AvoidCrowd

Walking Crowd Detection System

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Abstract. The Covid-19 pandemic has drastically changed the daily lives of people around the world in the last two years. This work describes the implementation of an application, for Android mobile devices, aimed at the user who usually goes on walks and wants to avoid the constant use of a face mask and avoid crowds. With this application the user defines from how many detected Bluetooth devices he wants to be warned to put on the mask. He may be with a group or even in an area where people are in constant movement. There is an assumption that there is a high probability that each pedestrian is carrying a smartphone and that the probability of having Bluetooth turned on and detectable is a little lower. Attempts were made to find another applications with this approach, but without success. They will certainly arise because the answer given by the AvoidCrowd application, and the current need of such tools so demands it.

Keywords: Bluetooth, Android, Covid-19, Crowd Detection, GPS, Google Maps.

1 Introduction

In these last two years behaviors in society have changed. They really look like something out of a science fiction movie. People walk around wearing masks in the street, do not greet each other, large groups of people are not allowed, and there are those who fear being around others. These are attitudes and rules that seem to stay for a while, being sure that nothing will ever be the same.

Technology is available to help in everyday life and people are already used to this dependence often without realizing even the simplest tasks and routines.

Whenever a person leaves the house for a long walk or a short walk, whether going alone or accompanied by those they live with, there will be the possibility of going without a mask on, facilitating breathing and making the walk healthier. During this route, you may find other people or small groups doing the same, as especially in an urban environment, there is a tendency to use the same routes. There is also the possibility for these groups to intersect and interact. Knowing that the possibility of each person having a smartphone with them will be around 100 percent and that Bluetooth being turned on will have a slightly lower percentage, but still high, this will be a good way to check the density of equipment close to the walker and be able to warn them to put on the mask and remind them of the attitudes to take for their safety and those around them.

So, the goal is to create a path application, with a focus on user protection in relation to Covid-19. This application will warn the user when they are near other people about the need to put on the mask and keep their distance. In addition to this warning, after some routes the application will show which routes are less densely populated to increase user comfort.

This paper is organized as follows: After this introduction, the work methodology will be discussed in the next section. Next, in section three, an analysis of the state of the art will be carried out, which will be followed, in section four, by the app environment with implementation and results. Section five will be tests and the conclusion and future work section will be number six.

2 Work Methodology

The project needed to produce functional software in a short period of time. The work methodologies used are shown below.

2.1 Agile

In this methodology (agile) it is intended that self-organized teams where members are not only placed but work at a pace that sustains creativity and productivity. These principles encourage practices that accommodate changes in requirements at any stage of the program development process. In addition, customers are actively involved in the entire process, facilitating feedback and reflections that can lead to more satisfying results. These principles are not a formal definition of agility but act as guides to achieving high-quality software in an agile manner [1].

This was the method selected due to the requirement to have a working application in a short period of time and there is the possibility that it will be necessary to implement changes in the requirements at any stage of the development process. As potential customers, the programmers were actively involved in the entire process, giving feedback very quickly.

2.2 Scrum

A SCRUM [2] team has a maximum of seven programmers, who have a to-do list (product backlog). This to-do list may contain software requirements, implementations, or descriptions. The group needs to make incremental deliveries of the program each cycle without testing (potentially shippable software). The sprint is the code development phase typically two to four weeks in length. At start each sprint, there is a selection of tasks and its planning (select items / sprint plan). At the end of each cycle, the work is evaluated (sprint review) and the planning for the next begins [3].

This framework allows to implement agile methodologies, and its main feature is the interactive development. Consequently, SCRUM is the combination of the Iterative

Model and the Incremental Model because object-oriented implementations are successive. Under the supervision of the Scrum master, teams work in consecutive sprints to achieve the sprint goals [4].

This methodology has three phases, an initial one where the general objectives of the project and the software design are established, another named "sprint cycles", in which each cycle develops a better system than the previous one and finally the end of the project, where the complete the documentation and evaluate the project (Figure 1).

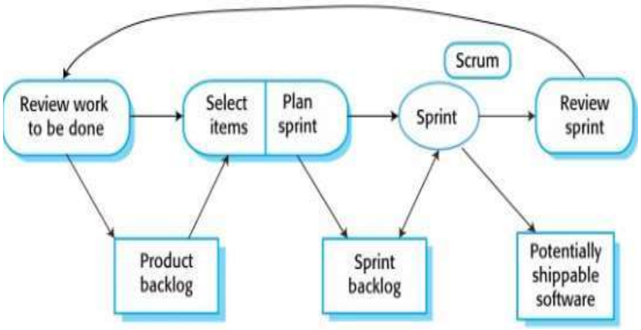

Fig. 1. SCRUM Model [1].

