MOBILE APPLICATION FOR TRAFFIC LIGHT-BASED PERSONAL RISK ASSESSMENT FOR EARTHQUAKE ALARMS

Juan Carlos García Zepeda
Universidad Autónoma Metropolitana - Cuajimalpa
Vasco de Quiroga 4871, Santa Fe Cuajimalpa, Cuajimalpa de Morelos, México City.

Wulfrano Arturo Luna Ramírez
Universidad Autónoma Metropolitana - Cuajimalpa
Vasco de Quiroga 4871, Santa Fe Cuajimalpa, Cuajimalpa de Morelos, México City.

ABSTRACT

Natural disasters are an increasing domain of application of a full range of technologies and a matter of scientific and social studies due to its implications for human security, including infrastructure safety and economic savings for both persons and governments.

We endeavor in producing a system to situate people in case of a natural disaster accordingly to the risk, vulnerability and personal features of individuals, mean of a traffic light signaling. The risk traffic light-based alert proposed in this paper allows calculating the risk index of a person in a natural disaster through an app developed to Android OS, considering seismic events as its case of study.

This personalized calculation considers physiological, sensory and location variables of the user together with the data provided by the official seismic monitoring systems. In this way, the risk traffic light allows informing in a visual and personalized way the risk presented by the user, by means of three colors: green, red, and yellow.

The mobile application it is called Semáforo Móvil de Riesgo Personal (SMRP), and its purpose is to provide an auxiliary digital tool for people when an earthquake occurs, based on their own physical and sensory characteristics.

KEYWORDS

Application for mobile devices (App), Danger, Personal Risk Rate, Risk Traffic Light, Vulnerability.

1. INTRODUCTION

The main objective is to develop an application for mobile devices with Android system to improve the calculation of the risk index with the use of the built-in sensors of the device so that users can see graphically (with a traffic light of three colors) the level of vulnerability to which they are exposed given their own conditions at the time of an earthquake.

This requires the development of a module for reading the user's personal data related to the risk index: disability (visual and hearing) and mobility, as well as implementing a graphical representation (traffic light) with the data obtained from the analysis of the risk index and displaying recommendations from official sources of earthquakes in our country (Mexico) such as CENAPRED (Centro Nacional de Prevención de Desastres | Gobierno | gob.mx, s. f.) and SSN (Servicio Sismológico Nacional, s. f.).

2. DEVELOPMENT OF THE SMRP APP

Currently, there are applications designed for mobile devices, which offer different services in the event of a natural disaster, for example, notifications before the event occurs and even messaging between the same devices without the need to be connected to a network or have coverage. However, none of these applications offers a level of customization that includes the user's physical capabilities, which may represent an obstacle to their actions and which, together with other criteria such as their real-time location and their location within a building, allows them to know an estimate of the level of vulnerability to which they are exposed in an emergency caused by an earthquake.

2.1 Related work

At this point it can be deduced that, based on the search of applications for current mobile devices operating both in Mexico and in some Latin American countries (SkyAlert, s. f.) (SASSLA: Monitoreo y Registro Sísmico, s. f.) (quakeRisk - Apps on Google Play, s. f.) (Earthquake Network, 2022), there is no application or web system whose objective is to indicate to a user the vulnerability to which he/she is exposed to an earthquake, considering his/her physical and sensory capabilities, as the application in question intends to do (Vazquéz-Espino et al., 2021). In the following paragraphs, a brief review of the related applications is presented.

