

# Citizen Science with Immediate Feedback

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## Abstract

Citizen Science it's a powerful data sourcing tool that can be a driving force for a wide range of scientific scopes. Through surveys, information can be collected from the users to support the existing data available for the researchers community. Global change – including climate change, air pollution and land-use change, is affecting human health and ecosystem functioning. There is a need to map its effects over space, but the amount of information is low. This scarceness is derived from the insufficiency of monitoring stations available. In addition, its data is not enlightening enough to obtain information about the effects of the global change drivers. Lichens, being sensitive to air pollution and climate change are frequently used as ecological indicators. By analyzing its biodiversity, lichens allows to extract some indexes based on their functional diversity, understanding the relative impact of different environmental effects. Aligned with the principles of Citizen Science, this method can be used to tackle the existing scarceness of information by extending a Generic Crowdsourcing System with the ability to be modified and improved, providing immediate feedback to the user.

**Keywords:** Crowdsourcing, Global Change Drivers, Lichens, Climate Proxies.

## 1. Introduction

The impacts of global change are worldwide in scope and unprecedented in scale. The pollution and climate change effects maps are an excellent way to understand the effects of global change factors over space. On the other hand, the available maps are scarce in information, providing inaccurate and unreliable data for researchers. Global change effects could not be accurately represented in map due to their variations at high scale. This low map resolution represents a problem for local analysis that demands a spatially explicit sampling with high resolution.

Citizen science, a narrower subset of crowdsourcing, is emerging as a new form of interaction between scientists and citizens, allowing for social participation and involvement in scientific activities. Mapping and spatial data collection are two activities that shifted from a situation of researchers exclusiveness to public involvement due to the significant technological advances during the last decade [17]. Thus, crowdsourcing campaigns can be used in the framework of air pollution and climate change, collecting geolocated data that can be used to support the lichens mapping process.

Lichens, considerably sensitive to air pollution and climate change, are frequently used as ecological indicators. They are particularly sensitive to climate change and air pollution, especially sulfur

dioxide pollution. This happens because lichens derive their water and essential nutrients mainly from the atmosphere rather than from the soil [11]. It is proven that lichen functional groups have a strong association with the surrounding environmental variables [12]. Analyzing lichen diversity: species richness, lichen cover, and lichen community composition provides information about global change metrics. Thus, lichens can be used by researchers as ecological indicators, contributing to tackle the existing information scarceness.

The Centre for Ecology, Evolution and Environmental Changes (cE3c) - FCUL, supported by iLTER, proposed to sample lichen diversity in a citizen science project, to map the effect of air pollution and climate, using an app-based interface. By returning immediate feedback to the user, processed surveying data is immediately provided. This will enhance user experience, allowing a better user engagement and involvement in scientific projects.

## 2. Background

### 2.1. Global Change

Global Change is composed of a series of separate problems – climate change, biodiversity loss, dwindling water resources, air pollution, land-use change and many more. The ecosystems on Earth are not isolated, presenting dynamic inter exchanges. For example, Greenhouse gases and inferred tempera-

ture show regular synchronised variations over hundreds of thousands of years. In the framework of the global change is important to highlight to this work the climate change, the air pollution and the land-use changes and their environmental impacts.

Cardiovascular mortality and respiratory illnesses due to heatwaves, altered transmission of infectious diseases and malnutrition from crop failures are some of the nefarious effects of climate change on human health [14]. "Changes in temperature and rainfall conditions also may influence transmission patterns for many diseases, including water-related diseases, such as diarrhoea, and vector-borne infections, including malaria" according to the World Health Organisation. WHO also claims that patterns of food production can be affected by climate change, having health impacts in terms of rates of malnutrition.

The source of the major public health concerns come from anthropogenic sources related to air pollution. Motor vehicles, industrial facilities or to natural sources such as forest fires are some of the responsible for the emissions of air pollutants that contribute to human health issues such as particulate matter, benzo(a)pyrene, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide [16]. Respiratory diseases and lung cancer are one of the many consequences of the exposure to poor air quality at different life stages, ranging from prenatal period to adult life making this a public health issue that must be taken seriously [10].

Human activities influence the surrounding environment by altering the distribution of ecosystems and their associated flows of energy. Water vapor, trace gases and particulates are emitted with the human presence activity on field. This management regime that humans impose on a site is called land-use. For example, when large areas of forests are cleared, transpiration is reduced. This changes in land-cover patterns can directly impact energy and mass fluxes, resulting on less cloud formation, less rainfall, and increased drying [9].

## 2.2. Lichens as Ecological Indicators

Unlike vascular plants, Lichens have free exchange of both gases and solutions, occurring across the cell surfaces. Almost all their nutrients from the atmosphere through uptake over their entire surface, rather than from the soil [11]. With this nutrient atmospheric absorbency, pollutants are also consumed. As a result, some species are more sensible to that pollutants absorbency, and others more tolerant. The same happens regarding the lichen surrounding climate, resulting in heterogeneous levels of tolerance towards aridity and humidity. This divergent species tolerance allows to aggregate lichen species in functional groups. Lichen sensitivity to

various environmental factors made lichens to be widely used as indicators of climate changes [13] and as good surrogates of air pollution and climate change during the last 30 years.

