A Framework to Enhance Smart Citizen Science in Coastal Areas

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ABSTRACT

Life quality in a city can be affected by the way citizens interact with the city. Under a smart city concept, citizens are acting as human sensors reporting natural hazards, generating real-time data and enhancing awareness about environmental issues. This crowdsourcing knowledge supports the city's sustainability and tourism. Specifically, smart seaside cities can fully utilize citizen science data to improve the efficiency of city services, such as smart tourism, smart transportation etc. Environmental assistance and awareness is a beach monitoring issue that could be enhanced through crowdsourcing knowledge. Especially for coastal areas which are under the Natura 2000 network and are characterized as blue flag seas, it is important to identify and map citizens' knowledge. To facilitate this, we introduce a novel framework aimed at: i) utilizing biodiversity data from open source platforms and organizational observations, ii) collecting the knowledge generated from citizens, iii) enhancing citizens' awareness, and iv) reporting environmental issues in their city's coastal areas. The proposed framework exploits these aspects and through the creation of a novel knowledge platform, it aims to provide geospatial, collective awareness applications as an output to support the sustainability of smart coastal spaces.

CCS CONCEPTS

• **Information systems** → Information systems applications; Data analytics; • **Human-centered computing** → Social network analysis.

KEYWORDS

citizen science, tourism analytics, collective intelligence, crowdsourcing, coasts, smart beach

ACM Reference Format:
Maria Papoutsoglou, Konstantinos Markakis, Loukas Chatzivasili, Georgia Kapitsaki, Kostas Magoutis, Leonidas Katelaris, and Chryssoula Bekiari. 2022. A Framework to Enhance Smart Citizen Science in Coastal Areas. In *Companion Proceedings of the Web Conference 2022 (WWW '22 Companion), April 25–29, 2022, Virtual Event, Lyon, France.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3487553.3524852

WWW '22 Companion, April 25–29, 2022, Virtual Event, Lyon, France.

ACM ISBN 978-1-4503-9130-6/22/04.
https://doi.org/10.1145/3487553.3524852

1 INTRODUCTION

Over the past ten years, smart cities have been turned into the most developed urban smart space instance. In a smart city context, different aspects of urban life are enhanced such as economy, government, mobility and people [2]. These aspects define the smartness of a city with the most popular smart features being smart living, smart mobility, smart environment, smart people, smart economy and smart governance [10]. The smartness of a city relies on the usage of technology for improving citizens' life [9]. Integrating smart actions into the daily habits of people (i.e., studying, living, working, or visiting the city as a tourist) demands human contribution. This necessity requires the contribution of smart people for a successful smart program [5].

Traditionally, smart cities have sensors installed in order to monitor traffic, pollution, parking conditions and predict attendance in cultural events amongst others [21]. However, smart people could act as sensors as well [23]. Citizens and visitors in a city are two important stakeholders who act as human sensors in a smart city and broadcast real-time information about the city's pulse. Visitors (i.e., tourists) or permanent citizens generate a massive amount of geolocation content, modeling city's spaces into dynamic areas [11]. User generated content (UGC) constitutes valuable contribution for enriching the city's crowdsourcing knowledge. More specifically,

there is a growing number of services and applications available for real-time analytics and observations of environmental conditions. Through the utilization of social and crowd sensing, citizens provide the human contribution for the "smartness" of the city's facilities [3].

The profusion of this available information was one of the factors which have accelerated the urbanization of smart cities. However, the progress of urbanization has caused issues in the environmental sustainability of a city. As a result, a rising need for a climate-smart city, pham2020smart is obvious with a special focus not only in the reduction of emissions [18] but also urban biodiversity requirements for a smart sustainable city. An ideal smart space to establish monitoring mechanisms for environmental issues are coastal areas [22]. The most well-known characteristic of smart coastal cities is beach monitoring [7]. However, analyzing coastal areas could provide a reasonable solution to enhance climate-smart cities, as these areas are enriched with terrestrial or marine biodiversity. Taking into consideration the above, in this work we introduce a knowledge platform - SocioCoast - that aims to gather data for beaches and coastal areas, utilizing the concept of citizen science. Tourists and visitors can report their findings to the platform and the collective information can be explored by relevant government or non-government bodies, such as municipalities or environmental organisations. Using this information, the relevant authorities can be called to action (e.g., municipalities) in case the users' observations require their intervention for environmental or legislation purposes. The aim of the platform is to enrich the existing information that is provided for beaches under the framework of the Blue Flag awards programme. Generally, as coastal areas are important indicators for cities' sustainability and this framework combines environmental indicators with crowdsource knowledge, it can be related to the ISO/TR 37120:2014 standard. The ISO/TR 37120:2014 is a standard for environmental indicators in a smart city's framework [4].