- **SkyAlert:** This application for mobile devices with Android and iOS operating systems and with coverage in Mexico City, State of Mexico, Puebla, Morelos, Michoacán, Guerrero, Tlaxcala, Jalisco, Colima, Oaxaca, and Chiapas, sends alerts up to 120 seconds before an earthquake, according to the epicenter detected (SkyAlert, s. f.). SkyAlert launches an alert based on its intensity scale, that is, it is based on the Mercalli scale to assign a color label according to the intensity of the telluric movement.
- **SASSLA**: Is an alternative to SkyAlert that detects earthquakes and sends alerts to the cell phone up to 120 seconds before a strong earthquake and without delays, using information from SASMEX and is available for both iOS and Android (SASSLA: Monitoreo y Registro Sísmico, s. f.). Unlike SkyAlert, SASSLA has notifications with a higher priority with respect to those of other applications on the mobile, so they can: Interrupt any current activity or notification on the mobile (notifications, calls, music, apps). Play the alert audio at maximum volume even when the phone is in silent mode and/or do not disturb. Increase the screen brightness to the maximum to facilitate the reading of the alert information. Repeatedly activate the vibration and the led light of the device so that the user notices the alert in situations where there is so much noise.
- **Sismo Detector:** Is an application for mobile devices with Android and iOS and is part of the Earthquake Network research project that seeks to develop an early warning system based on smartphones (Earthquake Network, 2022). The way the application works is as follows: when the device detects earthquake waves, a server is notified along with the geographic position of the earthquake. The server decides whether an earthquake is occurring and, if so, all users with the application are alerted in real time.
- **QuakeRisk:** It is an application for mobile devices with Android and iOS systems and tablets with Windows operating system that allows the user to enter the address of the building, its characteristics such as date of construction, number of floors and type of construction and other parameters to evaluate it against earthquakes of different magnitudes (quakeRisk - Apps on Google Play, s. f.). The app's algorithm, created by engineer Mario Ordaz Schroeder, from the UNAM Engineering Institute, gives a risk percentage for each building, and can be used to determine economic losses in up to one million buildings in the city. QuakeRisk is the result of more than 25 years of work on algorithms for estimating damage from natural disasters.

2.1.1 Comparison of functionalities of every app

In Table 1 a comparison between the mentioned application is showed and, in the last column it shows the characteristics of the SMRP in contrast with these apps.

Table 1. Comparison of applications for mobile devices in the current market with respect to the application for the personal risk traffic light.

Comparison of current seismic warning apps in contrast with the Mobile Personal Risk Traffic Light (SMRP)					
Application´s name / Feature	**SkyAlert**	**Earthquake Detector**	**QuakeRisk**	**SASSLA**	**SMRP**
System	Android and iOS	Android	Android	Android and iOS	Android
OS version required	Android 5.0+ iOS 11+	Android 5.0+	Android 9.0+	Android 4.4+ iOS 15+	Android 5.0+
It´s free?	✓	✓	✓	✓	✓
App target?	Smartphone user	Smartphone user	Real estate and insurance companies	Smartphone user	Smartphone user
Where does it get the information of the earthquakes?	SkyAlert Network	Earthquake Network	It does not obtain data because is a build risk simulator	SASMEX	Project server
Does the application have a web version with the same function?	✗	✗	✗	✗	✓
Does the application consider the user´s characteristics?	✗	✗	✗	✗	✓
Does the application consider the user´s ubication in a build?	✗	✗	✗	✗	✓

In the case of SkyAlert and SASSLA, although it detects when there is an earthquake in a certain location of the Mexican Republic and distributes it in alerts to other locations near the epicenter, is a large-scale alert dissemination.

On the other hand, users of the Earthquake Detector application can send a report as soon as they perceive an earthquake and a map with the affected area will be available in less than a minute. Depending on the intensity shown on the map, civil protection, and all other agencies responsible for people's safety can send emergency assistance and emergency teams where it is a priority. As for QuakeRisk, it is mainly based on a simulation of how catastrophic an earthquake would be in each house or building.

The SMRP app will be in one of those apps which will receive the alert propagated by the media in case of an earthquake like SkyAlert and SASSLA, with the difference that it will be based on personalized parameters for each user of the application and will give a personalized result to represent the risk index of each one of them and also gives sound recommendations on how the user should act during and after the seismic event. This is the main feature of this application that differentiates it from the rest.

2.2 Personal Risk calculation

2.2.1 Calculation of the risk rate and its interpretation on a risk traffic light

The following input data are used to calculate the earthquake risk rate: the danger represented with P and the vulnerability represented by *V*. For the calculation of *P*, a relationship between magnitude and danger of the earthquake inspired by the Mercalli scale is proposed and can be seen in Table 2.

Table 2. Relationship between earthquake magnitude (n) in Mercalli scale based and Danger (*P*).