In order to get high spatial resolution maps of pollution and climate change, the existing monitoring stations don't provide sufficient data for the researchers community and so, ecological indicators are a powerful tool to overcome this problem. Besides the lack of monitoring data stations another problem is the collective effect of the pollutants in urban environments, making it difficult to unveil their effects [15] and so, since bioindicators integrate the results of air pollution over time, they are also a good option to analyze this collective pollutants effect [8].

## 2.3. Citizen Science

Citizen Science [17], an emerging new form of interaction between scientists and citizens, allows social participation and involvement in scientific activities. It can lead the participants to have a great social engagement with science through the participation in real science projects. Interacting directly with scientists, the participants are able to acquire a perception of the scientific activity by the educational and engaging value that these projects can have in particular circumstances.

Mapping and spatial data collection are two activities that have dramatically changed in the last decades, shifting from a situation of researchers exclusiveness to public involvement due to the significant technological advances during the last decade [17]. The ease of creating content online more easily through Web 2.0 and the proliferation of advanced mobile devices are some of the technological advances that made possible the public involvement.

Urban areas offer enormous potential for citizen science projects because there are already a enormous amount of possible volunteers. The ecology of urban areas is a growing field that still has a lot to be developed and investigated since the type and scope of information citizen scientists can provide is invaluable.

## 2.4. Lichen Sampling Method on a Citizen Science Scope

Similarly to the standard lichen sampling, the goal of this approach is to head to a tree on any location and quantify the amount of some lichen species in the main tree trunk. Each tree will be one observation, i.e. one survey.

The tree trunk must be vertical, with more than 20 cm of diameter, without branches and between 1m and 2 m height. All tree species are welcome except those with very smooth bark or that peel easily (maples, eucalyptus, pines, poplars).

At each tree look for the aspect facing north,

and looking at approximately 1.5m from the ground imagine a rectangle oriented vertically with approximately 20x30 cm (like an A4 paper). Then estimate the area occupied by each lichen species within that rectangle.

Specie	Metrics		
	$\lambda$	$\varphi$	$\varepsilon$
Flavoparmelia Caperata	3	4	2
Evernia Prunastri	3	3	2
Xanthoria Parietina	4	4	3
Phaeophyscia Orbicularis	4	5	3
Hyperphyscia Adglutinata	4	5	3
Candelaria Concolor	4	5	3
Diploicia Canescens	3	4	2
Chrysothrix Candelaris	3	1	2
Parmotrema Hypoleucinum	2	2	1
Lecanora Allophana	4	3	2
Dendrographa Decolorans	2	3	2
Usnea Rubicunda	2	2	0
Ramalina Fastigiata	3	3	2
Physcia Adscendens	4	5	3

Table 1: Metric Indexes based on Lichen Species where  $\lambda$  represents Aridity, Poleotolerance is represented by  $\varphi$  and  $\varepsilon$  represents Eutrophication.

Thus, having set lichen sampling method and the metric indexes based on lichen species on Table 1 the existent variables can be processed with a set of equations in order to obtain the final Metric Index Model.

$$\alpha_i = \sum_{l=1}^L p(l)_i \quad , \quad i = 1, 2, 3, 4, 5 \quad (1)$$

The equation 1 represents the sum of the percentages per metric value, where  $\alpha$  represent each metric and  $i$  represents the metric indexes that can be found on table 1. After the lichen sampling method, each  $\alpha$  will be the sum of the  $p$  occupation percentage of the found lichens, with  $L$  lichens available, that have the  $i$  metric index. Each metric index has a weight  $\omega$  that is described on table 2.

$i$	$\omega_i$
1	-5
2	-2
3	1
4	2
5	5

Table 2: Weight of each metric value.

$$\eta = \sum_{i=1}^5 \alpha_i \omega_i \quad (2)$$

On the equation 2,  $\eta$  represents the weighted sum of the each metric  $\alpha$ , where  $\omega$  represents the weight of each  $i$  index.

$$m = \frac{\eta}{\sum_{i=1}^5 \alpha_i} \quad (3)$$

On the equation 3,  $m$  represents the final metric index, having  $\eta$  representing the weighted sum and  $\alpha$  the sum of the  $p$  occupation percentage of the found lichens that have the  $i$  metric index. This model equations can be applied to the 3 metrics highlighted on this project: aridity, poleotolerance, and eutrophication.

### 3. Architecture

The Architecture of the GCS was done independently from the scientific scope of this thesis, being able to fulfil the generic requirements for this framework. This framework had the contribution of another student of Masters in Electrical and Computer Engineering, Miguel Leitão, developing its Msc thesis regarding Urban Green Spaces, in order to map UGS while assessing urban dwellers preferences within these spaces.

