APPLICATION OF STANDALONE SMART WATCHES IN EARTHQUAKE EMERGENCY RESPONSE

M.S Hossain¹, G. C. Krishna², M. Numada³ and N. Morimura⁴

ABSTRACT

There has been a growing consensus among academics and practitioners to increase the resilience of communities by reducing the casualties and damages caused by earthquake. Developing resilience at the national level remains a considerable challenge, which needs sustainable improvement of the emergency response plan along with other critical components of disaster management cycle. Hence, the emergency response plan (ERP) is an important indicator of national resilience. Initially ERP involves two major activities, namely search operation and rescue operation after an earthquake. Successful search and rescue operation, as well as recovery strategies require accurate information, managerial skills and efficient use of resources. These activities also have political significance as they are directly associated with the survival of the entrapped victims. With the existing emergency response practices after a large earthquake in consideration, this research has developed an approach by integrating standalone smart watch and geographic information system to determine the rescue area and find the trapped victims within the shortest possible time. For real time far-off triage, threshold heart rate values have been fixed to classify the victims. Victims are classified as deceased, critical, or slightly injured based on heart rate. Finally, hypothetical real time heart rate distribution maps have been prepared for different types of first responders. As time is a crucial factor in earthquake emergency response, this proposed method will reduce response time by identifying the rescue area within the shortest possible time as well as to help grasp the overall condition of the affected area.

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With the existing emergency response practices after a large earthquake in consideration, this research has developed an approach by integrating standalone smart watch and geographic information system to determine the rescue area and find the trapped victims within the shortest possible time. For real time far-off triage, threshold heart rate values have been fixed to classify the victims. Victims are classified as deceased, critical, or slightly injured based on heart rate. Finally, hypothetical real time heart rate distribution maps have been prepared for different types of first responders. As time is a crucial factor in earthquake emergency response, this proposed method will reduce response time by identifying the rescue area within the shortest possible time as well as to help grasp the overall condition of the affected area.

Introduction

The casualties in a disaster tend to increase even though geophysical hazards remain the same over ages. There are several reasons behind the rise of casualties, including rapid and unplanned urbanization, dense settlement in seismic active zones, and poverty. UNISDR estimates that around 1.35 million people were killed by natural disasters from 1996 to 2015 while more than half of these people died due to earthquakes [1]. Furthermore, large-scale catastrophic events like earthquakes represent one of the most significant challenges to the emergency response system [2]. The most challenging part of earthquake management cycle is the emergency response as there is a definite relationship between response time and mortality rate. If we can reduce response time, it will increase the number of lives saved, which is the primary goal of earthquake emergency response. To minimize response time, we need to identify the trapped victims, rescue area, triage the trapped victims and assess the overall damage of the affected area as soon as possible after the earthquake. Earthquake emergency response (EER) initially involves two major activities, namely search operation and rescue operation after analyzing the situation of the affected area. The most common search methods are physical void search, audible call-out, use of fiber optics, search cameras, infrared/thermal imaging, electronic search and canine search, etc. [3]. Also, disaster response robots, FINDER (finding individuals for disaster and emergency response) and unmanned aerial vehicles (UAVs) are also being used on a limited scale [4, 5, 6]. In addition to these tools and techniques, successful search and rescue operations and recovery strategies require reliable information, excellent organization, and efficient use of resources. The Sendai framework also emphasised the use of real-time or near real-time data [7]. Hence, a real-time disaster triage system is essential to maximizing the efficiency of earthquake emergency response. Researchers have tried to create smart technology based triage systems such as AID-N and ITTs to minimize morbidity and mortality [8, 9], but have yet to create a real-time remote triage system to find the rescue area and assess the conditions of the affected area just after an earthquake. This study proposes a new method for improving the efficiency of the existing earthquake emergency response using real-time data from smart watches worn by victims.
Methodology

The underlying architecture of the proposed system consists of four parts, namely: transfer of data, categorization of the victims, visualization for different first responders and identification of the trapped victims and rescue area (Flow Chart -1).

<table>
<thead>
<tr>
<th>Event</th>
<th>Situation Analysis</th>
<th>Emergency Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake</td>
<td>Smart Watch (Log, Long)</td>
<td>• Grasp overall conditions</td>
</tr>
<tr>
<td></td>
<td>Server (Data Base)</td>
<td>• Real time triage of victims</td>
</tr>
<tr>
<td></td>
<td>victims are classified based on heart rate</td>
<td>• Prioritize Rescue Area</td>
</tr>
<tr>
<td></td>
<td>Rescue Area Identify</td>
<td>• Resources allocation</td>
</tr>
<tr>
<td></td>
<td>Trapped Victims Identify</td>
<td>• Additional resources need</td>
</tr>
<tr>
<td></td>
<td>Visualization (First Responders)</td>
<td>• Helpful to take crucial decision</td>
</tr>
</tbody>
</table>

Flow Chart 1: Architecture of proposed system

A smartwatch application has been developed to transfer the heart rate and location of the users from their smartwatch to the web database. The application has been developed by using android studio with a sampling period of 100,000 ms. It also allows for transferring user’s information like ID number, name, gender, age, etc. After that, the threshold values of heart rate (Table 1) are chosen to classify the victims immediately after an earthquake based on the recommendation of emergency medical experts and the scene aide memoire for major incident medical management and support [10].