Magnitude (Mercalli scale)	Danger (*P*)
n < 4	1
4 ≤ n < 5	2
5 ≤ n < 6	4
6 ≤ n < 6.5	5
6.5 ≤ n < 7	6
7 ≤ n < 7.5	7
7.5 ≤ n < 8	8
8 ≥ n	10

For the calculation of *V*, two feature vectors are created that represent both the data obtained from the seismic monitoring system as well as the user's personal data. These are denoted as *V1* and *V2* respectively where:

- *V1*: is the user´s ubication in a build represented as *U* and the distance between the epicenter of the earthquake and the current user´s location represented as *D*.
- *V2*: is the user´s physics capabilities represented with dfis and the sensory capabilities as well as the hearing and visual impairments represented as *dAuditiva* and *dVisual,* respectively.

In the case of the *V1* vector, the weighting of these elements can be seen in Table 3

Table 3. Weightings for user's ubication and locations of the earthquake used in *V1*.

Radius of distance between earthquake and user (km)	Value (D)		User location on a build	Value (U)
n < 80	2.5		**From the sixth floor and up**	2.5
80 ≤ n < 140	2		**Fifth floor**	2
140 ≤ n < 200	1.5		**Between the fourth and second floor**	1.5
200 ≤ n < 300	1		**First floor**	1
300 ≤ n < 400	0.5		**Clear area**	0.5

The purpose of the weightings shown in Table 3 is to obtain a quantifiable value based on the user's environment to have an estimate of how affected the user may be given an earthquake with a specific magnitude. As for the physical and sensory capabilities of the users, they are required to calculate *V* so a weighting of these is also needed. Table 4 below shows this conversion.

Table 4. Weightings for user data such as physical and sensory capabilities used in *V2*.

Physical user capabilities	Value (dfis)
Cannot move	2.5
Depends on the help of others to move around	2
Use wheelchair or crutches to move around	1.5
It can move with slight complications, without the need for assistance	1
Can evacuate in case of emergency without assistance	0.5

Hearing user impairment	Value (dAuditiva)		Visual user impairment	Value (dVisual)
Cannot hear	2.5		**Cannot see**	2.5
It is difficult to listen	1.5		**It is difficult to see**	1.5
It can listen without complications	0.5		**It can see without complications**	0.5

By the other hand, the purpose of the weightings in Table 4 is to obtain a quantifiable value of the user's capacities which may affect his actions in the event of a possible evacuation of a building at the time of an earthquake. The sum of the values calculated in Tables 3 and 4 will result in V as shown in Formula 1.

$$\begin{gathered} V = V1 + V2 \\ V1 = D + U \\ V2 = dfis + dsen \end{gathered} \tag{1}$$

Where:
V: the vulnerability of the user represented with a numeric value.
V1: the vector of the characteristics of the earthquake according to the user’s location.
V2: the vector of the personal characteristics of the user.
D: weighting of the distance between the user and the earthquake.
U: the weighting of the user's intramural location.
dfis: the weighting of the user's physical capabilities.
den: the weighting of the user´s sensory capabilities.

The *dsen* value is also calculated with a simple division by two considering that this value is the sum of the user's visual and hearing capabilities represented with a numerical value. The Formula 2 shows this :

$$dSen = \frac{dAuditiva + dVisual}{2} \tag{2}$$

Where:
dSen: weighted value of sensory impairment.
dAudituva: weighted value for hearing impairment
dVisual: weighted value of visual impairment

Later, the values of V and P (weighting of the magnitude of the earthquake) are introduced into the Formula 3 to get the Risk Index.

$$IR = a_0 + a_1 P + a_2 V + a_3 P^2 + a_4 V^2 + a_5 PV \tag{3}$$

Where:
IR is the Risk Rate calculated.
P is the danger of the seismic event.
V is the vulnerability of the user under his/her own conditions.