The future extended system for this work, an app-based interface named **eFlechten**, will allow lichen diversity sampling campaigns aligned with citizen science conducts. User data will be processed in a remote server, providing immediate feedback and, ultimately, its presentation to the user as a map, portraying the spatial effects of global change drivers.

After development, the Generic Crowdsourcing System will be used in both thesis in order to prove the extensibility and the adaptability of the developed tool to any crowdsourcing context.

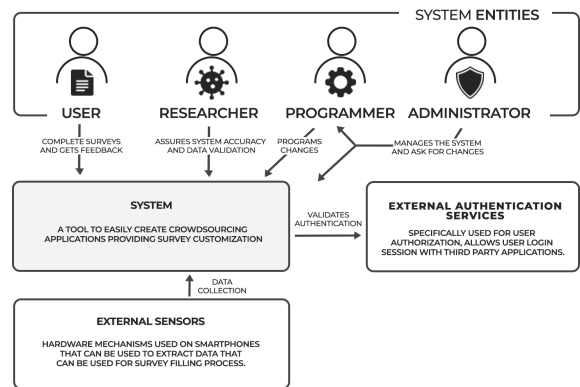


Figure 1: System Context Architecture Diagram.

Four system entities are identified: Users, Researchers, Administrator and the Programmer. Users are the ones responsible for completing surveys, receiving the feedback generated based on their inputs. Researchers, that can use the platform

like normal Users, are responsible for ensuring data reliability, identifying possible problems or errors and proceeding to their adjustment or repair. Administrator manages the system entities, defining which users are considered to be researchers, and the system performance, demanding the Programmer to proceed to system software amendments.

The System, providing generic crowdsourcing features, is composed by several components and modules that are going to be inherited to any extended system application, allowing further modifications. On Figure 1 are also defined External Authentication Services and External Sensors, as well as the relations with the main software system.

The External Authentication Services allows GCS users to authenticate with external third party applications. The External Sensors are composed by all the hardware mechanisms used on users smartphones or other devices. This allows external data extraction from the wide range of technologies available.

### 3.1. System Components Architecture - Client

On Figure 2 are represented the client interfaces: the mobile and the web application having in green the component blocks developed through this dissertation work and in red the ones developed by Miguel Leitão.

The Authentication component, common to both interfaces, provides a normal mode and a third party authentication mode, OAuth. This component offers a register and a login service allowing any person to use the crowdsourcing system.

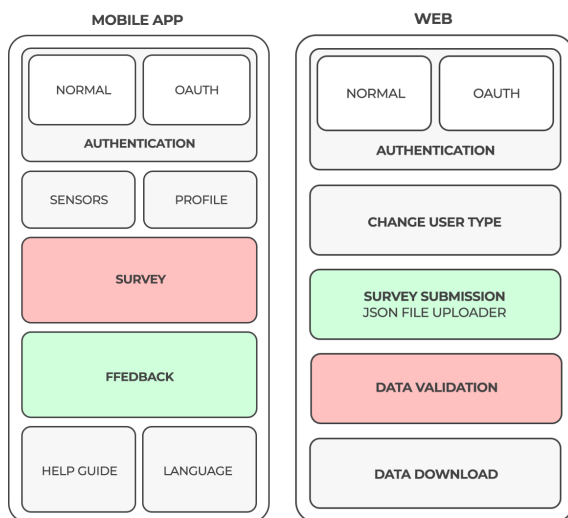


Figure 2: Client Component Diagrams

The Survey mobile component loads questions from the server to the client with JSON configuration files. This files are then used to render a simple UI Survey, to be displayed in the mobile application

to the user. After the survey filling process, the user inputs are then submitted and sent to the Server. This user data will then be handled and stored by the server for later processing or validation.

After processing, the Server returns survey processed or unprocessed data back to the mobile application, the Feedback module. This component receives a server response to its request, containing the survey feedback. This file is then handled by the mobile application, rendering a simple UI that can display the received feedback to the user.

The Language Component that despite being isolated from the server, offers system advantages in terms of user adaptability. It configures the system to display to the user a certain requested language, not affecting the system behavior. The Help Guide component displays to the user a tutorial with a set of information relevant to the system usage, avoiding dubiety and misapprehension.

On the web application, if the Administrator is logged in, a user list will be rendered through an HTTP request with a REST API. For each user on that list, the Administrator can toggle user types between normal users or researchers. Furthermore, the Administrator can delete users from the system that are considered disposable.

If the Researcher is logged in, with Survey Submission module, there is the possibility to upload a JSON file that will generate a survey to be displayed in the Mobile Application. This file will be sent to the Server that will handle the received data. Furthermore, Researchers, with the Data Validation component, can visualize all the user survey inputs. This list can be analyzed and validated by this system entity, requesting the Server to handle the necessary modifications. Lastly, the Researcher can extract the user survey answers with the Data Download module, containing the desired data fields.