Table 1: Threshold value of heart rate [11]

<table>
<thead>
<tr>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Heart Rate Threshold Value (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1 Year</td>
<td>50-80</td>
<td>3-10</td>
<td>Black: 0, Yellow: 90-180, Red: &lt;90 or &gt;180’</td>
</tr>
<tr>
<td>1 to 5 Years</td>
<td>80-100</td>
<td>11-18</td>
<td>Black: 0, Yellow: 80-160, Red: &lt;80 or &gt;160’</td>
</tr>
<tr>
<td>5 to 12 Years</td>
<td>100-140</td>
<td>19-32</td>
<td>Black: 0, Yellow: 70-140, Red: &lt;70 or &gt;140’</td>
</tr>
<tr>
<td>Adult (Over 12 Years)</td>
<td>&gt;140</td>
<td>&gt;32</td>
<td>Black: 0, Yellow: 60-120, Red: °&lt;60 or &gt;120*</td>
</tr>
</tbody>
</table>

*Child heart rate is faster than adult * Due to stress or anxiety conditions ° only for mass people not athletes

In traditional triage system, victims are classified as red (immediate, priority 1), yellow (urgent, priority 2), green (delayed, priority 3) and black (death) to allocate medical treatment with limited resources. The proposed scheme differs from the traditional triage system in that the objective of this study is to identify the trapped victims while considering the critical rescue area. The relation between earthquake injuries and heart rate threshold value is explained in Flow Chart 2. In this study, victims are classified as red, yellow, and black based on heart rate according to the suggestion of emergency medical experts, where red (heart rate <60 or >120) represents high probability in life-threatening condition and requiring immediate treatment, yellow (heart rate from 60 to 120) represents less probability of critical conditions, and black (heart rate = 0) represents death or away from watches. This is based on the assumption that a heart rate exceeding 120 bpm indicates tachycardia, early stage of hemorrhagic shock or early stage of hypoxia, while a heart rate lower than 60 bpm indicates bradycardia, later stage of hemorrhagic shock or hypoxia. These values account for the effect of stress following a major earthquake. Furthermore, it is possible to analysis heath condition of trapped victims on an individual basis by plotting heart rate versus time.
Algorithm for Identify trapped victims

Input: Set of Positions (Pos), Persons (Pr), Heart Rate (HR), Time (T). Disaster Time(dt)
Output: Trapped Victims (TV)

Begin:
Step-1: Set Pos, Pr, and HR are a one to one correspond data
Step-2: For each t from T, Where t > dt
    For each p From Pr
        If HRp > 120 and < 60 Then
            For each pos in Pos
                Check if there is any change in person positions > 30 m
                If ‘no change’ Then
                    TV ← TV U pos
                End
            End
        End
    End
End

Flow Chart 2: Relation between earthquake injuries and heart rate threshold value

Flow Chart 3: Identify rescue area

(a) Community boundary map

(b) Heart rate distribution map

(c) Trapped victims distribution map

(d) Rescue area map

Fig. 1: A thematic presentation for application of smartwatch in EER
The Shinjuku ward of the Tokyo Metropolitan area has been chosen for the visualisation of real-time heart rate distribution for different first responders, i.e. local community, fire department, emergency medical team, and local administration. The jurisdiction boundary of the fire department and the local administration is already known. Based on the location of medical centre, the Shinjuku area was divided into 13 emergency medical team zones by using ArcGIS 10.3 (Thiessen polygon method), and 36 local community zones basically based on elementary school boundaries (Fig. 1a). Fig. 1b shows the real-time heart rate distribution for the community. Finally, an algorithm was developed to identify the trapped victims from real-time heart rate distribution map. Flow Chart 3 depicts the logic for obtaining critical rescue area using trapped victims just immediately after an earthquake. Fig. 1 illustrates the thematic presentation for application of smartwatch in earthquake emergency response; note that all points have been created randomly in ArcGIS environment.

Discussions and Conclusions

The feasibility of the proposed approach has been discussed with Emergency Response Experts from the Tokyo Fire Department. According to the interview, Japan depends on 119 emergency calls to get information immediately after a large earthquake. The existing system has some constraints like line congestion, and sometimes getting more calls from a less affected area, which makes it difficult to allocate resources appropriately. To minimise these problems, emergency response technology such as helicopters, high altitude cameras, and drones are being used, but the process can be time-consuming. By integrating geographic information and smartwatch data in real-time for remote triage based on heart rate, trapped victims and critical rescue area can be easily identified, which will lead to appropriate, efficient, and timely resources allocation. This research can make a direct impact on EER by reducing response time, thereby significantly increasing the possibility of survival for trapped victims, as well as by assisting the assessment of the overall situation of an earthquake-affected area more efficiently to aid decision-making within the shortest possible time.

References