Assessing the usability of Air Quality mobile application

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Abstract—**Rapid technological development and industrialization have brought with them side effects that have little by little damaged the atmosphere, whose importance is vital for the survival of all living beings and the climatic balance. Air pollution is one of the biggest causes of mortality and environmental issues claiming 7 million lives annually due to cardiovascular and respiratory diseases. Urban centers contain millions of people of all ages and health states. However, certain daily activities could be avoided by sensitive population, if the awareness of air quality conditions would be more user friendly/accessible. This paper summarizes the heuristic evaluation carried out to the Quito Air Quality application, a new mobile application to display the concentrations of air pollutants in the whole city of Quito. Since, there is a limited number of monitoring stations (9 stations only) the mobile application use an interpolation method to estimate the concentration of pollutants whatever the location in the city. The development of the interfaces is carried out by an agile, collaborative and user-centered methodology. The results have allowed us to obtain a series of recommendations that could be applied to improve the functionalities and the user interface of any air quality application.**

Index Terms—**Usability, Heuristic Evaluation, Air Quality, Air pollution, Smart Cities**

I. Introduction

More than half (54%) of the world's human population lives in the cities and this number is expected to reach 66% by 2050 due to the rapid urbanization in developing countries [1]. These effects are reflected in the scarcity of natural resources, deforestation, motorization, climate change and environmental pollution. Currently, 92% of the world population living in cities with more than 100,000 inhabitants does not comply with the air quality guidelines of the World Health Organization (WHO), while this value increases to 98% in low-income countries [2], [3]. At this point air pollution is the fourth cause of premature mortality and the main environmental risk, causing 7 million premature deaths annually, and is expected to double by 2050 [4].

The population most suffering the health effects due to the poor air quality are children, elderly and risk groups with respiratory and cardiovascular diseases. These effects can be avoided or at least diminished through raising the awareness of the air quality conditions in the cities. While some cities have air pollution monitoring networks and governmental sites that can be consulted to learn about the environmental conditions, it is much easier to access a mobile phone application to smartly plan daily activities. Such mobile phone applications are available on Google Play and Apple Store, such as: Air visual[1], Air matters[2], Breezometer[3], Air bubbles[4], Plume[5], among others. Some of them have alert systems to make sure the user gets notified about the dangerous conditions, and some are simply used to consult as needed. The applications work by connecting to the database from the nearest, or an available air quality monitoring station (governmental, research or private project). This data is often public and relatively easy to obtain, and working with it is a common environmental interest in all countries of the world.

While certain regions have suitable conditions for creating awareness on the air pollution, others, either lack the air quality network, or are located in very complex terrain, resulting in a poor coverage for the network alert system. This is for example the case of Quito, which the present study is focused on. Previous works on machine learning techniques have been published on improving the prediction of air pollution in the complex terrain of the capital city of Ecuador [5], [6], [7]. On the contrary to the current mobile applications, the proposed air quality App tackles the low spatial resolution of the estimation of the urban air contamination by integrating an interpolation algorithm that improves the accuracy of the prediction between sparsely distributed monitoring stations. Development makes use of a user-centered approach [8], where the user interface is one of the most important elements of development. There are no previous studies investigating the usability of these type of mobile applications, with one exceptions on accessibility [9]. However, accessibility does not guarantee the usability of a mobile application. Furthermore, the efficiency and effectiveness of an air quality mobile application can be influenced by different factors: the user interface, the user interaction and/or the quality of the contained information. Considering heuristics and metrics to measure the usability of systems is essential in early stages of a user-centered development process [8]. The purpose of the study is to explore the usability of the air quality mobile application and to investigate the extents of this application.

The paper is organized as follows: the following sections present some related work in the domain of the usability evaluation. Section 3 describes the case study. Section 4 presents a task-oriented usability evaluation method. In section 5, the usability evaluation results are presented. Section 6 suggests some recommendations in order to extend the air

[1]https://www.airvisual.com/
[2]https://air-matters.com/
[3]https://breezometer.com/
[4]https://shop.hellowynd.com/pages/air-bubbles
[5]https://plumelabs.com/en/products/air-report

quality mobile application. Finally, conclusions and some remarks for future work are presented.

