An Autonomous Emergency Warning System based on Cloud Servers and SNS

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Abstract

There are no warning systems for earthquake, fire and gas disasters in Almaty (Kazakhstan). We propose an autonomous emergency warning system that provides useful awareness against unpredictable disasters. The system mainly consists of sensor network, disaster information mapping server, SNS module, and web server. When the system detects a disaster it distributes real-time warnings with levels of danger and signs of severe damages by the sensor data and GPS position to residents by both SNS (twitter) and the Website with Google maps including real-time safety places. We built a prototype system and could confirm the effectiveness of the warning system.

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Keywords: cloud computing; autonomous warning; disaster; sensors network; evacuation map;

1. Introduction

Over the past decades in the field of information technology has evolved a new paradigm - cloud computing. Although, cloud computing - a special way to provide computing resources which is caused a revolution in the methods of providing information and services [1]. Therefore, using of sensor data becomes more useful feedback for making decisions of the next effective action of people in emergency situations [2]. In case of earthquake situation it is extremely vital for people to be informed and quickly evacuated from a dangerous area [3, 4, and 5]. Earthquake Early Warning system (EEWS) of Japan Meteorological Agency (JMA) provides citizens with earthquake warning of

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a severe earthquake that is stronger than “intensity 5 lower” by mobile phones, radio, and TV, etc. in Japan. JMA also provides information about both tsunamis and the intensity only in typical spots where JMA has earthquake sensors after the earthquake. JMS and local disaster prevention centers do not provide real-time sensor data in the other local areas. A UML model of a center server type of self-organizing earthquake EEWS was designed and the prototype system was developed for Istanbul [6]. Almaty city is located in the mountainous area of southern Kazakhstan, it is also known as a seismically active area. From the city history in 1887, 1889 and 1911 there were three big earthquakes with magnitude 9. Almaty almost totally was destroyed by the first big earthquake. Seismology experts predict a new big earthquake may occur next 10-15 years. 6149 buildings in the city are quakeproof, 3309 buildings are non-quakeproof and 1836 buildings still pending. It means approximately half of buildings are not reliable for earthquake [7]. We propose an autonomous emergency warning system for Almaty residents based on cloud servers and SNS. We built a prototype system and discuss the effectiveness by experiments.

2. Problems in case of disasters

The major problem of Almaty city is no warning system against earthquake. Earthquakes also have embedded problems such as fire, buildings breakdown etc. There are a lot of industrial companies and gas stations in Almaty city. Each of them would become flammable zones [8]. Especially, open air gas pipes which are prolonged to each house, may lead to serious consequences in case leaking of gas and fire [9]. Lots of gas pipes in high human density areas in suburb are extremely dangerous in case of earthquakes.

Compared with all cities in Kazakhstan, Almaty city has a problem with traffic jams between 08:00-10:00 am and 18:00-20:00 pm. The traffic information in emergency situations is very important to know how to save the time to get to safety places.

Fallen concrete block, fires in gas stations, road collapses, and evacuation ability of aged persons should be provided by the warning system and disaster cloud servers.

(P1) Lack of emergency warning system

No warning system has often increased serious damage in disasters and emergency situations. Public organizations and human need a long time in order to prepare the warning although immediate warning should be distributed.

(a) No warning system by P wave detection. Residents should evacuate from dangerous place to a safer space within a ten seconds after P wave detection.

(b) No information distribution of the change of safe places.

(c) No information distribution of accidents of Gas stands and Gas pipelines.

(d) No assists for cooperation in resident’s evacuation, such as avoiding traffic jams.

(P2) Carbon monoxide poisoning

In the winter season some people do not follow the rules of fire safety in the operation of the heating furnace. According to empirical findings, the most of carbon monoxide poisoning was due to “human factor”, like ignorance, carelessness, negligence etc. Moreover carbon monoxide is colorless, odorless, and tasteless, but highly toxic gas.