### 3.2. System Components Architecture - Server

On Figure 3 is represented the Server Component Diagram. Surveys and Answers are the Server component responsible for sending the survey to be presented on the mobile application and handle the user inputs after submission. The Surveys to be presented on the mobile application can be static or dynamic. The first option displays the same questions to all users regardless of their previous inputs. On the other hand, the second option refers to the survey questions that are dependent from the previous user survey answers, defining a dynamic surveying system. This questions are generated by the JSON file, fetched from the database, that was initially sent from the web application in the Survey Submission module. Surveys and Answers are also the component responsible for handling the survey answers, storing user inputs. After the data storage

process, Data Validation from the web application can request it and perform any necessary modifications directly. After validation, data is able to be processed, generating survey results and providing feedback to the user.

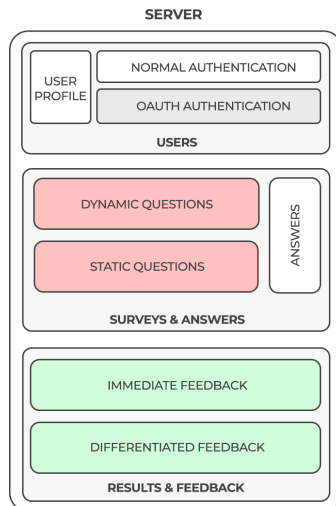


Figure 3: Server Component Diagram

Results and Feedback are the Server component that returns survey processed data in the form of immediate or differentiated feedback. The first is a simple feedback object that is sent as a response to the REST request made by the client. On the other hand, the differentiated feedback is a mechanism to handle Survey user inputs in a sequence of processing modules. These processing modules will run asynchronously, storing data throughout the process, being sent to the mobile application to be displayed to the user.

Users are a Server component used by both client interfaces, Mobile and Web. It provides the authentication and allows to handle user profile information. On the first, a REST call with credentials are received, using normal authentication or OAuth. The second, provides user information to be displayed on the Profile, allowing modifications. It also handles user type changes done on the web application.

#### 4. Implementation

The Generic Crowdsourcing Implementation pretends to detail how the several components described on the previous chapter are going to be implemented, relating technologies with requirements, defining components, modules, functions, endpoints and API calls.

##### 4.1. Development Environment

MERN is the acronym for MongoDB, Express JS, React and Node JS. Is a combination of the above technologies, all based on JavaScript, used to build

advanced applications. It is an open source full stack development framework i.e. it provides entire front-end to back-end development components.

With MongoDB as a database for higher scalability, Express JS for speed enhancements, JavaScript as its primary language for end-to-end development, MERN is one of the best full stack development. React JS is the best when it comes to UI layer abstraction. It provides the best-in-class tools for faster code development. While React is only a library, it gives freedom to build the application and code organization, by providing the necessary tools. To preserve the React Native hot reload Expo, an open-source platform for making universal native apps for Android and iOS, is a perfect build and production environment. Expo allows to run the project server, viewing logs, making code changes to be reflected instantly in the application simulator.

##### 4.2. Authentication

For registration, system entities must use the client interface, web or mobile. The user credentials are obtained with input fields, being sent in a JSON structure to the Server with POST. The Server register endpoint will receive the request, inserting the new user in the MongoDB if not registered.

For login, system entities must use the client interface, web or mobile. The user credentials are sent to the Server in a POST request to be validated. If verified, the user email will be used as a key in the Memcached with a predefined login timeout.

Every HTTP request client-server will make a caching validation, checking if the user login session state is still active. Upon Logout or Login Timeout reach, user is removed from the caching service, blocking any further actions.

All this mechanisms regarding database and caching service are also applied when concerning the third party authentication, OAuth, an alternative method. If the application identity and the authorization grant code is valid, the authorization server sends an access token to the application as a response. From this moment, having a valid access token, the resource server will serve the resource requested by the application.

##### 4.3. Remove User & Change Type

Only for the web application, this feature allows the administrator, upon login, to remove users or change their types. Firstly, a list of users is loaded through a POST request done with Axios, sending the administrator email for caching validation and receiving a JSON with the list of users as a response from Server.

Each user is then presented to the administrator as well as two icons to each user: a delete button and a toggle button that are able to perform two

tasks, remove a user or change its user type, respectively. The first will perform a request that will be sent to a narrowed endpoint, making the Server to delete the user. The second task sends a POST request with the new user type and its email. This request will be sent to a narrowed endpoint on the Server that will handle it. Both tasks are processed by requesting it to the database, using the affected user email as key for identification.

#### 4.4. Surveys

Surveys are a key component of the Generic Crowdsourcing System. The main objective is to implement a module fully customizable, providing a simple UI to the client, ensuring extensibility to the GCS. This surveying process, declared endpoints and the necessary mobile-server data flow was developed by Miguel Leitão, developing its Masters in Electrical and Computer Engineering thesis regarding Urban Green Spaces.