II. Related Work

In this section, we start with defining usability, next we focus on the heuristic evaluation method proposed in [10].

A. Usability

The ISO standard 9241-11 [11] provides a framework for understanding the concept of usability and applying it to situations where people use interactive systems, and other types of systems (including built environments), and products (including industrial and consumer products) and services (including technical and personal services). The official ISO 9241-11 definition of usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use [11].

Usability evaluation can be formative or summative [12]. Formative usability evaluation aims to evaluate a product or a design. It allows to identify shorcomings in order to produce a set of recommendations with the goal of improving the design before it has been finalized. Currently, there are many methods of inspection and testing that make it possible to obtain the usability of an application. These inspection methods are based on usability problems known as heuristic metrics, among which Nielsen's 10 usability heuristics are the most widely used [13]. A systematic literature review to develop usability heuristics was presented in [14]. This work performs an exhaustive review of 73 studies related to usability heuristics conducted between 2006 and 2016. Recently appeared an extended set of usability heuristics integrating the usability heuristics of Nielsen [10] with the ergonomics criteria presented in [15]. However, we focus on using a set of usability heuristics for the evaluation of the air quality mobile application because the heuristics have been grouped under for ergonomics principles as follows: user guidance, user effort, user control and freedom, and user support [10]

III. Case study

A. The Quito Air Quality mobile application

Quito Air Quality is an application for Android mobile devices that provides the user with an information on the air quality index (AQI) of the main atmospheric pollutants in the capital city of Ecuador. The value of the AQI of carbon monoxide (CO), sulfur dioxide (SO2), ozone (O3), and suspended particles (PM2.5 and PM10 particulate matter under 2.5 and 10 μm, respectively) in the air are obtained from the website of the Environmental Secretariat of Quito. This city office manages nine monitoring stations of the atmospheric conditions (meteorology and air quality) across the city. However to get this information is not straightforward, therefore, the purpose of such an App is to inform and alert the sensitive population on pollution peaks and possible health threats.

The functionalities of the application are as follows:

1) Since it is necessary to load several data from a server, the program starts with a progression bar that provides the user with a feedback on the delay before the application is available.
2) The geolocation of the user and the stations are displayed on a map of the city.
3) It is possible to move across and zoom-in/zoom-out in the map by using the established joint gesture of thumb and forefinger.
4) A menu on the upper-left corner of the screen enables the users to select the contaminant they are interested in knowing about. Once the pollutant is chosen, its name is highlighted to give a visual confirmation that the request is proceeded.
5) Since the distribution of the monitoring stations is relatively sparse, an Inverse Distance Weighting interpolation [16] is used to estimate the in-situ AQI index of a determined pollutant by only considering the actual values provided by the stations inside the footprint area surrounding the user.

"Fig. 1", is a screen-shot of the main user interface to select a contaminant and navigate on the map.

