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Smart Triage System towards Crisis and Resuciation

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***Abstract*—** Disaster is a sudden accident or a catastrophic calamity that causes incredible damage or loss of life. Disaster has different types like Tornadoes, Floods, Wildfires, and Earthquakes. When a disaster occurs, many people get injured and many people die due to delay in timely treatment. But in a traditional rescue system, rescue workers are unaware of suitable and nearest health centers (hospitals) per patient condition. Rescue teams need to be updated about the capacity of the hospital and to know the shortest route to bring disaster patients to the most suitable hospital in minimum possible time. If resources are not available or occupied once they have arrived, retransfer from one hospital to another will be required which takes longer time and in severe condition, the patient could die. Smart Resource Allocation and Information System increases the chances of life in disaster by providing timely treatment. With the help of Smart Resource Allocation and Information System, the rescue teams will be aware of the shortest path, availability of specialist per patient condition and capacity of the hospital where disaster patient is to be assigned. So, the application allows timely treatment and better resuscitation services for catastrophic victims. Our designed system provides the solution for patient load balancing and patient load migration, better utilization of available resources, especially in resource constraint scenarios.

***Keywords*—** Automation, emergency rescue system, load balancing, cloud database; Information sharing; mass disaster

I. Introduction

Disaster is a sudden accident or a natural catastrophe that causes large destruction or loss of life. Disasters are of two types, natural and man-made. Natural hazards are naturally happening like earthquakes, tornadoes, landslides, wildfires, and floods. Man-made hazards are proceedings that are caused by humans like emergencies, conflicts, industrial accidents, transportation accidents, and terrorist attacks. Many countries have experienced a significant number of catastrophic disasters during the past 20 years which cause global effects on nature and societies [1] [2], as is shown in Table 1.

For reducing mortality during earthquakes well-planned disaster response is required. When a disaster occurs, some people die on spot but a large number of people die due to late treatment. Disaster patients require fast treatment that a traditional rescue system does not provide. In 2014, three hundred and twenty-four natural disasters occurred which caused the death of more than 7,823 individuals, 140.7 million people got injured, and 99.2 billion dollars' financial damages [3]. Asia has experienced the highest number of disasters (44.4%) with the highest number of victims (69.5%) [4]. The studies show that if first aid had been available immediately after disaster attack then around 25% to 50% of people who got injured could have been saved [5]. But they died slowly due to delay in timely treatment [6]. Figure I-1 shows that the chances of survival of victims decrease with time.

Table 1. Disaster Deaths

Date	Disaster Deaths	
	Location	***Deaths***
Dec 28,1974	Hunza earthquake, Pakistan	5,300
Oct 8, 2005	Muzaffarabad Earthquake, Pakistan	78,000
Aug 3, 2014	Ludian County, Yunnan Province, China	617
April 25	Nepal Earthquake	8,964