The rest of the paper is structured as follows. Section 2 reviews the current state of citizen science and smart beaches. The proposed framework to enhance smart citizen science in coastal areas is described in Section 3. Section 4 presents relevant scenarios which utilize the proposed framework. Finally, Section 5 contains the final conclusions and discusses some future prospects.

2 RELATED WORK

The purpose of this section is to clarify that UCG is one of the most valuable information not only for smart cities' development but also for citizen science. As a result, we try to define what citizen science is and how it can be utilized in a climate-smart city's needs, especially for coastal smart areas development and as a solution for environmental issues in an urban smart city.

The massive gathering and utilization of UGC has been proven as one of the most successful sources (e.g. other sources are sensors, smart city labs etc.) of information to shape the development of a smart city and also as a destination concept [15, 20]. An additional asset of UGC in smart areas is the tourism analytics [13, 16]. If a citizen happens to be in a city either temporarily or permanently, they support the city's crowdsourcing intelligence with their generated content. A new direction for smart areas is to utilize this knowledge to support environmental issues in a city [8, 17]. Specifically, there is a rising interest in urban biodiversity requirements for a smart sustainable city.

Generally, biodiversity data analytics in citizen science are well enriched. Currently, there are many datasets and approaches which utilize UGC to continuously inform and develop biodiversity analytics for different areas and needs. One of the most well known citizen science open data is the iNaturalist[1]. iNaturalist is a multifaceted species recognition system and an organism tracing tool. It can be used to record observations from the public, to help identify a species from the community, to create synergies in order to gather that kind of information for a common purpose, or simply to access observational data collected by iNaturalist users. It is an effort with a significant impact and it is considered a "success story" in the field of biodiversity crowdsourcing. The iNaturalist dataset is huge and a valuable tool in the hands of biodiversity researchers and anyone who wants to draw conclusions from such a dataset. This dataset can be used for terrestrial [19] or marine [6] biodiversity analytics. Another interesting platform which is based on crowd knowledge for biodiversity monitoring is the LifeWatchGreece (LGW) platform [14]. LWG is a central platform that supports data exchange and integrated analytics. It includes a number of e-Services and virtual labs under development to facilitate both data rates and users. Finally, an exemplary implementation of a citizen observatory is the CITY-SENSE framework [12]. This work describes step by step the concepts and the architectural elements that are needed to create a CITY-SENSE observatory. Aiming at raising the public awareness of the environment around them, it seeks to empower users to generate knowledge through reporting personal observations about important measures that define the quality of life in a city in a structured manner.

As it can be observed, biodiversity data are available and they could be turned into ideal sources of information, in combination with UGC, to construct climate-smart city concepts. Coastal areas are suitable areas for these concepts, thus there are many developed smart cities which are coastal areas (i.e. Barcelona, Valencia etc.) [7] until today. Especially, smart beaches are areas where IoT sensors are used for monitoring the beach [7] or for improving beach safety using smart cameras [1]. However, in order to support a climate-smart space concept, it is not enough to map a coastal area using smart IoT solutions for its sustainability, therefore other aspects need to be taken into consideration such as biodiversity, oceanography and weather data, and citizens' reports for environmental hazards and issues in these areas. In this work, in relevance to prior work, we propose a framework which receives as input the aspects mentioned previously and provides a biodiversity-inclusive solution for a climate-smart coastal area utilizing crowdsourcing knowledge.

3 PROPOSED FRAMEWORK

The proposed framework is captured in Figure1. In this section, we analyze its basic components as depicted in the Figure.