The other problem in Kazakhstan is heating systems by gas resource. The vast majority of them use coil. The Ministry of Emergency Situation’s statistic shows 1049 people were poisoned and 131 people died by wrong use of carbon monoxide in Almaty for the first 11 months of 2013 [10].

(P3) The big fire caused by the wind

“Embedded fire areas” might be high level of danger due to strong wind. The typical example is the great Japan Kanto earthquake in 1923. The greatest loss of life was caused by a fire tornado in downtown Tokyo, where about 38,000 people were incinerated after evacuating to shelters. Fire tornado may occur when intense rising heat and turbulent wind conditions combine to form whirling eddies of air. If strong winds expand the fire over the first shelter, residents should change the place of refuge from the first safe place to the second safe place and know safe routes to get there [11]. In addition, people should receive separate warning messages and instructions to be evacuated according to the levels of danger.

(P4) Normalcy bias

In The Great East Japan earthquake about 70 % of residents did not evacuate although they knew the tsunami warning of the government in text and reading out by an announcer. That is why only giving warning of tsunami is not enough since the citizens have been safe for 58 years. They tried to avoid panic and trust their experiences with
no serious damage by tsunamis for 38 years. They need to acquire the motivation and chance to start evacuation from the giant tsunami [12].

3. The feature and architecture of warning system

Major roles of the warning system during earthquake are (R1) to (R4).
(R1) Distribute information about the first wave and the next wave of earthquake.
(R2) Reduce psychological disorder (Normalcy Bias) of people [13].
(R3) Make the latest evacuation map with effective routes to safety places by using the Big Data of sensor data.
(R4) Distribute real-time dangerous spots in local areas to residents.

Our warning system mainly consists of “Earthquake Sub-system (ES)” with P-wave sensors, “Multiple Sensor's Pack sub-system (MSP),” disaster database server “CloRob,” google-map server, SNS module, and emergency web server (see Fig. 1). ES is controlled by Arduino Mega shield [14] with ATmega328 microcontroller. P-wave sensor is attached on the Arduino Mega ADK and works independent from MSP (see Fig. 2). We modified earthquake sensor: “Rebex earthquake detector DESTA-5” to obtain earthquake signals of magnitude 3 by P-wave sensor and S-wave sensor. ES simultaneously sends earthquake warnings with GPS position data both to the twitter server and to the MySQL database server via the Internet connection by using Arduino Ethernet shield. "CloRob" saves earthquake signals in "Events" table in the earthquake database. "CloRob" also generates maps from the table's data using Google map API functions [15] and sends to the emergency web server. Here we have two kinds of maps. The first is event map, where fire/gas places are shown with red/blue markers respectively. The second map for evacuation shows the latest “local safety places,” after "CloRob" removes dangerous places from “safe place table” corresponding to real-time changes by both disasters and accidents. The two kinds of maps are provided by the system web site (http://ictedu.u-tokai.ac.jp/miyachi/maps.php). Moreover, there are some information/news about emergency situations and detailed information about the system in the web-site.

MSP is controlled by Arduino Mega ADK shield, because it needs more memory resources to work with several sensors such as GPS, flame, two gas sensors and TFT display. The MSP has a similar functionality with ES. All data from these sensors are saved into the table "Events". The MSP uses WiFi shield to connect the Internet, so it is more convenient to choose WiFi connection type, due to SPS should be network and check safe/danger places. GPS sensor is attached as well on the Arduino Mega ADK.

![Fig. 1. The system architecture of autonomous emergency warning system](image-url)
Finally, Almaty residents could get the warnings from the twitter and website using the gadgets (PC, tablet, mobile phone, etc).

4. Autonomous evacuation warnings and guides based on sensor data

4.1. Communication between sensor's systems, disaster cloud server, disaster Web-server, and users

Major communications between sensor’s system, disaster cloud server, and disaster Web-server are performed in (rc1) to (rc4) [16, 17].

(rc1) The sensor system upload new sensors’s data to the disaster cloud. The disaster cloud updates the latest sensor data in a web-site of emergency warning system “CloRob Website” (see Fig. 1, 2, and 3).