The sprints for this project lasted a week, but normally every two days a small meeting was held.

3 State of the Art

It is intended to make a state of the art, never forgetting the predictions of Mark Weiser [5], who undoubtedly had the vision, within the reality existing in the 90s of the last century, of the way people would interact and always have with them or around them equipment that would connect them the world. Ubiquitous Computing, also known as Pervasive Computing, is a vision of computer systems to infuse the physical world and human social environments. It is concerned with making computing more physical, in the sense of developing a broader range of computing devices that can be usefully deployed in more physical environments, being designed to operate in harmony in human and social environments [6].

3.1 Related Work

For the analysis of the system to be implemented, knowing that it was a ubiquitous system, a survey was carried out that helped to understand the approach in the context of software engineering for ubiquitous systems [7] [8]. It was also tried to understand if there was a way to reduce the use of GPS by using another positioning system that would consume less energy, to please the user than and for the sake of sustainability [9]. Naturally, a study of Bluetooth had to be done and the fact that it is possible to detect devices up to 18 meters away with the current versions can lead to the application being too zealous [10] [11]. On the other hand, Leith and colleagues [12] question the validity and identify problems of proximity detection methods based on Bluetooth LE received signal strength used to detect periods of close contact between people.

It was found that the interaction between human and computer (Smartphone) is a source of information that goes beyond what the user intentionally does [13] [14]. The accuracy of the sensors available in the equipment to be used was also analyzed to get a sense of the confidence they convey [15]. For example, in [16] the authors propose the SocializeME framework, designed to collect user proximity information and to detect social interactions based on the collected wireless signals. In [17] and [18] the authors present a review of smartphone contact tracing apps, and discuss and compares their key attributes: system architecture, data management, privacy, security, proximity estimation, and attack vulnerability. A comprehensive and detailed study highlighting the limitations, potential and challenges of digital contact-tracing apps is also presented in [19]. The authors analyze a wide range of factors, from technical, epidemiological and social categories, incorporating them all into a mathematical model that they propose and use to evaluate results. In the same vein, Alo and colleagues [20] present a review of existing and deployed Contact Tracing and Social Distancing solutions and technologies against the coronavirus disease, highlighting and discussing strengths and weaknesses. Some examples are GoCoronaGo [21], a COVID contact tracing app, where the authors describe the deployment process and analyze results and effectiveness, and Goatvid Trace [22], a solution for passive contact tracing and users' risk of exposure to Covid-19 score generation. In this case, the authors applied machine learning methods to estimate the proximity distances between two phones from Bluetooth RSSI signals.

Less direct, but with the use of smartphones in the tested environment, its constant use being essential to obtain the results, there is the contribution of tests carried out in a controlled environment in which the fundamental part was this equipment that communicated with the other systems of that Test environment [23]. As proof that the connection between the different systems is essential for the well-being of populations, it was very interesting to realize that sensors placed in cities with certain goals can be used for different purposes, more specifically to improve people's lives regarding health care [24]. Some studies were also considered that show the behavior and prediction of pedestrian trajectories as well as the unpredictability of city routes [25] [26].

4 Application Environment

The AvoidCrowd application, developed on Android, should analyze Bluetooth devices within the user's range, ignoring the number of devices identified in an initial configuration. It should also suggest to the user the placement of a mask using defined parameters such as the number of devices found, distance and the period in which they are within reach. It is also intended to record the routes taken with the information on the number of detected devices and their location. The activity diagram of the application is presented in Figure 2.

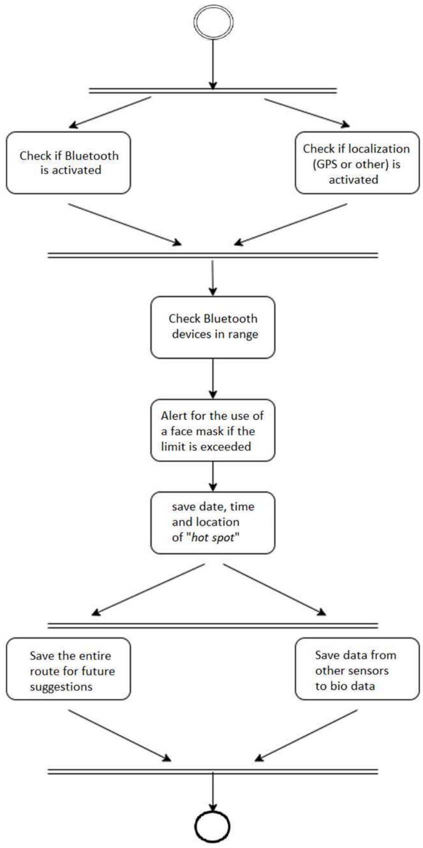

Fig. 2. AvoidCrowd Activity Diagram.