[1] https://www.inaturalist.org/

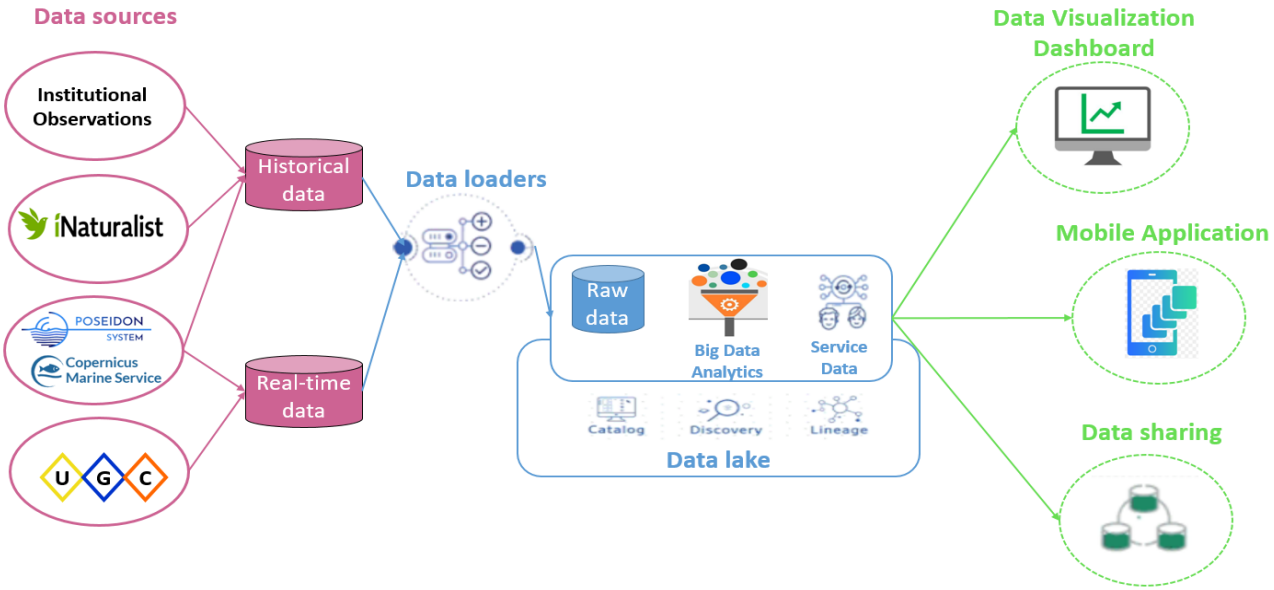

Figure 1: A framework to enhance smart citizen science in coastal areas.

3.1 Data sources

The data sources of the proposed framework are divided into institutional observations, open-source datasets and dataset applications for oceanographic and biodiversity data, as well as UGC. Institutional observations are observations regarding coastal areas and beaches that are taken from experts using appropriate measuring tools such as observations in areas of Greece coming from HCMR (Hellenic Centre for Marine Research). Oceanographic and biodiversity data will be collected for the knowledge platform from various open-source applications. One such example concerning oceanographic data is the Copernicus Marine Environment Monitoring Service (CMEMS[2]), an EU Programme which provides free and open marine data and services. Respectively, iNaturalist, which was analyzed in the previous section, is one important data source for biodiversity data. Historical and current (real-time) data are collected from these sources through APIs or other similar ways of collecting data. The UGC component refers to geolocation data provided to the framework by the users via the use of the dedicated mobile application. By combining the above data sources, the proposed framework can contribute to shaping dynamic/smart coastal areas and beaches.

3.2 Data loaders

This part of the framework will contain calls to all the heterogeneous data sources mentioned in the previous section (intermediate level of communication), in order to provide the appropriate data to the users who will request them. More specifically, a REST API (Representational State Transfer Application Programming Interface) will be created on the web knowledge platform in order to allow registered users to extract the data of their choice and use it in their own applications or for further analysis purposes.

[2]https://marine.copernicus.eu/

FIWARE - dataset format: FIWARE[3] is an open source platform that can be used to build a set of templates for developing smart applications for different sectors, such as smart cities, smart ports, smart logistics, smart factories and more. Smart applications require the collection of data from different sources about what is happening and these data need to be relevant to the application at all times, whereas we can refer to them with the term "environmental information". FIWARE promotes a template that describes how environmental information is collected, managed and published, adding some elements that allow the data collected to be exploited. An intelligent application must be able to understand these context aware data and react accordingly by displaying intelligent behavior. In the framework of a smart city, we consider as context anything that is or happens in the city, such as roads, city services, citizens, etc. Respectively, regarding the proposed SocioCoast framework for beaches and coastal areas, context aware objects of interest could be garbage cans, showers/taps, toilets etc.

3.3 Data handling component

This component if visible in the middle section of Figure1. As aforementioned, the data of the SocioCoast framework are drawn from various sources and need to be handled appropriately in order to be useful and easy to use. Large volume and historical data are stored locally in files of different format (csv, netCdf etc.) in order to reduce the response time of the API calls used to collect these data. For the real-time data, we intend to set a narrow time window, so as to frequently update these data during the day. Regarding the data processing, the use of stream processing technologies for continuous processing could possibly lead to the production of warning or other notifications on the web knowledge platform or on the mobile application. Its use will thus, be further examined.