There are two types of surveys that can be presented to the user: static or dynamic. The mobile application makes a request to a server endpoint that retrieves a JSON configuration file containing the static or dynamic survey to be displayed. Then the JSON file received in the mobile application must be handled. Therefore, a library package, detailed on Subsection 4.4.1, was developed for this thesis with the collaboration of Miguel Leitão. The necessity of a package was raised for the amount of files needed to cover all the diverse components that are considered fit to a survey.

##### 4.4.1 react-native-json-forms

This library was developed to create forms using an uploaded JSON file, containing all the pretended form structure. This tool was developed to be compatible with forms created using, for example, SurveyJS [6], having some extra developed features. The extension problem mentioned previously is covered with this tool by allowing the developer to upload a JavaScript custom extension component to the project, activating it through the JSON File. This library contains some important props: **json**, prepared to receive a JSON configuration file containing the survey, **extension**, containing the custom survey elements specifically developed for the application and, **onSubmit**, able to receive a function that implements the submission steps considered for a narrowed system.

The developed open source tool has its source code available with a package installer [4].

#### 4.5. Data Validation

Only for the web application, this feature firstly displays a list of answers. This is made by a POST request done with Axios, sending the researcher email

for caching validation and receiving a JSON with the list of survey raw inputs a response from Server. Each answer has an ID associated and is presented to the researcher with a delete icon per item, able to delete it from the system. This removal feature is done by sending the researcher email for caching validation and the answer ID of the answer to be deleted. This request will be sent to a narrowed endpoint, making the Server to delete the user input from the 'answers' collection on database.

#### 4.6. Data Download

Another generic crowdsourcing system feature is the download of the survey raw user inputs. This is done by using a library 'react-download-link' that provides a simple mechanic easy to understand by the programmer. This system entity is responsible to define what fields from the JSON file, received as a response from the server, are going to be used in the file to be downloaded.

#### 4.7. Help Presentation Guide

There is also a Help Presentation Guide, a responsive React Native Horizontal Carousel. This generic component consists on screens displayed horizontally, allowing the user to scroll between them, presenting ordered information pages to the user. The main objective of this component is to explain to the user with a simple UI the basics of the crowdsourcing application.

#### 4.8. Feedback

Citizen Science with Immediate Feedback, a thesis proposed by the Centre for Ecology, Evolution and Environmental Changes (cE3c) - FCUL, supported by iLTER, requires a Feedback mechanism capable of returning Immediate Feedback to the user.

Thus, it was developed for this thesis a Feedback component that represents an important role of the Generic Crowdsourcing System. This component, being inherited to any extended application, will be formatted to fit in the scientific framework that is at issue. This extension procedure is made by the programmer, leaving up to researchers administration to understand the scientific needs of the extended tool. The implementation of the Feedback Module is represented on the Figure 4, detailing the Server and the Mobile system components, relevant for the module to be issued in this subsection.

Upon Survey submission, user data is fetched and stored by the Server and the Feedback endpoint is called through a HTTP POST request. This API call sends the user email for caching validation and any content that is found appropriate to be used on the Feedback module.

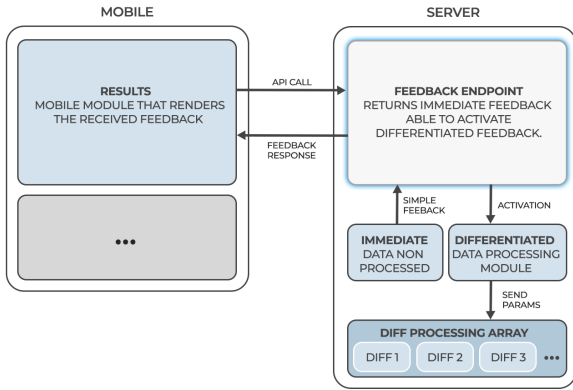


Figure 4: Implementation of the Feedback Module

The Feedback server endpoint is connected to the feedback module that has two segments: the immediate and the differentiated feedback. The first is a module that returns a simple feedback to the user, forming the body content of the response of the POST request made to the Feedback server endpoint. This immediate feedback can be a simple string or a simple object that does not require data processing. This means that no survey data is used to form the response made by this module.

The other segment, the Differentiated Module depends of the user will of activation, being optional and customizable. It sends the pretended parameters to a mapping function that runs each differentiated component sequentially. This consecutive order happens for the output data dependency generated by the previously executed block. Furthermore, data can be progressively stored, allowing a better error handling or processing modifications.

## 5. Usage

The Generic Crowdsourcing System is available on the GitHub Page [3] 'generic-crowdsourcing-sys' with the contributors: Guilherme Eugénio (guilherme.eugenio@tecnico.ulisboa.pt) and Miguel Leitão (miguel.s.leitao@tecnico.ulisboa.pt), INESC-ID, under the MIT Licence. This package has 3 main folders: server, mobile and client (web). All the information to run each system component is described on the Wiki section of the GitHub Page [3], requiring the installation of development environments and dependencies. For the installation and the initiation of each system component npm was used, a package manager for JavaScript environment.