In such situations, triage is performed by the rescue team to

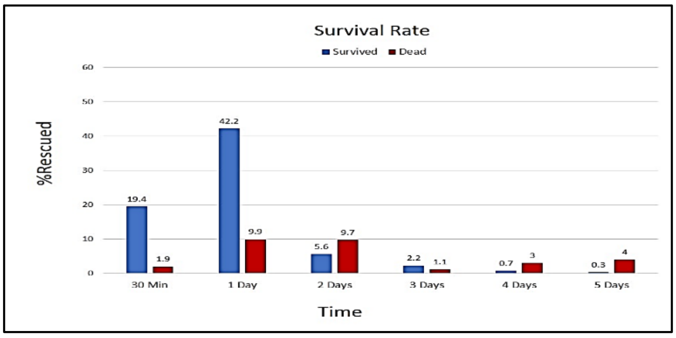

Figure 1. Survival Rate with the Passage of Time

prioritize the treatment of victims depending upon injury severity and treatment urgency. Management performance is affected by the increase in patient density [7]. Walking wounded are identified first and the remaining casualties will be divided into three categories: patient with immediate care requirement, patients whose treatment can be delayed and dead. They will be prioritized and treated further based on this triage. More lives can be saved by using limited medical resources efficiently based on this triage. The rescue teams provide help after reaching the disaster location. The basic task of rescue teams is to shift the patient to a hospital with the required resources and facilities. In this context, lack of proper infrastructure encompassing facility limits of hospitals, availability of specialists therein, hospital database as well as nearby hospitals makes it a tough target for rescue workers to help the victims in the best possible way. In emergency situations and unfamiliar environments, such information is very important. The type of injuries, the patients can have in a disaster are very similar and they need almost the same type of specialists and medicines. The scenarios during a disaster situation can be as follows:

- Numerous injuries may require highly qualified treatment (e.g. surgery) in urgent. An unsuitable circumstance which may confront restricted limits in nearby hospitals is in the form of equipment and specialists etc.
- The number of patients can significantly increase and will require additional hospital units and facilities.
- The rise of mobility problems, since many ambulances should shift the patients to more than one hospital.

So, there is a requirement of much better communication at different levels. Apart from unwavering and strong cooperation between all the acting bodies to handle the arisen situation of a catastrophic disaster, the cooperation between hospitals and other responsible organizations should be improved, hospitals also need a better organization for deployment of specialists, equipment, facilities, and medicines. The sharing of information between the hospitals and ambulances is another aspect to be improved.

The severity of the patient's condition is indicated by the assigned bands which points out whether the patient can be shifted to a different hospital or not. During a crisis workload balancing among available hospitals guarantees efficient distribution of workload. A load-balancing scheme is proposed which aims to prevent the hospitals from becoming overloaded. For bringing the hospital load in the acceptable limit a framework is outlined.

In this underlying work, a system that makes this rescue faster and efficient is proposed. It mainly focuses on the proper assignment of patients to hospitals and available facilities therein to patients, and communication between hospitals and ambulances. It provides information about patients to hospitals prior to their transportation to hospitals. It is developed to increase the chances of life in disasters by speeding up the working of rescue teams. The system allocates the resources automatically in a careful and efficient manner to escape more time so that precious lives can be saved.

This paper is organized as follows. Section II gives what has been done in the past relating to our work. Proposed scheme; Smart Resource Allocation and Information System for Victims of Catastrophic Disasters is discussed in detail in section III. Section IV presents the Implementation of our proposed scheme followed by results and conclusion in the succeeding sections.

II. RELATED WORK

For emergency services, there are different meanings of tracking a casualty. One of the concepts refers to the tracking of the physical location of the patient and others. It shows the progress in the treatment of the patient. [8] Tracking the injured patient in disasters refers to recognizing and enlisting names of the injured, recording their data and condition, organizing plans for their evacuation from scenes as per the color of bands and positioning them to hospitals.

In the Katrina disaster in the USA, tracking of victims was inefficient and later it was recognized as a weakness in planning preparedness for handling the event [9]. In the Bam earthquake, the information of patients was insufficient and due to this inefficiency difficulties had to be confronted in management and effective assessment of their condition [10]. Marres stated that there is a need for coordination of different organizations when facing catastrophic disasters but the establishment of coordination among organizations in different locations is a complex process [11]. In such a condition, one of the biggest challenges is patient tracking. Mostly, there is no information about a number of patients, their condition and their transfer [12].

In an earthquake scenario, many victims dead or injured are at the sight. Such a large number of victims are beyond the capacity of the emergency system. Information is not provided to hospitals about the number of patients that they are about to admit. Supervisors or rescue teams do not have proper information such as how many patients are transported to hospitals. They are not updated with information about the hospital whether it has the capacity to admit patients or not. The hospitals which admit the patients are overcrowded due to this lack of communication and coordination among hospitals and rescue teams [13]. The patient doesn't have time to be retransferred from one hospital to another. So, it's necessary to transfer disaster patients directly to a suitable hospital that has the required facilities and specialists for treatment. The plans for disaster response should move toward comprehensive coordination between hospitals and rescue teams that can track not only the patients but the resources as well [14].