[3]https://www.fiware.org/developers/catalogue/

Big Data Analysis: This component will operate as a large-scale data analytics engine and will handle algorithms and techniques for big data which are collected and stored on the knowledge platform. Some of its operations will be: continuous data storage, extraction of features, training, understanding and prediction. Towards this purpose, proper functions will be implemented for the statistical analysis of big data leading to the production of specialized knowledge and conclusions regarding these data. From a scientific point of view, the use of cutting-edge algorithms and tools for machine learning to generate knowledge and facilitate rapid responses, will be adopted. The proposed engine will potentially expand to a virtual lab as a scientific tool for visualization, representation and export of large volume data analysis.

Data Lake: This component contains all forms of data that are stored on the knowledge platform in one way or another. This includes all types of digital data representation, such as structured data in SQL or NoSQL database format, encoded files, text, CSV files, or distributed system files such as HDFS (Hadoop Distributed File System) or RDD (Resilient Distributed Data-sets). It could also include data collection processes from external sources and basic processing for storage and archiving.

3.4 Data visualization – dashboard

A dedicated dashboard will be included in the web knowledge platform of the proposed framework and it will target all users of the platform, while the functionality available on the dashboard will depend on the user type (e.g. researcher, visitor). Users will be able to browse the platform and view information and data about the various beaches that will be included. However, some selected data or information will only be available to users with a valid account on the platform such as crowdsourcing data or problem reports. Via the dashboard, a user will also be able to project data of a beach or a coastal area, such as biodiversity data, in the form of graphs by selecting a default graph or by selecting the appropriate parameters to create a desired custom graph.

3.5 Mobile application

The framework is complemented with a mobile application that is intended to be used mainly by visitors of the beaches/coasts. Special emphasis will be given to the user experience for this part of the framework, in order to make its use more attractive to users. The user will be authenticated in the knowledge platform through the mobile application. The application will contain rich and accurate information that will help the users to utilize the comforts and characteristics of each beach in order to be properly informed before they visit the area, or while being at this beach or coastal area. The application will also allow the user to report issues regarding the condition of the infrastructure of the blue flag coastal area or any other problem of this coastal area. Examples of such problems are overfull trash bins, accessibility issues to the beach etc. Through the use of the mobile application, the users will also be able to contribute new data that they identify through their personal observation, to the knowledge platform. For instance, a species of terrestrial fauna that is not already included in the information available in the mobile application and the web knowledge platform. Both issue reporting and contribution with new data will rely on receiving geospatial information from the user's mobile in order to identify the location of the observation.

3.6 Data sharing

Users with a valid account on the knowledge platform or on the mobile application respectively will have the chance to export part of the data that will be available through the REST API. A researcher or data analyst may use this data to create new applications or reach new conclusions, for instance, about the weather in a local beach in Cyprus. Another point worth mentioning about data sharing is the scalability of the framework in order to function in the opposite direction and share new data obtained from the SocioCoast users - mainly biodiversity data - to the same data sources from which such data are derived and used in the framework. Such an example is iNaturalist that was mentioned in section 2.

4 STAKEHOLDERS AND SCENARIOS

4.1 Stakeholders

The proposed framework will be used by various categories of users. The main stakeholders that will be involved are visitors (ordinary people or explorers), relevant organizations (authorities), businessmen/women based near coastal areas and administrators of the system. A better analysis of their role is described below:

- **Visitors:** Visitors of beaches and coastal areas can be further divided into ordinary citizens and explorers. Citizens usually visit coastal areas for entertainment purposes. These people could use the framework to gain general information about a beach like weather conditions, services, lifeguards etc. Explorers are people that visit these areas having some ultimate purpose related to their research interests. They are expected to look for more specialized information such as biodiversity data or oceanographic data from the knowledge platform of the framework, and also have the chance to contribute to crowdsourcing through the mobile application of the framework. Both citizens and explorers could also report possible problems that they observe during their visit on a coastal area.
- **Relevant organizations (authorities):** This group consists of organizations and local authorities that are related to the preservation of beaches and coastal areas (or the Blue Flag award programme) such as non-profit organizations and municipalities of the regions in which the beaches are located. By interacting with the proposed framework, such organizations will be informed about possible problems in beaches or coastal areas and will also be responsible for solving the ones that are under their jurisdiction. For example, the municipality of the area of a particular beach will be responsible to clean the amount of rubbish in this beach. Another point worth mentioning for them is to raise environmental awareness of citizens and especially young people.
- **Businessmen/women:** Citizens who own businesses near beaches and coastal areas are considered in this group. More specifically, this group may include owners of cafes, restaurants, beach bars, water sport clubs, hotels, etc. Entrepreneurs can help promote the proposed framework to the local community providing their means, resources and contacts. At

the same time, they will also benefit through the advertising of their businesses on the web platform and the mobile application and through a possible increase in the number of visitors which may lead to an increase in the profits of their businesses.