Here are the cards for a User Story showing what the application can do, for a Story Card that makes the description and for a Test Case where test data and expected results are indicated (Figure 3).

Fig. 3. User Story Cards.

On the User Story card, you can see the main purpose of the application, which is the warning for the user. In the Story Card, there is a view of the walker and in the Test Case an example of a test is made to measure the effectiveness of the system.

4.1 Architecture

The architecture of the AvoidCrowd system is illustrated in Figure 4. The tools used were Android Studio as well as access to smartphone sensors (Bluetooth, GPS, WI-FI and Mobile Data) and of course the smartphone itself.

The user configures the application indicating from how many devices detected he wants to be warned and how long he can be stopped in a place during the route.

From the moment you start walking (start of the application) Avoid Crowd analyzes the environment according to the settings. If you have already recorded hikes, ask the destination to suggest the best route. Whenever there is a "hot spot" the user is warned. Coordinates are registered in the database. If the user gives the instruction to end the walk or the user is stopped for more than the time defined for this, the application closes, stopping the analysis of the environment.

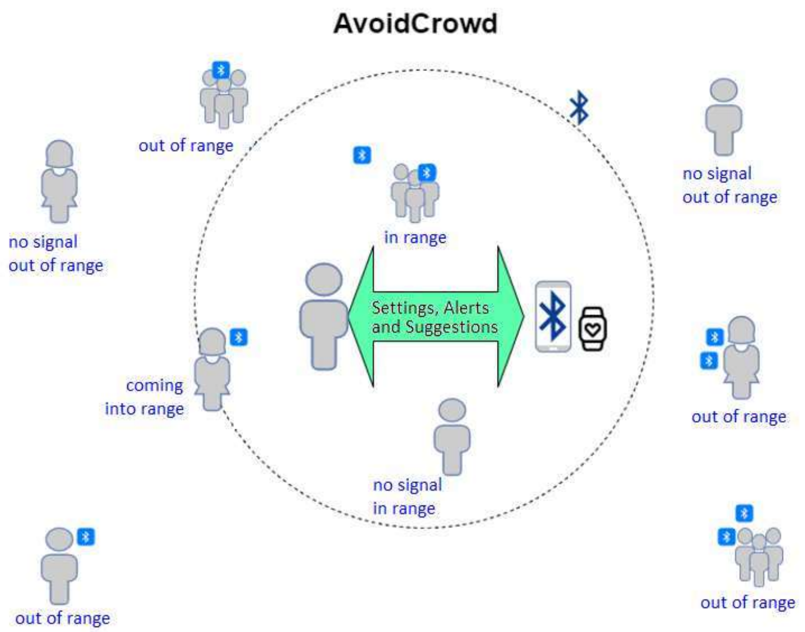

Fig. 4. AvoidCrowd System Architecture.

4.2 System Properties

The developed system has implicit Human-Computer interaction. There is data collection using smartphone sensors without user intervention. The alerts and suggestions given by the system are autonomous. The context is at the user level as data is collected from the smartphone sensors that belong to the user, namely the GPS that identifies their position. The system is autonomous because, when accessing the sensors, it records your data without the intervention of the smartphone owner. The application acts proactively [27] suggesting the placement of the mask.

Assuming that in the Smart DEI system model three architectural patterns can be defined (smart Devices, smart Environments, smart Interaction) [6], the system developed can be classified as Smart Environment as data are collected and, through the settings, the mask alert and suggestions for care are made.

The application is of primary context, because the information is obtained through sensors and will be given to the user without being processed. Functionally, it is characterized as a presentation application [28], in which the sensor values are presented to the user and the placement of the mask is suggested. The level of interactivity that is applied is a passive context, as it will constantly monitor the environment, suggest the placement of a mask or care when interacting with other people, but it is the user who decides what he wants to do.

4.3 How the system works

The system is very easy and intuitive. The user just must use buttons to increment or decrement the number of devices from which it should be notified. It should also indicate the beginning and end of the walk and decide whether he want to use the mobile network operator's GPS or towers (Figure 5).