(rc2) The cloud collects real time photos of situations from CloRob Website. The photos have been uploaded to “CloRob Website” by users and can be sent to a screen of the sensor system.

(rc3) The system (ES and MSP) and the cloud generates several kinds of maps for evacuation, dangerous place, statistic safety places, real-time safety place's by considering the Big Data of latest sensor data and the information in hazard maps. It also shows a map of traffic jams.

(rc4) By using updated Big data the cloud prepares an safe optimal route for users [18].

Communication between warning systems and the users can autonomously start based on real-time sensor data, GPS position and evacuation maps. The warning system distributes warning to users by either twitter or GSM messages. The user can acquire evacuation maps that include the latest safe places and dangerous in real time by clicking the link in twitter to the website of the warning system (http://ictedu.u-tokai.ac.jp/miyachi/index.html). GSM users can access the website of the warning system and find such maps with evacuation guides. GSM users can also acquire such evacuation maps and guides from twitter’s users in their homes. Residents can ensure trusted evacuation guides by such human communication. Human communication in Almaty would be more effective than that in a mega-city like Tokyo since that in Almaty culture is faster in a spirit of cooperation than that in the mega-city.

4.2. Mapping

Evacuation maps must be easy for all residents to understand evacuation routes, strategies and key information. The system has four kinds of layers in the maps, such as general safety, real time safety, dangerous places, and traffic.

A general safety and real time safety maps. In case of emergency situations a general safe place often changes into dangerous. The system has general static safe places in a table of safe place in the database system and manages such change in the table. The vital concern is defining safety places earlier. A safety place is defined by a coordinates (latitude, longitude) and geographic data. A safe place would be affected by fire, dangerous gas in disaster. If the safety place near the dangerous area would become dangerous, it should be removed from “real-time safe evacuation map.” The warning system removes a safe place in the table of safe places when a sensor would detect a dangerous gas or fire and send sensor data with GPS position to the warning system (See Fig. 2 and Fig.3).

The system verifies the general safety places in radius 200 meters. In addition, it shows a distance from the nearest dangerous place and calculate the distance between two coordinates. In this concept “Haversine formula [19]” had been used to calculate distance (1). It calculates the distance based on the latitude/longitude of that row and the target latitude/longitude, and then asks for only rows where the distance value is less than 200 meters.

\[ d = R \cdot c \]
\[ a = \sin^2(\Delta \phi / 2) + \cos \phi_2 \cdot \sin^2(\Delta \lambda / 2) \]
\[ c = 2 \cdot a \cdot \tan(\sqrt{a} \cdot \sqrt{1-a}) \]

where \( \phi \) is latitude, \( \lambda \) is longitude, \( R \) is earth’s radius (mean radius = 6,371km);
5. Experiments and evaluations

The system introduces several basic concepts: Cloud servers, sensors, SNS – twitter, MySQL, database structure, Google API functions, Arduino, JQuery [20], PHP. Arduino is an open-source electronics platform based on easy-to-use hardware and software. In our system, we used Arduino Mega ADK board and Arduino Ethernet, Arduino WiFi shields and several sensors.

**Earthquake sensor.** The earthquake sensor has two different mini sensors: P wave and S wave sensors. P wave sensor is used to detect the first wave (P-waves) of an earthquake. As p-wave sensor we chose “Rebex earthquake detector DESTA-5” device.

**Fire sensor.** The fire sensor has digital and analog outputs. It is very cheap around 160 yen and suitable with Arduino’s boards. The fire sensor can be used to detect fire or other light source with wavelength of 760 nm – 1100 nm light. It is not convenient to use only this sensor due to light source that is why we use a smoke sensor to detect fire. Minimum three wires interface, but user may always use four wires and uses both digital and analog pins. The power consumption is 5 V.

**MQ 2 gas sensor.** MQ2 flammable gas and smoke sensor detects the concentrations of combustible gas in the air and outputs its reading as an analog voltage. The sensor can measure concentrations of flammable gas of 300 to 10,000 ppm. The sensor can operate at temperatures from -20 to 50°C.