To tune the a_i coefficients we perform regression against a set hypothetical or theoretical cases for representing the (P, V, IR) values. As the parameter configure a set of boundaries of acceptability to be used to determine the color of the signal provided to the user, these parameters need to be adjusted, we take experimentally the following values according to the Formula 4:

$$\begin{gathered} P_1 = (P_{min} + 0.5, V_{max}, 5) \\ P_2 = (P_{max}, V_{min} + 0.5, 5) \\ P_3 = \left(P_{min} + 0.35P_{ptp}, V_{min} + 0.35V_{ptp}, 5\right) \\ P_4 = \left(P_{min} + 0.6P_{ptp}, V_{min} + 0.6V_{ptp}, 7\right) \end{gathered} \tag{4}$$

Where:
$P_{min} = 1; P_{max} = 10;\ V_{min} = 1.5; V_{max} = 10; P_{ptp} = P_{max} - P_{min}; V_{ptp} = V_{max} - V_{min}$

The values obtained for the coefficients using these points are:
$(a0,\ a1,\ a2,\ a2,\ a3,\ a4,\ a5) = $ (0.23698655, 0.59396298, 0.63429914, -0.02897832, -0.02830087, 0.02829105)

Finally, the IR value is considered in Table 5 according to the result of the application of Formula 3 considering the pondered P and V values with Tables 2-4. As shown, if the IR is less than or equal to five, it corresponds to a green traffic light, if it is greater than five and less than seven it corresponds to a yellow traffic light, and if the IR value is greater than seven the traffic light will be red.

Table 5. Relationship of the risk rate to a phase of the traffic light.

Phase	Risk Index (IR)
Green	IR ≤ 5
Yellow	5.1 < IR ≤ 6.9
Red	7 ≥ IR

2.2.2 Implementation of the risk traffic light in a mobile application

For the development of the application, the OpenUP model will be used, which is a minimally sufficient agile software development process, meaning that only the fundamental content for the construction of a system is included (Balduino, 2007) and the type of application to be developed will be native because it allows the use of all the hardware components of a cell phone such as GPS, accelerometer, among others (Gill, 2022) (Descripción general de sensores | Desarrolladores de Android |, s. f.). The implementation of the application will be based on the following deployment diagram shown in Figure 1.

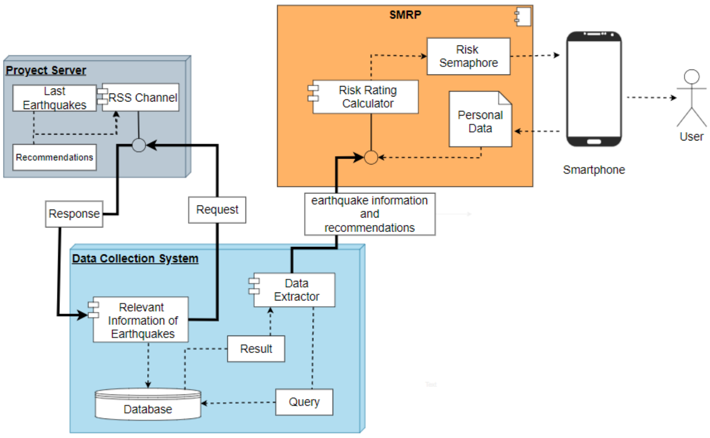

Fig 1. Deployment of the SMRP application.

2.2.3 Testing and Results

The Figure 2 show the result of the implementation of the risk traffic light in the mobile application for android devices. It shows a screen with the data entered by a user, the representation of the risk index in a traffic light given the simulation of an earthquake. In the case of an alarm, the app will trigger sound alerts according to the color determined by the IRP calculation and display a traffic light accordingly. Additionally, the user is noticed by sound directions about how to act during and after the earthquake. Finally, the details of such a natural disaster event are displayed in a screen in the app.