## 6. Demonstration

A powerful proof of concept of the Generic Crowdsourcing extensibility is the parallel development of the eFlechten, described on Subsection 6.1 and the Urban Green Spaces, described on Subsection 6.8. By extending modules and creating different versions of the same core system it is possible to

develop divergent successful applications with little programming effort.

### 6.1. eFlechten

Available on [2], eFlechten was the result of the Generic Crowdsourcing System extension to fulfil the scientific requirements for this thesis. Thus, some extension files were modified or new ones were added, performing system modifications to the existing GCS. The following subsections describe the GCS extended adjustments made to the available generic features, turning eFlechten into a successful proof of concept of this system extensibility.

### 6.2. Surveys Extension

In the context of the problem proposed by cE3c - Centre for Ecology, Evolution and Environmental Changes, concerning the information scarceness in the framework of air pollution and climate change maps. The Survey module will be extended in order to present a efficient surveying tool that tackles the problem presented in this work with the lichens mapping method. This surveying GCS feature will be used to fulfil the mapping lichens sampling method, described on the Section 2.4.

#### 6.2.1 Static Survey

The first survey to be rendered corresponds to the tree trunk identification having three elements: **Geolocation Sensor**, **Tree Bark Rugosity** and the **Tree Trunk Diameter**. The first element, stored natively in the sensors directory, is sent to the 'react-native-json-forms' library with a generic type 'ext:sensor' so that it can be handled appropriately. It provides the location of the user, creating geolocated data. The second element, intends to describe the Tree Bark Rugosity, being used the Image Picker element from the 'react-native-json-forms', displaying 3 rugosity levels: Rugose, Intermediate, Smooth. The third element, Tree Trunk Diameter, is a component created specifically for this project. It is stored in the extension directory, the TrunkSlider, and is loaded to the FormExtension file just like the Geolocation Sensor. This file is then passed as the extension props to the 'react-native-json-forms'. This third element displays a slider from 0 cm to 200 cm with steps of 10 cm with an explaining support image.

The Second Survey only has one element: the **LichensImagePicker**. The main objective of this element is to, in coherence to the Lichen Sampling Method described on Subsection 2.4, obtain the lichens present and their respective percentage on a study site. Mattering the fact that lichens percentage is needed, a extended Image Picker must be created, the LichensImagePicker, a natively stored element to be used by the 'react-native-json-forms'



library. The user upon lichen selection, is faced with a pop up box, containing the lichen in question zoomed up and a 5% step slider, with a 0 to 100% coverage percentage.

### 6.3. Feedback Extension

After data submission, the server feedback endpoint will be called, sending the recently added data. This endpoint will handle data and give feedback to the system. For this work, the instantaneous feedback is crucial, having two features of the Generic Crowdsourcing System to be activated: the Immediate and the Differentiated Feedback. These two feedback components are completed somehow asynchronously, which means that the Immediate Feedback don't needs to 'wait' until the Differentiated Feedback completes. In the case of this work, the Immediate Feedback, is a simple message to be displayed on the mobile application upon submission.

#### 6.3.1 Differentiated Feedback

The Differentiated Feedback is more complex than the Immediate Feedback and does the data processing necessary for the metrics calculus needed for this system functionality. The `feedbackArray` file imports the `diffFeedback` files needed to fulfill the different stages of the data processing. In this work, it was declared 2 files to be loaded.

**diffFeedback1**, the first differentiated feedback module loads all the 'raw answers' from the database, even its own, and compares to the recently added one. If the distance between them is lesser than the one declared on the configuration file, in this case 30 meters, than the user inputs are stored in an array and declared as being in range. This processing step is a simplified approach to obtain an average, having considered a 30m x 30m block of influence that will taken in consideration on the metric index model, described on Subsection 2.4. Then, each one of the user inputs that are considered in range have to updated as well so, the same logic have to be applied to them too. In the end of this `diffFeedback1`, a JSON file is saved to the 'DiffFeedback1' collection on the database. This file contains the latitude and longitude of each point to be inserted or updated. It also contains the survey id of each point and the compilation of all the lichen species and respective occupation percentages that belong to the block of influence.

**diffFeedback2**, the final differentiated feedback module loads the Metric Indexes based on Lichen Species, represented on Table 1. It also loads the `DiffFeedback1` JSON file associated with the recently submitted survey, generated on the previous step. By mapping each point to be updated, this module generates the final indexes with the equations that are described on the Metric Index Model,

detailed on Subsection 2.4. Thus, all the points in consideration are updated based on their id, the survey identifier. Since the mobile interface will display the indexes with maps, this differentiated module will generate files in a JSON format containing the latitude, longitude and the respective indexes of the three metrics associated with that location.

### 6.4. Results Extension

Since the metric scales are relative, the system output must be represented by maps and not absolute values. The `ResultsScreenExtension` file, present on the extension directory, is modified to import the `MapExtension`, a file that is stored in a newly created folder called `map`.