**MQ 7 gas sensor.** This Carbon Monoxide (CO) gas sensor detects the concentrations of CO in the air and outputs its reading as an analog voltage. The sensor can measure concentrations of 10 to 10,000 ppm.

**The evaluation method.** We had a group of 9 students (5 Japanese and 4 international students) to evaluate and get feedbacks for our system. Firstly, we showed our experiments to the group, secondary we gave to them a questionnaire with 13 questions.

**Experiment 1.** Sending warning messages from autonomous ES/MSP to the twitter server
In Arduino’s library has some functions for the twitter’s projects and by changing also adding some functions. we could send sensor’s data and warning messages from the arduino to the twitter account (@BanujanB) (see Fig. 4). A red square shows a link to the latest hazard-map with real-time safe places. A user can easily touch it and access the map.

**Experiment 2.** Fire, earthquake and smoke detections.
The dangerous places are marked by using flame, gas, and earthquake sensors. Each event (fire, gas, and earthquake) has different color of markers and all these markers are determined on the map (see Fig. 5 and 6). For instance, fire is red, gas is blue, and earthquake is orange markers. Markers use the latest data of sensors from the database. Moreover all markers show both the exact date and time when event occurs, and event’s type (fire, gas, and earthquake) information. As we can see one safety place (red circle) was removed on the map (see Fig. 7) because that place was near dangerous places in radius 200 meters.
Experiment 3. Avoiding psychological disorders.
As we discussed before about providing real-time video (photos) with name of area it will be shown on TFT LCD (see Fig. 8). This shows how to evacuate from disasters and dangers.
Evaluation and discussion. Subjects answered a questionnaire and offered comments after the demonstration of our system.

Interview 1. “Are you satisfied with information provided by the warning system?”
All students were satisfied with system's data, see Fig. 9. 44% subjects were strongly satisfied with the information.

Interview 2. “Do you find the various sensors, such as fire, gases, and earthquake, are well integrated?”
All subjects except one international student agreed with the useful combination of an earthquake sensor and a set of other sensors (see Fig. 9 and 10). One subject that neither agreed nor disagreed with the experimental demonstration expected the demonstration in an actual training.

Fig. 9. Satisfaction of the system                                              Fig. 10. The functionality evaluation is the system.

Interview 3. Information from twitter was trusted by students. 55% subjects trusted the warning with sensor data and GPS position although the warning was based on the sensor networks (see Fig. 11). They consider that the warning was one of helpful real time data since warnings by the government were often too late to safely evacuate. The government also concealed dangerous facilities and places that were inconvenient for a person who was charged in them. However 34% subjects suspected the information in twitter. 34% was a reasonable value. Those subjects didn’t trust the robots, machines and systems since they thought human's tweet is more trusted and faster than those by the system. One Japanese subject only trusted messages from the national organization.

Interview 4. Information of dangerous place's map is easy to understand (see Fig. 12). However one subject suspected the information about dangerous place's map is not easy, because they couldn’t understand the dangerous place's markers on the map.

Fig. 11. User's trust to the sensor's information                                        Fig. 12. Understanding of the dangerous areas on the map.
6. Conclusion

In this paper we propose the emergency warning system based on cloud servers and SNS that provides useful awareness against unpredictable disasters. We have discussed functions of the system autonomy and awareness based on relative analysis as well. We built a prototype of the system. By detecting earthquake waves, flame and dangerous gases the system could autonomously distributed the warnings by twitter and the system’s web-site. As the result of evaluation we could confirm that our system might be useful for warning system in Almaty city with inexpensive facilities. We can easily introduce our system to the Government and citizens. The system can indicate levels of danger and sign of severe damages by sensor's data in the twitter and maps for some citizens who live near the dangerous area.

References

4. Miyachi T., Buribayeva G., Saiko Iga and Takashi Furuhata. “Ultrasonic beam communication for collaboration between wheelchair person, helper and assist robot,” The 1st International Conference on Transport & Health” (to be appear); 2015.