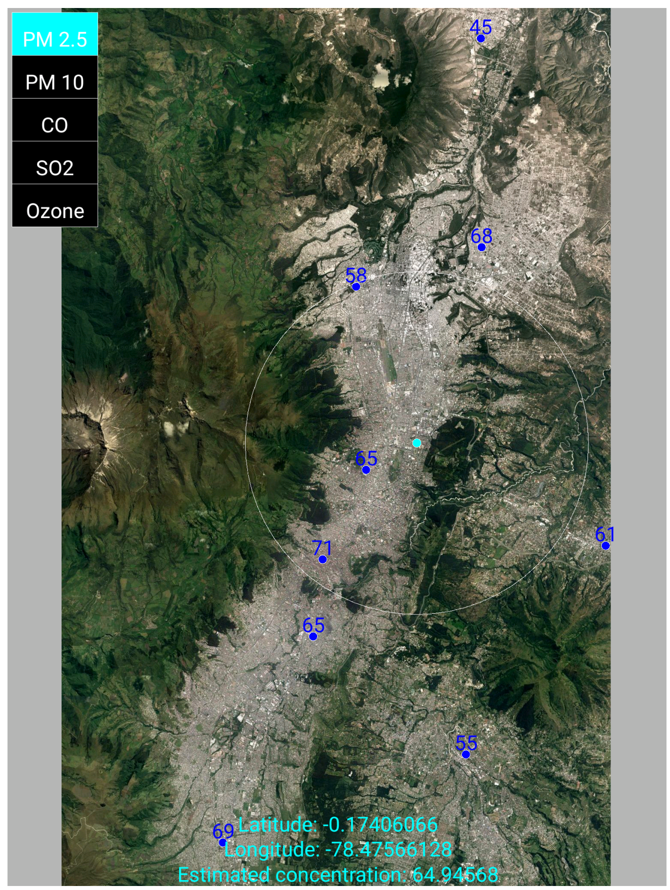

Fig. 1. Main graphic user interface of the App

B. Application's tasks

According to the case study, Table I shows the main tasks of the mobile application. These tasks will be used by the experts to make the heuristic evaluations of the user interfaces of the air quality mobile application.

TABLE I
THE EVALUATION TASKS

Reference	Task
T1	Move across the map
T2	Zoom-in/zoom-out in the map
T3	Select the contaminant to know the AQI

IV. USABILITY EVALUATION

This section describes the task-oriented usability inspection method used [10] for the usability evaluation of the Air Quality mobile application.

A. Materials and methods

Three experts were invited to test the mobile application in order to find the difficulties that real users might have when using the application. Each expert received a user manual for the application, including the evaluation tasks, the set of usability heuristics according to [10], a series of steps to perform the evaluation, and an evaluation template.

The usability experts used the set of 14 heuristics presented in Table II. Theses heuristics are described in [10].

TABLE II
THE SET OF USABILITY HEURISTICS [10]

Group	Reference	Usability heuristic
User guidance	H1	Prompting
	H2	Feedback
	H3	Information architecture
	H4	Grouping/distinction
User effort	H5	Consistency
	H6	Cognitive workload
	H7	Minimal action
User control and freedom	H8	Explicit user actions
	H9	User control
	H10	Flexibility
User support	H11	Compatibility with the user
	H12	Task guidance and support
	H13	Error management
	H14	Help and documentation

Usability problems are evaluated based on the severity list presented in Table II. The levels of severity range from 1 to 5. The value of 1 represents the lowest level of severity while a value of 5 represents the most serious problem of usability.

B. Procedure

The usability problems are evaluated by following a task-based approach. Table I presents the evaluation tasks that were used in the present usability evaluation.

Each heuristic presented in Table II was used to explain and comment the usability problems found by experts when analyzing the tasks presented in Table I.

The evaluation procedure was as follows:

TABLE III
THE LIST OF SEVERITIES

Reference	Description
1	a usability problem is not considered, in its entirety
2	Barely aesthetic problem: it does not need to be modified, unless there is time available
3	Less usability problem: the solution to this problem should have low priority
4	Major usability problem: it is important to solve it, for this high priority must be given
5	Usability catastrophe: it is mandatory to resolve it, before the product is disclosed

1) Each expert became familiar with the application.
2) Each expert made an individual evaluation considering the set of heuristics evaluation and the severity's levels.
3) The results of each expert were consolidated for further analysis.

V. EVALUATION RESULTS AND DISCUSSION

The number of problems detected by each expert, after the individual evaluation, varied between 11 and 12. We analyzed each individual evaluation in order to eliminate the duplicates and the false problems. Overall, the collaborative consolidation resulted a total of 35 usability problems, as shown in Table IV.

Some usability problems have been found:

1) The text color used to give the information of the stations is not perceived clearly.
2) When the user manipulates the map, he/she does not have the option to reinitialize his visualization according to his/her location.
3) The system does not allow to activate or deactivate the GPS.
4) There is no help option and documentation for the user.
5) The pollution value is not easy to understand without a scale.
6) There is no recommendation to the user of the pollution value.
7) Filtering by contaminant is not allowed.
8) The user can not change the map display mode.

