

A GAMIFIED APPLICATION FOR MITIGATING PLASTIC POLLUTION IN COASTAL AREAS

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ABSTRACT

Marine pollution constitutes an environmental and socioeconomic threat of paramount importance, as millions of tons of debris accumulate in marine ecosystems every year, resulting in the decrease of various touristic activities. The research presented in this paper directs its attention to the mitigation of aesthetic and other consequences of this severe global issue, which has multiple deleterious implications on the economy of many seaside countries. To that end, the proposed paper demonstrates a platform that will integrate data into a gamified application in order to motivate citizens' behavioral change towards proper waste disposal and marine ecosystems protection. After the concise description of the integrated methodology, which will be supported by an innovative technology solution utilizing drones, sensors and station pad technologies, more emphasis will be put on the definition of the gamification methods and elements that will be combined and selected to increase users' engagement and incentivize them to adopt eco-friendly attitudes.

KEYWORDS

Marine Littering, Gamification, Serious Games, Wireless Sensors, Behavioral Change, User Engagement

1. INTRODUCTION

Marine littering is undoubtedly a ubiquitous problem that is becoming extremely intense in the course of time, as approximately 4.8 to 12.7 million tons of plastic and other types of waste end up in marine environments every year (Jambeck et al., 2015), causing detrimental impacts on various ecosystems, the economy and subsequently, human life (Jang et al., 2014). To make matters worse, according to a WWF research (2018) the anthropogenic activity of tourists who travel to a great number of Mediterranean shores, increases the produced waste by 40%. In addition, the aesthetic consequences stemming from marine littering are immensely crucial, given that the factor of cleanliness plays a cardinal role affecting the beach choice for tourists and local residents (Balance et al., 2000). As a result, the high concentration of plastic waste can lead to the decrease of touristic activities, which are the financial backbone of many coastal countries. According to Leggett et al. (2014) cleaning beaches on a regular basis and removing 75% of the existing plastic waste would increase beach visitors by 43%, while the total benefit would be roughly \$53 million.

In light of the above and considering that climate change remains a critical issue to be tackled; it comes as no surprise that marine littering should be solved without any further delay. Nevertheless, lack of education has driven citizens away from adopting sustainable methods and recycling habits. As a consequence, innovative and interactive techniques have been investigated in order to raise awareness about practices that mitigate global warming (Ouariachi et al., 2020). More specifically, it is believed that game-based learning, which is the utilization of games that have educational purposes can enhance the adaptation of people so that they can handle the upcoming demands that stem from complicated learning fields and teach them how to adopt multiple habits in a creative way (Ifenthaler et al., 2012; Digital Learning Institute, 2022). Even so, the use of gamification has emerged as a promising tool, which leverages game-design methods for impelling users to become engaged in non-entertainment environments (Bunchball, 2010; Schoech et al., 2013). Since "gamification" and "serious games" share a lot of characteristics, their terms are often being mixed up. The former is the embedding of a number of game-design elements, into non-game contexts in order to increase users' engagement and motivation, whereas serious games put more emphasis on the game's objective, which is beyond entertainment and apply all the elements (Hammady & Arnab, 2022; Preeti GT, 2023). Furthermore,

gamified learning is the application of game elements, such as leaderboards, points, badges, rankings, levels, narrative, competition, achievement, avatars, suitable environment, game fiction, interaction among the users, engagement, and specific goals in order to enrich the users' experience and lead them towards the desirable learning behaviors (Landers, 2014; Limantara et al., 2019). Hence, it is observed that the correlation between gamification and learning is a combination based on four essential substances: instructions, game elements, behaviors, and related outcomes aiming at the increase of motivation to cultivate new attitudes (Landers, 2014). Additionally, Toda et al. (2019) has classified gamification elements according to five dimensions:

- the performance dimension elements, e.g., points and levels that demonstrate the user's progress.
- the ecological dimension elements, e.g., time pressure which sets the temporal boundaries for the implementation of a task.
- the social dimension elements which define whether the gamified environment should be competitive or cooperative.
- the personal dimension elements which are based on the user's experience that is created by the application.
- the fictional dimension elements, e.g., storytelling; an activity that uses words to create new worlds and experiences in users' imagination or narrative which is achieved through personalized characters.