Although, many solutions aim to position the patients and track their medical conditions, yet there is a need to address the issue of selecting a suitable hospital for patients in accordance with their injuries that have necessary resources so that retransfer is not required. Rescue teams need to choose a hospital with the capacity to admit new patients, that are not overcrowded [15].

III. SMART RESOURCE ALLOCATION AND INFORMATION SYSTEM FOR VICTOMS OF CATASTROFIC DISASTERS

The effectiveness of disaster response depends upon specific disaster plans and efficient emergency coordination between hospitals and rescue teams. Currently, communication between hospitals and rescue teams is traditional. The communication available between hospitals and ambulances is via phone calls. The patients are then sent to hospitals without informing the hospital about any detail of the patient. Without the digital map, the rescue workers are not aware of the shortest distance hospital from the disaster location and they may not know the capacity or facilities availability with hospitals. With these limitations, there are chances that the patient is transported to a hospital where the required resources are not available. The resources are calculated in terms of facilities and capacity of each hospital and type of specialist there. In such a situation, the patient should be retransferred to another hospital which is a time taking the process and this may also lead to the death of the patient.

The proposed system allocates the resources automatically in a careful and efficient manner so that precious lives can be saved. Rescue workers can select injury types of patients and find suitable hospitals with sufficient required facilities. The information of resources i.e. capacity of a hospital, available facilities, equipment and specialists that a hospital can provide will be in a database in the cloud and this information will be updated time by time. With pre-information about resources in hospitals and their limits, there is no need to retransfer the patient to another hospital. It gives more time to patients and increases the chances of their survival, especially in the resource constraint scenario.

When a disaster occurs rescue workers at the disaster location using this application can search this location and find nearby hospitals in 50 km area. This hospital list becomes the source and all the resources are searched and assigned from this list. An alert about disaster location will be sent to these hospitals for preparing resources and making them available for disaster response. The rescue workers triage the patients and assign color bands. According to the condition of injuries, the victims are classified into four groups

- RED: a patient with major injuries and need immediate medical treatment
- BLACK: a casualty is deceased
- GREEN: a patient with minor injuries
- YELLOW: a patient with significant injuries but treatment can be delayed

The patients are prioritized in accordance with the color of their bands and they are dispatched to the hospital accordingly. According to injuries or casualties like maxilla, neck, femur, spinal injuries, the application suggests hospital with required resources and sends an alert to the hospital with patient condition, attributes and facilities required for treatment as well as band assigned. The hospital will be able to prepare the equipment, facilities, and specialists for the patient before their arrival. Thus, giving treatment to casualties will be well in time. The application also shows the track from disaster location to the nearest hospital assigned to the patient. This proposed system enables us to perform the following functions: extract location of nearest hospitals within 50 km driving distance of closest hospitals, send the information to rescue teams, people with severe injuries will be shifted to hospitals with required facilities. People whose care can be delayed will be shifted to any nearest hospital. Infected people are assigned to a hospital per number of doctors available and the capacity of hospitals.

The main modules of smart resource allocation and information system for victims of catastrophic disasters are:

1. *Find nearby hospitals* – It finds hospitals in a range of 50 km around the disaster place.
2. *Check availability of suitable resources* - Resources available in hospitals and specialists are checked
3. *Assign patients to doctors with facilities* - Triage categorizes the patients with different injury types and assigns to suitable doctors.
4. *Show the shortest path towards the assigned hospital*
5. *Send alert to the related hospital about patient's condition*

IV. IMPLIMENTATION

An android-based mobile application is developed to classify casualties into four triage categories. This mobile application can transfer the patient priority data to hospital via available cellular interface such as GSM [16]. The application allows a rescue worker to input the patient's condition and assign a color band. It also sends an alert message to that hospital that was assigned.