Table IV shows the usability problems per usability heuristics. Most of the usability problems found are related to the "user guidance" (5 aesthetics problems, 5 less usability problems and 2 major usability problems), "user support" (which 2 catastrophic usability problems), "user control and freedom" (which 2 catastrophic usability problems stand out), "user effort" (with 4 aesthetic usability problems and 2 less usability problems). User guidance problems are mainly related to all heuristics. It is difficult to have the feed-back of the user tasks and the does not help the user to understand the result of their task. These problems are aligned with user support. This is mainly because the system does not offer good compatibility with the user, nor does it provide help and documentation. The problems obtained in the group of user control and freedom are due to the fact that the user does not have enough control to return to the initial position of the map according to his

TABLE IV
USABILITY PROBLEMS AND SEVERITY FOR ALL TASKS

Usability heuristics			Severity					Total Problems
Group	***ID***	***Description***	***1***	***2***	***3***	***4***	***5***	
User guidance	H1	Prompting	0	1	1	1	0	3
	H2	Feedback	0	2	1	0	0	3
	H3	Information architecture	0	2	1	0	0	3
	H4	Grouping/distinction	0	0	2	1	0	3
Total - User guidance			0	5	5	2	0	12
User effort	H5	Consistency	0	2	1	0	0	3
	H6	Cognitive workload	0	2	1	0	0	3
	H7	Minimal actions	3	0	0	0	0	0
Total - User effort			3	4	2	0	0	6
User control and freedom	H8	Explicit user actions	1	1	1	0	0	2
	H9	User control	0	0	0	1	2	3
	H10	Flexibility	0	0	1	2	0	3
Total - User control and freedom			1	1	2	3	2	8
User support	H11	Compatibility with the user	0	0	1	2	0	3
	H12	Task guidance and support	1	0	2	0	0	2
	H13	Error management	2	0	0	0	1	1
	H14	Help and documentation	0	2	0	0	1	3
Total - User support			3	2	3	2	2	9
Totals			7	12	12	7	4	35

position. The system is also not flexible in terms of changing the perspective of the map and filtering the polluting elements.

VI. RECOMMENDATIONS

This section presents some recommendations as an alternative to solve the problems encountered by the evaluators. “Fig. 2” (panel 1), shows a proposal for the main interface of the application. We suggest to apply 3 modifications such as:

1) Reinitialize the map according to the user’s position.
2) Change map display settings.
3) Filter the contaminants and change the radius of the measurement area.

We propose the pollution value being associated with a color scale. The user can consult the documentation of this scale, by means of a help option. The user can also know the recommendations to follow according to the value of pollution, as shown in “Fig. 2” (panel 2). The recommendations can be directed to the citizens that are inside and outside of houses and buildings. They can also give advises for citizens with health sensitivities, children and those who wish to practice some sports activity.

We also propose that the color of the text be yellow when the map is shown in satellite or hybrid mode. In addition, the user may share this information through the use of social networks of their choice. This will allow the user to alert their relatives, friends and other citizens.

“Fig. 2” (panel 3 and 4), presents the recommendations to the settings user interfaces. We suggest that the user can select the type of map according to the views: normal, terrain, satellite and hybrid. We suggest that the user can activate or not the visual description of each station. In the case of wanting to turn off this option, the station will only show the pollution value. Likewise, the user can deactivate their location and finally receive notifications or alerts when the system detects dangerous values of pollution.

“Fig. 2” (panel 5), shows the recommendations to the filter tasks. We suggest that the user can increase or decrease the measurement range according to their position. Another proposal is that the user can adapt the menu of selection of the polluting parameters, by turning them in the status on or off.

VII. CONCLUSIONS

Quito Air Quality is a new mobile application to display the concentrations of air pollutants in the whole city of Quito.

In this paper, we carried out an usability inspection in order to explore the usability of the application and to investigate the extents of this application. The results obtained suggest new functionalities and development perspectives.

Future efforts should concentrate on repeating the evaluation of usability with the modified version of the mobile application and especially focus on studying usability involving user testing in real conditions.