The user can also see a record of occurrences in the walks made, in addition to being able to see where they were recorded on the map. The app has a color system in which, based on a value where everything above six is to be watched, it goes from green to red every two devices detected. Even ignoring the warnings, just a quick look at the application is enough to know if the area where the hike is taking place is safe.

5 Tests

Tests were performed through short walks during application development. In the end, a test was carried out on a 3.82 km walk lasting 1h06m in which the definition that indicates from how many devices should receive an alert was varied. There was a total of 18 notices. Whenever the walker approached another group, people sitting in the gardens, children playing, there was a variation that indicated the detection of devices. Whenever this value exceeded the defined limit, the alert was given, and the application changed to red. Only when the limit was lowered, the application returned to the original green. See Table 1 with tests performed with varying durations and changing connection types.

There was only a group of five pedestrians who crossed paths with the user performing the test and there was no variation, the reason is not known, but it could be because those pedestrians did not had equipment with them emitting Bluetooth signals. A detail that can be considered overzealous and maintain or that can be changed in the future by setting the range of action to a lower range is the fact that, when passing terraces and restaurants, the application indicates an increase in available devices with these people away from the user. The reason is the possible range of Bluetooth, especially in the latest versions (Figure 6).

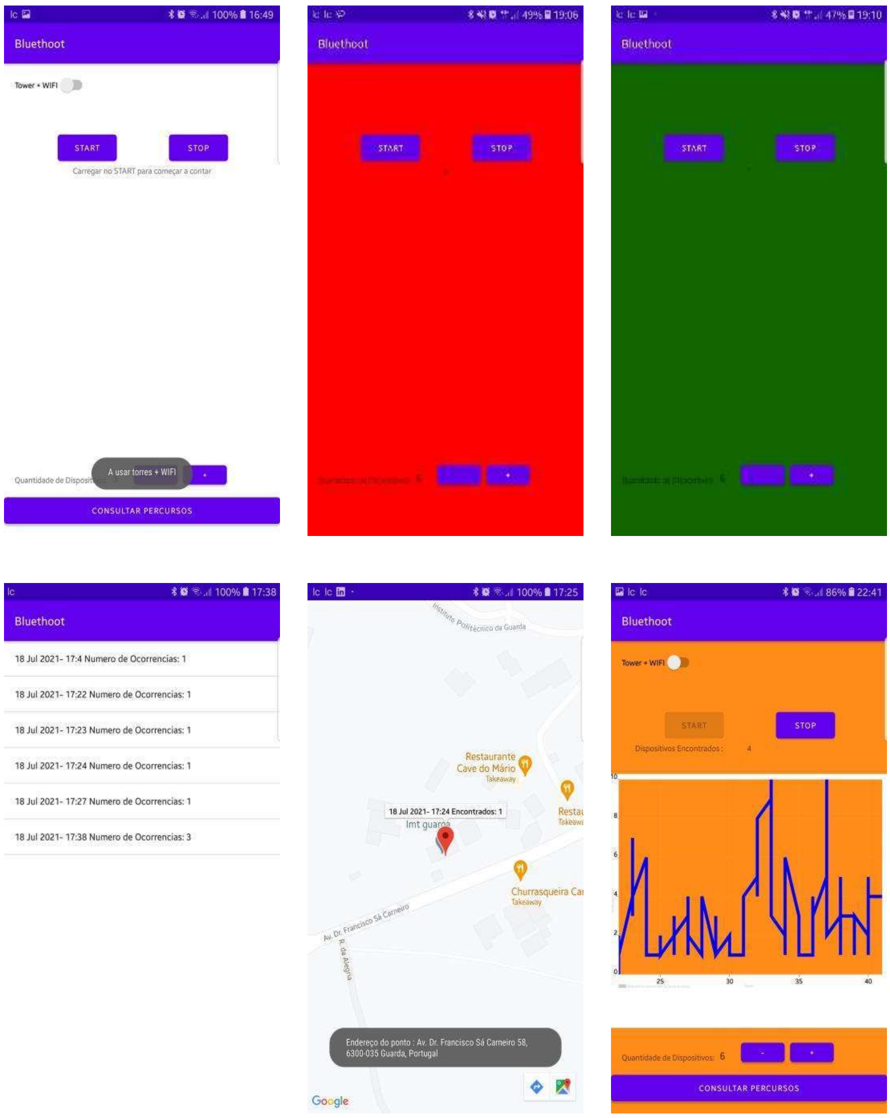

Fig. 5. AvoidCrowd System.

Table 1. AvoidCrowd Field Tests.