The `MapExtension` imports the 'react-native-maps' library [5] that allows to use Google Maps API. A map can be then rendered on the mobile application on the Results Section, showing the user location. In order to display the geolocated metric indexes the most efficient and perceptible way possible, Heatmaps were used. Besides the map mobile render, the imported package provides some components API, including Heatmaps. This component API needs weighted geolocated points, loaded from the 'DiffFeedback2' collection from the database. The results of the Differentiated Feedback is then passed as props to the `HeatMap` file, a component created in the `map` directory.

Each metric will be represented by a unique heatmap, a specific gradient that is imported from the `metrics` file on the same directory. The file passed as props containing the geolocated information with the three metric indexes will be assigned respectively. Lastly, a button was created to perform the toggling between heatmaps, giving to the user an immersive experience.

### 6.5. Help Guide Extension

There is also a Help Presentation Guide for eFlechten, a component that consists on five screens displayed horizontally, allowing the user to scroll between them, presenting ordered information pages to the user. The main objective of this component is to better understand the Lichen Sampling Method, applied to this Citizen Science Scope, described on Subsection 2.4. It also provides information about the Survey filling process and the Results dynamic, providing UI support. These files are defined on the presentation folder, inside the extension directory.

### 6.6. GeoJSON Download

On the web application, Data Download feature, described on Subsection 4.6 is extended to this work, allowing to transfer surveys answers data. The format chosen is GeoJSON, a format for en-



coding a variety of geographic data structures that can be loaded for example, to ArcGIS [1], a geographical information system that is used to collect, analyze, and represent spatial data in a way that can be easily understood.

### 6.7. JSON Survey Submission

On the web application, JSON Survey Submission feature was programmed specifically for this work, providing a button that upon click, renders a text input box. This box receives a JSON format file that is uploaded to the Server by a POST request to the 'surveys/submit' endpoint. Then, on the back end side, this JSON file is stored in the database, on the 'surveys' collection. This is an important feature of the eFlechten, allowing to perform immediate modifications to the survey that will be displayed on the mobile interface.

### 6.8. Urban Green Spaces

In the context of his MSc Thesis for Electrical and Computer Engineering, Miguel Leitão, powered by the lack of documented reliable information about Urban Green Spaces (UGS), extended and adapted the GCS for this scientific context. The UGS development will be able to extensively gather detailed information about Urban Green Spaces by dynamically surveying its visitors. The projected is hosted in a GitHub Page [7] and is available for usage.

To fulfil the purpose of the surveying, this project extended the generic survey component to present a mechanism of dynamic surveying that will load a new survey question upon a submission. There are two survey sections presented: one is dedicated to describe the user experience while in the UGS and the other allows the user to mark points of interest.

On this project, the Differentiated module is left blank, being only used the Immediate Feedback mechanism. This module is programmed to send a simple response message to the mobile request, not requiring data processing.

## 7. Results

Using SUS, a simple, ten-item scale giving a global view of subjective assessments of usability, will be used to evaluate eFlechten. It covers a variety of aspects of system usability, such as the need for support, training and complexity.

### 7.1. Google Forms Analysis

Due to external circumstances that conditioned the planned Testing phase, the methodology to be used had to be restructured. So, in order to overcome this impracticability, a Google Forms was developed with the intention of being sent and answered, having as targets researchers and non researchers.

This Google Forms would be divided into two sections: the User Identification and the System Us-

ability Scale.

#### 7.1.1 User Identification Results

This section pretends to point out some results of the Google Forms regarding the user profile. The user sampling has only 2,9% of Researchers, resulting in a majority of 97,1% of non Researchers. 97,1% was too the percentage of users with age comprehended between 18 and 25. The mobile operating system of the users was balanced, having 60% of Android users. Most of the users have already used a crowdsourcing application, with an advantage of 62,9%.

#### 7.1.2 SUS Results

In order to make the System Usability Scale, an Excel table was generated based on the results from the SUS section in the Google Forms. Then the formula was applied to the available cells getting the SUS score for each result. The average of the SUS score was 82.4 in a 100 score range, having 9% of the results bellow 50, 89% of the results above 60 and 34% greater than 90.

### 7.2. Code Analysis

It was possible to obtain some coding conclusions when comparing the Generic Crowdsourcing System with eFlechten, the extended framework on this thesis scope. Inside each system component, the external modules that the developed projects depends upon, inside the *node\_modules* folder and 'package-lock.json', a large file that describes the exact dependency tree generated, were both ignored in this analysis. Thus, it was possible to obtain a 79.1% usage of the Generic Crowdsourcing System on the eFlechten framework, having this way 20.92% lines of code that belongs only to the extension fraction. JavaScript, the most dominant language used on eFlechten had a 97.4% of presence, while CSS had 1.7% and HTML 0.9%.

### 7.3. Safety

On the Generic Crowdsourcing System, one defensive coding technique was the encryption of the passwords. It was used 'crypto', a module in Node.js which deals with an algorithm that performs data encryption and decryption.

