropogenic and land-based activities and therefore it remains a critical issue to be tackled, especially in the case of plastic waste, which should be prevented from infiltrating the marine environment. Researchers have made many proposals and used a plethora of innovative technologies to deal with the phenomenon, one of the most promising of which is unmanned vehicles technology. Both aerial and surface unmanned vehicles offer feasible solutions in monitoring the evolution of the problem, although there is still room for improvement in achieving more efficient monitoring. In this paper, a solution utilizing data collected from a tracking plastic litter project is proposed, designed to monitor specific areas that accumulate large amounts of waste and inform the appropriate authorities, who will subsequently recruit volunteers to clean them up in time, before the plastics enter the marine environment.

KEYWORDS

Plastic Marine Littering, Unmanned Aerial Vehicles (UAV), Unmanned Surface Vehicles (USV), Internet of Things (IoT), Low-Power Wide-Area Networks (LPWAN), Citizen Engagement

1. INTRODUCTION

The number of review papers in the field of marine plastic pollution has been growing exponentially since 2015 (Aretoulaki et al., 2020). This extraordinary raise in published review papers means there are already significant efforts and findings towards tackling the problem and reducing marine littering. European Union’s objectives for sustainable development until 2030 and Paris Agreement to combat climate change and its effects, play an important role in the explosion of scientific interest in this environmental field.

The increasing demand has led to over 300 million tons of new plastics produced in 2015 (Beckman, 2018). The large amounts annually produced, along with the recalcitrant nature of the material and the waste mismanagement, are responsible for the progressive accumulation of plastics in the marine environment, a problem with serious environmental and socioeconomic effects (Aretoulaki et al., 2020). Plastics ending up in the marine environment have increased from 8 million tons in 2010 to more than 9 million tons in 2015 and are predicted to reach over 16 million tons by 2025 (Jambeck et al., 2015). Land-based sources are responsible for 80% of marine plastic pollution (Andrady, 2011) and 100% of freshwater plastic pollution (Schwarz et al., 2019) and consequently, it would be proved to be very efficient to tackle the phenomenon at its point of origin, namely the terrestrial environment.

During the past few years, innovative technologies utilizing Unmanned Aerial Vehicles (UAVs) with imaging sensors have been tested in order to effectively monitor the coasts (Deidun et al., 2018; Gonçalves et al., 2020). The urgent nature of the issue has led to the development of a multitude of proposals that complement UAVs, by utilizing machine learning to analyze acquired images with extensive use of image databases (Martin et al., 2021) or developing gamification techniques in order to increase citizen engagement (Stengos et al., 2019). The collection of comprehensive preliminary data is able to further support such efforts. Finding and visualizing the paths of plastic litter before it ends up in the marine
environment, in order to locate areas of high accumulation of plastic waste and entry points in the sea along the islands’ coasts, could significantly enhance the results of monitoring programs based on unmanned vehicles. Nonetheless, the authorities are not able to cope with plastic marine pollution in a cost-effective way, without the substantial involvement of citizens (Ponis, 2020).

2. TRACKPLAST PROJECT

The TRACKPLAST project is an innovative IoT technology system utilizing flexibility, range and cost effectiveness provided by Low Power Wide Area Networks (LPWANs) and sets its efforts in the determination of streams of plastic waste from land sources until they reach the shore and before entering the sea. More specifically, the project involves the development of a system aspiring to visualize the paths followed by plastic litter on specific islands, on their journey to the marine environment. The project develops an integrated methodology of plastic marine littering management through the use of a customized object identification, tracking and data capturing technology. This technology system is based on the basic principles of IoT technology and more specifically, utilizes wireless sensors operating on a LoRa Network. For the purposes of the project, LoRa end-nodes are integrated on PET water bottles produced with a custom-made mold (Plakas et al., 2020), making a unique commercial product, exclusively for the purpose of the project.

The project’s large-scale pilot will take place during tourist season, on a Greek island, which attracts a large number of domestic and foreign tourists. During this period, the bottles’ manufacturer will dispatch the LoRa-enhanced plastic water bottles to the island’s retailers, in order for them to be sold to locals and tourists. The end-nodes, which will be attached to every bottle, will be sending a signal every 4 hours, stating the bottle ID number and at the same time, the timestamp of the signal will also be produced and uploaded to the cloud platform by the LoRa gateways. The developed plastic waste tracking system is supported by an advanced cloud platform, which is responsible for data collection, processing and reporting to the project’s stakeholders. Main priority of the platform is the successful operation of a geolocation solver, which will provide the position of every LoRa-enhanced bottle having sent a signal and enable the visualization of the paths followed by the bottles to their final destination, either landfill, recycling center or sea. Among others, the project will draw useful conclusions about the waste and recycling habits of consumers that will buy one of the project’s water bottles during the pilot phase. A schematic of the project’s architecture is presented in Figure 1.

![Figure 1. TRACKPLAST Architecture](image-url)
3. PROPOSED SOLUTION

The project’s ultimate objective is to propose effective monitoring solutions and a roadmap including preventive measures for preventing or diverting plastic waste from reaching the sea, thus reducing marine littering. The success of the project’s proposal is based on the data collected from the LoRa-enhanced bottles. The project’s research team aims to analyze the geolocation data provided by the LoRa network, in order to determine vulnerable areas—in terms of plastic littering—all over the island. At this point, although the pilot has not yet started and there is no actual tracking data, the research team has already set its first goals on how to exploit the project’s outcome. The expected results from the project’s implementation will provide two pieces of information that if used properly, will be very helpful in providing successful solutions.