- **Administrators:** Authorized users who are responsible for the overall supervision of the system (the web knowledge platform and the mobile application) and its smooth operation. They will be able to accept (or if necessary also reject) requests for new users to register, change users' passwords, answer users' possible questions, etc.

4.2 Scenarios

At this point of implementation, two indicative scenarios are described below involving the interaction of the stakeholders with the framework's components:

- **Problem(s) reporting:** Suppose that it is a Sunday morning in summer. Tom, a local businessman (or just an ordinary citizen), has gone to a beach in his town for a swim. Before entering the sea, he notices signs of oil spills in the water. To help in solving this problem, Tom uses the mobile application of the proposed framework to report the problem (assuming he already has a valid account), specifying the place and time he located the problem with a short description and a clear photo as well. The administrators will examine the information provided and if the problem is considered as "valid", it will be sent via notification or email to the appropriate organization/local authority who will undertake the task of resolving it. At the end of this process, Tom will be informed if his report was taken into consideration or not, and if not then the reason of rejection will be revealed to him as well.
- **Contribution to crowdsourcing:** Nicole is a biodiversity data researcher who lives in Crete. As part of her research work, she decided to visit a local coastal area. Nicole studied about the flora and fauna of this area before going there and was expecting to observe some specific species. However, when she got there, she discovered some species of flora that she had not seen or read before regarding this area, so it would be an excellent idea to inform other people about them. By using the mobile application of the proposed framework, she could contribute new data to the system. The exact location of the user, a good quality photo and maybe also some text need to be provided for this purpose. The administrators will review the data and depending on the information provided by a user and their knowledge and experience with similar data they will accept or reject it. If, for instance, Nicole's data are accepted, then they will be visible to the knowledge platform of the framework but only to valid users.

5 CONCLUSIONS

This work aims to combine the elements of citizen science, crowdsourcing and an implementation of smart-city concepts, tailored for coastal areas. There is more flexibility to incorporate the necessary infrastructure to build a smart-city in an urban environment, such as sensors, IoT devices, etc. However, in this work we highlight the need to maintain a minimal interference with the natural environment of the coast, in the context of climate-smart areas. Therefore, there is a limitation on the amount of technological equipment that can be "tolerated" in a coastal area under this concept. This is where citizens and visitors come into play. They can effectively play the role of sensors through crowdsourcing, and at the same time they can promote the preservation of the natural habitat by cataloguing the marine and terrestrial flora and fauna. On the other hand, the end-user application, connected with the knowledge platform, will offer the visitor useful information about the coastal area they happen to visit. That information will be the result not only of the initial data sources that will be included in the project, but also of the data that comes from the users of the mobile application. In effect, the "citizen-scientist" will be able to reap the benefits of their own participation in the framework directly.

Our future plans concentrate mainly on four directions. The first one involves the implementation of the proposed framework using the real datasets, as they were described in the corresponding section. More specifically, we plan to develop specific data analysis algorithms which will extract knowledge from the raw data. The second concerns the thought to enrich the open dataset of iNaturalist using the UCG from the mobile application component. The third direction concerns the development of a smart online lab which will enhance the data scientists in biodiversity data analytics area to create their own reports. The final aims at configuring the system to correspond not only to the targeted coastal areas, but to be operable in other areas as well. Concluding, there are different appropriate stakeholders to evolve the proposed framework such as local organizations (i.e. local organizations, municipalities etc.) who will enhance with new data the knowledge platform, biodiversity data scientists using the virtual lab and researchers in the field of smart cities.

6 ACKNOWLEDGMENTS

Research for this paper was undertaken in the course of the Socio-Cast project of the Cooperation Programme Interreg V-A Greece-Cyprus 2014-2020, co-funded by the European Union (ERDF) and national funds of Greece and Cyprus under the grant agreement No 5050709.

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