Concerning the HTTP Requests, using GET makes it very easy to alter the data being submitted to the server as well. That is why confidential data is sent with a POST method, since the information is sent on the message body.

When using OAuth 2.0, an external browser is launched in order to ensure the native app cannot modify the browser window or inspect the contents, being the current safest practice.

Axios, used on the web application, comes built-in with some web security by protecting users against attacks such as CSRF, increasing the security of the HTTP requests and their responses done with this promised-based library.

The eFlechten Server is hosted on a Apache Server System, often described as one of the most popular and secure web servers.

## 8. Conclusions

As a proof of concept of the GCS adaptability, eFlechten System was developed to fulfill the narrowed requirements upraised by the Centre for Ecology, Evolution and Environmental Changes (cE3c) - FCUL, supported by iLTER. Urban Green Spaces, developed by Miguel Leitão for the MSc Thesis for Electrical and Computer Engineering, powered by the lack of documented reliable information about UGS, is another important proof of concept to take in consideration. By making a few changes to the singular source code of the Generic Crowdsourcing System, it was possible adapt native features to the surveying needs of a given scientific framework.

eFlechten, capable of returning immediate feedback to the user, is a crowdsourcing application inherited from the Generic Crowdsourcing System that allows to map lichens in order to fight the scarceness of global change drivers data. It provides a Register and a Login Section, with a normal and third party app authentication method. With an average SUS score of 82.4, eFlechten displays a menu screen that provides simple UI features to the user. It provides a Survey that lets users to insert tree trunk information and a lichens image picker that allows user to identify the species and the respective coverage. This sampling lichen method is explained in the Help Guide, present on the Menu Screen. There's also available the Results section, containing a map that presents the three metrics relevant for the climate change and air pollution scope. Aridity, Poleotolerance and Eutrophication indexes are represented in the form of heatmaps, representing a dynamic and interactive way of displaying the metric indexes to the user. For each survey submission, a Ranking component updates the user rank points, introducing a gamification level to this application.

## References

- [1] Arcgis: [arcgis.com](http://arcgis.com).
- [2] *eFlechten*: [github.com/guilhermeneugenio/gcs-lichens-immediate-fb-sys](https://github.com/guilhermeneugenio/gcs-lichens-immediate-fb-sys).
- [3] *GCS*: [github.com/mleitao27/generic-crowdsourcing-sys](https://github.com/mleitao27/generic-crowdsourcing-sys).
- [4] react-native-json-forms: [npmjs.com/package/react-native-json-forms](https://npmjs.com/package/react-native-json-forms).
- [5] react-native-maps. [github.com/react-native-maps/react-native-maps](https://github.com/react-native-maps/react-native-maps).
- [6] Surveyjs: [surveyjs.io](https://surveyjs.io).
- [7] *UGS*: [github.com/mleitao27/gcs-urban-green-spaces](https://github.com/mleitao27/gcs-urban-green-spaces).
- [8] M. Conti and G. Cecchetti. Biological monitoring: lichens as bioindicators of air pollution assessment—a review. *Environmental pollution*, 114(3):471–492, 2001.
- [9] V. H. Dale. The relationship between land-use change and climate change. *Ecological applications*, 7(3):753–769, 1997.
- [10] C. Guerreiro. Air quality in europe: 2013 report. 2013.
- [11] M. E. Hale. How to know the lichens. dubuque: William c, 1979.
- [12] E. Llop, P. Pinho, P. Matos, M. J. Pereira, and C. Branquinho. The use of lichen functional groups as indicators of air quality in a mediterranean urban environment. *Ecological indicators*, 13(1):215–221, 2012.
- [13] P. L. Nimis, C. Scheidegger, and P. A. Wolseley. Monitoring with lichens—monitoring lichens. In *Monitoring with Lichens—Monitoring Lichens*, pages 1–4. Springer, 2002.
- [14] J. A. Patz, D. Campbell-Lendrum, T. Holloway, and J. A. Foley. Impact of regional climate change on human health. *Nature*, 438(7066):310–317, 2005.
- [15] P. Pinho, S. Augusto, C. Maguas, M. Pereira, A. Soares, and C. Branquinho. Impact of neighbourhood land-cover in epiphytic lichen diversity: analysis of multiple factors working at different spatial scales. *Environmental Pollution*, 151(2):414–422, 2008.
- [16] M. C. Ribeiro, P. Pinho, C. Branquinho, E. Llop, and M. J. Pereira. Geostatistical uncertainty of assessing air quality using high-spatial-resolution lichen data: A health study in the urban area of sines, portugal. *Science of the Total Environment*, 562:740–750, 2016.
- [17] L. See, P. Mooney, G. Foody, L. Bastin, A. Comber, J. Estima, S. Fritz, N. Kerle, B. Jiang, M. Laakso, et al. Crowdsourcing, citizen science or volunteered geographic information? the current state of crowdsourced geographic information. *ISPRS International Journal of Geo-Information*, 5(5):55, 2016.