Date and Time	Occurrences (Devices detected)	AvoidCrowd Alert Level	Connection
July 18, 2021 – 05:04 pm	1	Green	GPS
July 18, 2021 – 05:22 pm	1	Green	GPS
July 18, 2021 – 05:23 pm	1	Green	GPS
July 18, 2021 – 05:27 pm	1	Green	GPS
July 18, 2021 – 05:27 pm	3	Yellow	GPS
July 18, 2021 – 05:38 pm	1	Green	GPS
July 18, 2021 – 10:21 pm	7	Red	GPS
July 18, 2021 – 10:37 pm	10	Red	Mobile

In the referred figure (Figure 6), it can still be seen that alerts are also given on devices associated with the smartphone, such as smartwatches or smartbands.

It is also concluded, as expected, with the tests that the definition of devices to detect and the duration of the walk influence the number of warnings received. There is no intention to distract the user with too many reminders, but the main objective is to keep him safe.

6 Conclusion and Future Work

In this paper, an Android application was presented to support people in their safety in a period when attitudes are completely different from those taken throughout their lives and can easily be forgotten. Some messages were also introduced for the application to be sustainable and help for a better future, appealing for ecological civility. Due to the nature of the application itself and the benefits it entails, principle 7 of "The Karlskrona Manifesto for Sustainability Design" that says "Sustainability requires long-term thinking" was applied [29].

With the AvoidCrowd app it is intended that the user can avoid contracting the disease, not infecting others, not having to go to the hospital and being able to leave the house safely. In this way, it combats absenteeism from work, avoids creating a social problem, helps to decongest the health system and combat problems related to sedentary lifestyle. There will also be savings on medication, resulting in savings in the country's expenses since medication and hospital expenses are covered by the national health system and help to maintain healthy routines. These goals are in line with the Sustainable Development Goals namely goals 3 (Good Health and Well-Being), 9 (Industry, Innovation, and Infrastructure) and 11 (Sustainable Cities and Communities). In terms of the methodology used, it was proven that the practice of delivering products continuously and frequently is very important in agile methods [30], if this practice fails, it will harm the development of the project.

Based on the results obtained, the "AvoidCrowd" application may be a tool of choice for people who take their walks. Due to the ubiquity of the use of smartphones and due to the degree of use of the Android system in Portugal, this operating system was the natural choice, but in the future, it is intended to develop the application for iOS to cover practically all users. It is also intended to suggest less congested routes based on the user's history since these data are registered in the database.

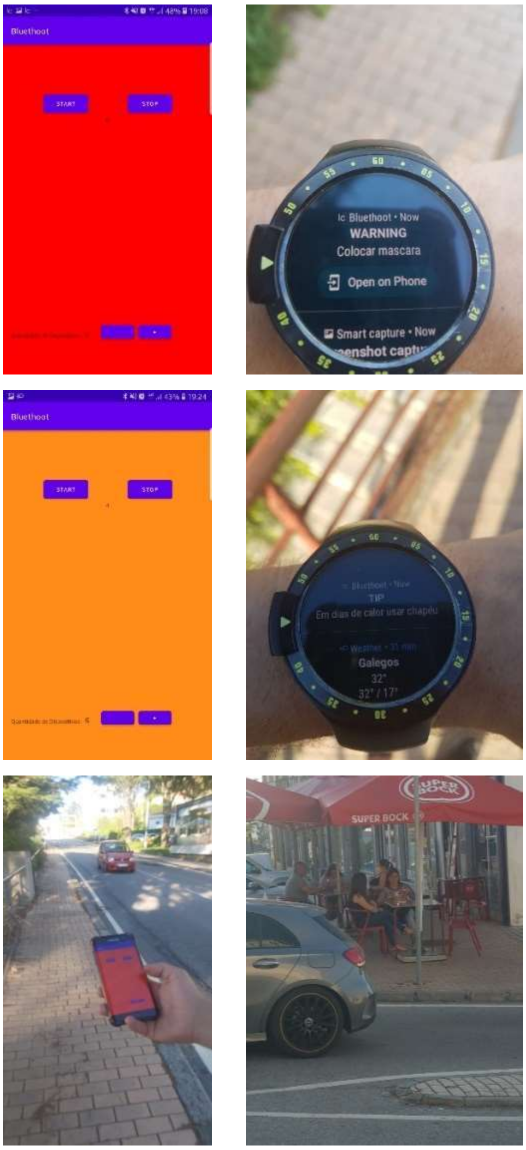

Fig. 6. AvoidCrowd Tests.

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