In general, gamification has a great potential as an immersive, persuasive technology that initiates environmentally friendly behavioral patterns and stimulates sustainable habits, which adoption is maintained even after the users' engagement with the application (De Guinea et al., 2009). Truelove and Gillis (2018) identify four main dimensions that can influence pro-environmental behavior: the environmental impact, the money saved by the person performing the behavior, the monetary cost of performing the behavior, and the behavioral cost. In addition, according to Li et al. (2019), the factors affecting pro-environmental behavior can be distinguished into two major categories: a) external variables, such as social norms and rules, cost and convenience, and b) individual variables, which include demographic and psychological variables such as attitudes, social capital, previous recycling experience and socio-economic characteristics. Given that the gamified application contains a specific amalgamation of persuasive techniques, it can encourage the required behavior and encourage users to change their attitudes based on the game's purpose.

Some of the most important gamification methods are: set clear goals, so that users are committed to a specific purpose, provide feasible challenges, which will impel users to overcome obstacles, provide feedback, in order to constantly monitor their progress regarding the desired outcome, offering awards, e.g., points, badges, when they reach milestones in their progress or providing leaderboards, levels, in order to demonstrate and compare their progress with other users, and emphasize on the element of fun, by creating narratives, stories and customized characters (Cugelman, 2013). Furthermore, based on Ourdas and Ponis (2023) free choices, badges, points, avatars, narrative, as well as feedback increases the usage of the application and leads to feelings of satisfaction, whereas gamification elements that intensify competitive emotions among users (leader boards, progress bars, ranking etc.) seem to make the experience less pleasant. Especially for environmental behavioral change, it has been evident that achievements, rewards, points, and leaderboards, as well as feedback based on personalized avatars stimulates users' interest and incentivize them to adopt eco-friendly habits (Berengueres et al., 2013; Gnauk et al., 2012; Liu et al., 2011).

2. THE PROPOSED SOLUTION

The project presented in this paper demonstrates a holistic management methodology for tackling marine littering reinforced by underwater and ground sensors, two types of Unmanned Vehicles (Aerial and Underwater), equipped with imaging and environmental sensors and supported by autonomous station pads, as well as a specialized web platform, leading to the data documentation and distribution to project stakeholders and users. More specifically, the imaging sensors that are embedded into the Unmanned Vehicles implement daily monitoring across the beach, especially early in the morning, in order to avoid causing noise pollution for the beach users and at least once per day for the regular collection of imaging information (e.g., photos and videos) about the inspected coastline. On the other hand, environmental sensors are applied for real-time monitoring and measuring specific environmental conditions (e.g., sound levels, air pressure, ambient temperature, CO₂ and CO emissions, humidity, wind speed etc.). As a result, the input value of the unmoving ones is advanced by sharing more information about the status of the beach and resulting in the integrated

enhancement of tourists' experience. It is also, worth mentioning that the Unmanned Vehicles are recharged by the station pads which analyze and quantify the accumulated waste on the beach and the underwater sections of marine ecosystems, as well as distribute the collected data to a cloud server, so that all involved stakeholders can process it, at any time. Last but not least, the most essential part of the proposed methodology that is presented in this paper is the game planning mechanism, consisting of two parts; the gamification platform and the project's application. A schematic of the aforementioned management system is demonstrated in Figure 1:

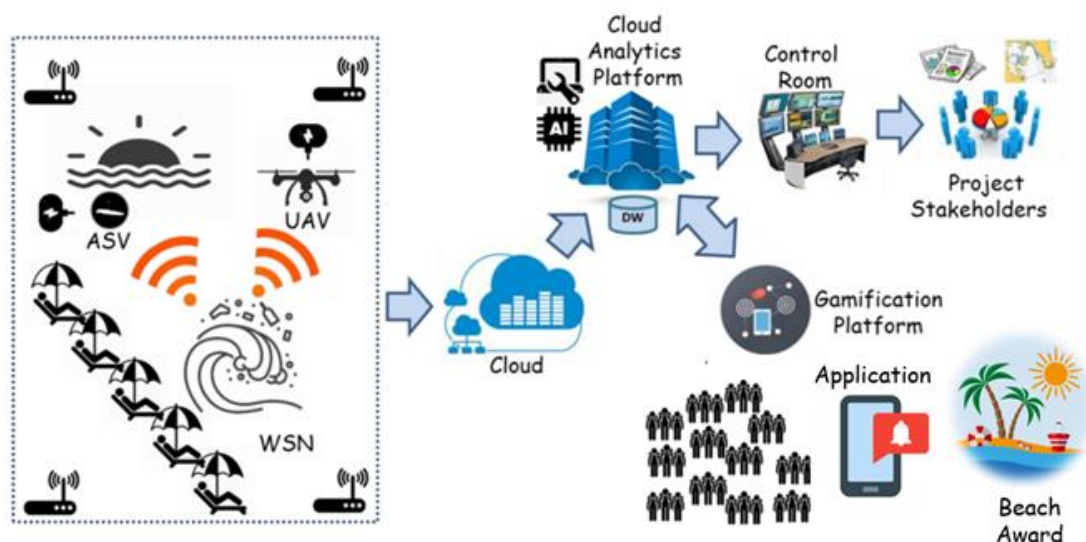


Figure 1. Management system of the proposed solution

This paper directs its attention to the gamification methods and elements that are leveraged for its application, as well as its effective combination which creates a friendly environment for the users and impel them to protect marine ecosystems, thus reinforcing the touristic industry. The applied game methodology has a twofold purpose. The first one is to inform beach visitors about the cleaning status of the selected beach via an algorithm that calculates the real-time debris concentration on the beach, whereas the second one is to raise awareness and encourage citizens to properly deposit their waste, as well as be engaged in cleaning activities. It should be also, noted that the algorithm is reinforced by the accumulated environmental data of the sensors in order to provide an integrated evaluation of the recreational experience of the beach user.

After downloading the project's application, the user has the ability either to get informed about the project and its technical aspects or select information about the participating beaches. According to the authors, a step of paramount importance, is to set a **specific goal**, otherwise the feeling of confusion dominates. Hence, the involved beaches compete with each other regarding its cleaning progress which is calculated by the extracted data from the imaging and environmental sensors and it is visible to the users, at any time. At the end of the week, one of the participating beaches is declared as the winning one and is awarded for contributing to the preservation of marine ecosystems and supporting tourism. It is also, worth highlighting that the start of measurements documentation has been implemented one week before the data documentation and distribution started, so that the progress of each beach is noticeable. Another essential method is to provide **feedback**, utilizing distinct gamification elements. As already mentioned, for environmental behavioral change it is observed that features that exacerbate competitive feelings (e.g., leaderboards and rankings) seem to discourage users from participating in applications that promote sustainability. Thus, progress bars with weekly targets for each participating beach, are being used which have a positive effect on engagement and appear to positively influence competence. Therefore, this gamification element demonstrates the real-time progress of the beach, in comparison to previous week's cleaning conditions. Furthermore, the **element of joy** should not be overlooked, as it has the ability to hold the users' attention and interest. As a consequence, a customized level-up dart for each beach is utilized and demonstrates its overall cleaning status based on the extracted data from the imaging and environmental sensors. To be more precise, the darts' levels fluctuate between 1 and 6, with level 6 being the cleanest one and motivating users to ameliorate its cleaning conditions, as the beach with the highest score gets recognition on a global scale. In addition, each beach collects badges based on weekly

targets, rendering the application more enjoyable for the users because they demonstrate users' accomplishments and status, as well as encouraging them to strive for more tasks and to compete with other users. Lastly, the user is guided to a link that leads to documents about marine littering and methods of contributing to the beach's cleaning improvement. A demonstration of the application's mock-ups is presented in Figure 2:



Figure 2. Indicative screens of the project's application

3. CONCLUSION

The research project presented in this paper demonstrates an innovative management methodology designed to mitigate marine littering reinforced by state-of-the-art technologies, as well as the optimal amalgamation of gamification elements that should be embedded into the proposed application. The integrated solution combines two types of Unmanned Vehicles with Internet of Things, while the collected data is distributed and the cleaning status of the inspected coastal area is visualized to all involved citizens. Furthermore, a plethora of gamification elements is leveraged in order to drive citizens towards green behaviors that are in alignment with circular economy and recycling basic principles and raise their awareness about marine pollution. It is also, worth noting that the proposed project could be implemented at any shoreline or beach, as its characteristics are generic and can contribute to the gradual tackling of marine pollution and the upscaling of the area's tourist industry.

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