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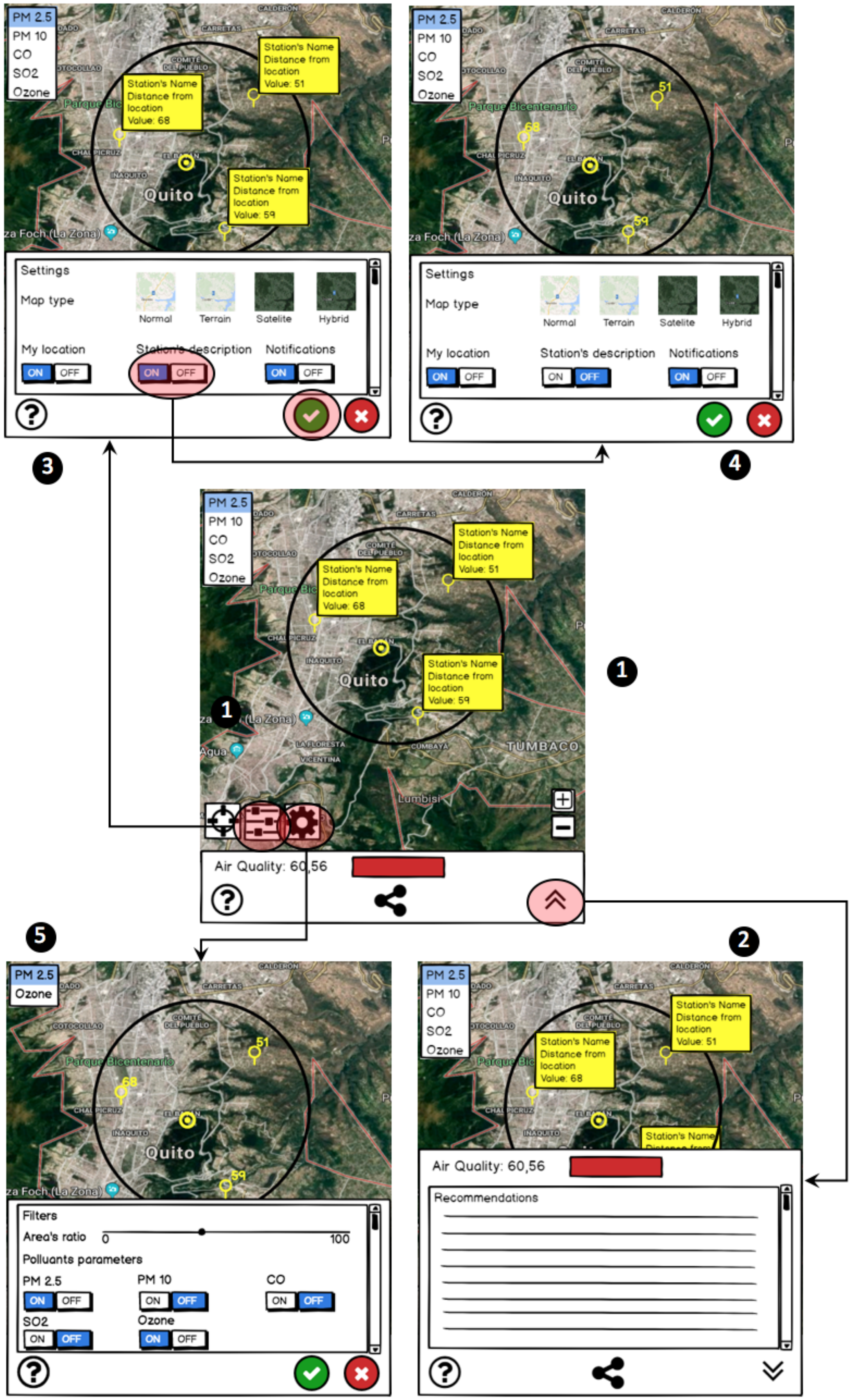

Fig. 2. Proposal for the graphic user interfaces of the air quality mobile application

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