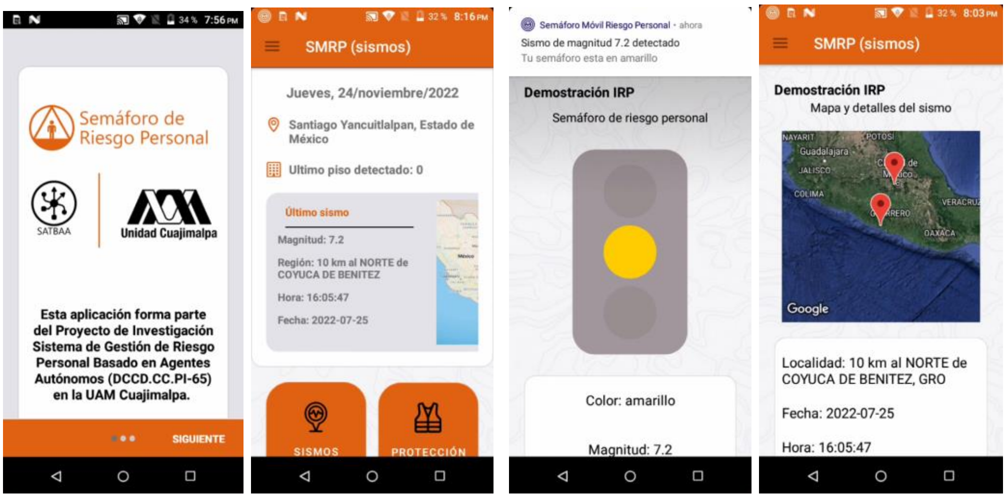

Fig 2. Demonstration of the app when calculates the Personal Risk Rate calculation and the associated traffic light witch details of the earthquake (In Spanish). It goes from the profiling of the user to the identification of the seismic event in a map.

In addition, the app was evaluated with five users who subsequently answered a test about the functionality, usability, design, and usefulness of the app. The results obtained from the test will be analyzed to determine which aspects of the application need to be improved and will be included in a future work.
Results are shown below in Chart 1. According to the results obtained by applying the user test to each of the five users, in the usability aspect there are aspects that still need to be worked on, although the users reported a satisfactory performance of the application now of its use, which is also reflected in the reliability that it produced in the users.

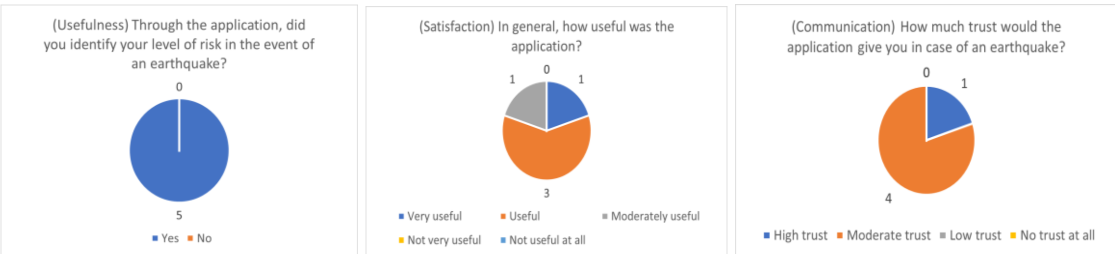

Chart 1. Results of the main function of the app according to the evaluation test applicated to five users.

3. CONCLUSION

In this work, a traffic light-based application is successfully developed to alert the user and display his Personal Risk Index. As a specific contribution of this calculation is the inclusion of user's personal data related to the risk index such as disability (visual and hearing) and mobility, which are considered in the graphic representation (traffic light) with the data obtained from the analysis of the risk index. Additionally, the user is provided with audio safety guidelines based on the official sources of earthquakes in Mexico. All this according to the usability and accessibility standards for mobile applications.

Additionally, the following aspects should be addressed to improve the application in the future:

- Implement intramural localization using Bluetooth beacons.
- Include new sections to determine user vulnerability more accurately in addition to physical and sensory impairments. These can be with emotional issues, i.e., how a person acts in an emergency, and the user's environment, i.e., what are the characteristics of the place where he/she is. Other

measures can be taken to increase the Personal Risk Index e.g., pulse, temperature, or blood pressure.

- Implement accessibility issues for blind and deaf users.
- Improve the tests sets based on the results obtained from the first test round to modify aspects like the user interface.
- It may be possible the app automatically perform message and calls for help to the rescue authorities or police.

Finally, the general model of this app can be extended to other natural disasters by integrating its particularities and introducing an adjusted IRP calculation.

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