The first result expected from the data visualizations will be the revelation of the island’s terrestrial areas, where progressive accumulation of large quantities of plastic is taking place. If a large number of signals is sent from a specific area, without an obvious reason (e.g., landfill), then this area has to be examined more closely and possibly monitored for some period of time. The second very important expected result from the project’s pilot will be the identification of the main points where plastic litter enters the sea across the island’s shoreline. To define these entry points, a mix of information will be used, such as, areas of high accumulation across shoreline, last signal’s location per end-node and signals located inside the sea.

The proposed technology solution involves the development of a system that utilizes Unmanned Aerial Vehicles (UAVs) and Unmanned Surface Vehicles (USVs) to exploit these very important findings, in order to protect the environment in a more efficient and cost-effective way, by specifically monitoring the most vulnerable areas of the island, either they are located inland, on the shoreline, or in the sea. Unmanned vehicles participate during the pilot phase of the project to enhance the LoRa network and provide environmental information and images through their sensors, but their key role is to be played after the pilot has ended and the LoRa network is no longer active. For the purposes of the proposed solution, two configurable unmanned vehicles have been chosen, equipped with powerful optical sensors, dual optical payloads and environmental sensors. The Atlas 4/8 is an Unmanned Aerial Vehicle (UAV), designed to be utilized in the fields of surveillance, environmental monitoring and research projects, while NIRIIS is an electric powered Unmanned Surface Vehicle (USV) also designed for applications, including surveillance as well as experimental and research applications (ALTUS LSA, n.d.). Both vehicles are shown in Figure 2:

![Unmanned Vehicles: a) ATLAS 4/8 (UAV); b) NIRIIS (USV) (ALTUS LSA, n.d.)](image)

The development of the monitoring system consists of a set of integrated modules interacting with each other to achieve the best possible result in cleaning up waste and tackling marine littering. The solution’s Cloud Platform contains the data and visualizations provided by the results of the large-scale pilot. Based on the platform’s preliminary data, the Control Room navigates the unmanned vehicles to the areas of interest to collect images on a daily basis, during daytime. UAVs, supported by a mobile land-based station (van), are used for monitoring the areas with high accumulation of plastics, found from the pilot data and the authors firmly believe that large quantities of more waste and garbage will be found there as well. On the other hand, USVs are navigated to specific sea areas near the marine entry points, defined by the pilot’s outcome, to capture images of plastic marine litter on the sea surface as well as under water. Data from the imaging sensors captured by both types of unmanned vehicles are sent to the Cloud Platform for aggregation and processing. The results are evaluated by the Control Room, which decides the locations to be monitored next,
based not only on the pilot’s preliminary data, but also the day-to-day imaging results from the monitoring program.

The Control Room is actually a key component of the solution’s final product, as it controls unmanned vehicles, evaluates data received from the Cloud Platform and most importantly is responsible for the effective planning of the cleanup activities, which are of course the ultimate objective of the project. First, the Control Room reports the results to the proposed solution’s stakeholders and informs the appropriate system users, i.e. local authorities and environmental NGOs, about land or underwater areas, where waste is piled up and actions are needed to be taken immediately. Alongside, the Control Room is responsible for scheduling timely cleanup activities and notifying -through a dedicated mobile application- the island’s volunteers, in order to achieve maximum efficiency. Locals and tourists are able to participate in these cleanups organized across the island, while volunteer cleanups under the sea are also planned for divers and fishing boats that wish to be summoned to offer their expertise. A schematic of the proposed solution is presented in Figure 3.

Traditionally, monitoring and cleanup activities related to plastic waste, require a large number of human resources and a lot of time to keep plastics outside the marine environment. The proposed solution aspires to support both of these activities, with a specialized and comprehensive program utilizing all available resources in the best possible way and achieve much more positive results. Especially for the volunteers, an efficiently organized schedule is essential, since they should feel that the time they provide is meaningful and makes a difference, in order to be kept engaged with such activities.

The authors are currently in the phase of deploying the technical components of the TRACKPLAST system (LoRa Gateways), integrating LoRa nodes to the produced water bottles and finalizing the specifications and scenario details for the large-scale pilot program. Parameters such as model accuracy, information reporting latency, range limitations and system scalability are some of the project’s technical results that will be demonstrated in the authors’ future works. At the same time, the authors are already working to integrate the proposed solution by enabling the communication of the cloud platform with the unmanned vehicles.

4. CONCLUSION

This paper aims to contribute to the plastic marine littering problem, which has been rapidly increasing during the last decades and significant measures and efforts have to take place for its mitigation. The technology solution presented in this paper proposes the usage of an integrated technological system utilizing
the power of UAVs and USVs, in combination with IoT technologies and LPWANs, in order to develop an ideal turnkey solution for tourist islands that are willing to tackle marine littering. The proposed system has the capacity of monitoring an island’s terrestrial areas, beaches and seabed for accumulated waste and timely scheduling its cleanup activities, therefore, protecting valuable natural resources, boosting circular economy and promoting the sustainable development of tourist islands. The proper use of resources provided by local authorities on the one hand, and the well-timed involvement of volunteers on the other, are crucial keys to the success of the proposed solution. Data analysis from the concluded pilot of the TRACKPLAST project will provide even more solutions to be proposed, both in terms of monitoring and cleaning up plastic waste, as well as improving citizen recycling behavior and participation in environmental actions.

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REFERENCES