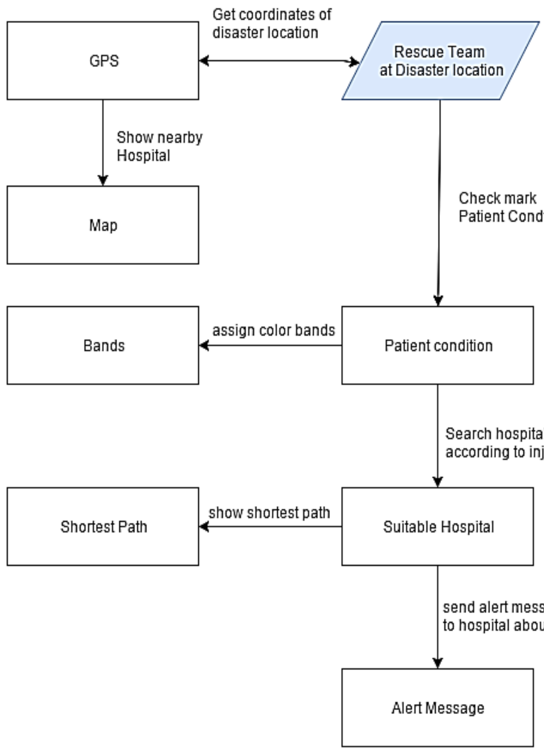

Figure 2. Work flow chart

Figure 3. Smart Resource Allocation Architecture

For positioning, the ambulance uses GPS inside a smartphone and using Google Maps API it finds current location i.e. disaster location as well as the location of hospitals in 50 km area. The application assigns a hospital with the shortest distance having treatment resources to a patient. Alert about the patient's condition is sent to the hospital so that resources are prepared pre-arrival of the patient. Figure 2 shows the flow of the rescue system and Figure 3 shows the architecture of the system. It also tracks effect time that is very important in such situations when resources are limited and need to be tracked when they will be free again. For example, a doctor checks five patients in 25 minutes, rescue workers can send five more patients after 25 minutes when the doctor is free again [17].

- ***Android Based Mobile Application***

The android-base mobile application is helpful for a rescue team in the fast selection of suitable and nearest hospitals. Figure 4 shows six application user interfaces describing the steps of finding a suitable hospital for patient treatment. The map provides the current location of rescue team by using Google Maps API and GPS services and show nearby hospital in the surrounding area on the map by using coordinates of the current location and store nearby hospital list in Cloud database. It sends an alert message about the location of disaster or damage to nearby hospitals to prepare for the response. This list searches resources from these hospitals and helps in searching and assign suitable hospitals to patients.

The application allows a user to select patient conditions from available possible injury conditions. Based on this condition application shows a list of hospitals that are suitable for this patient, have resources and are near to the location. Rescue workers can select a hospital that is more suitable and nearest to the current location. After the selection application shows the shortest path to the hospital and draws the track line which helps rescue the team in transporting the patient to the hospital. In this way, an alert about the patient's condition is sent to the hospital. This allows hospitals to prepare the required resources for the patients prior to their arrival and gives timely treatment to disaster patients. A database of hospitals that include the type of facilities available, number of medical officers, type of surgeon and capacity of hospitals is stored on the cloud. This database about the resources at the hospital is updated frequently. The updated information is helpful for rescue teams to track the resources in different hospitals.

V. Results

We assumed that an imaginary 25 storey building exists in a city. Such a building is supposed to have almost 10 apartments on each floor. Several hundred people present in the building will be affected if a disaster occurs in the form of an earthquake.

The system records the condition for all the patients. The application allocates victims to hospitals by assigning a suitable hospital to each patient. For this example, three hospitals were selected as the shortest distance hospitals within the radius of 50km of the disaster location. The main parameters of these hospitals labeled as H1, H2, and H3 for the selection of suitable hospital with appropriate resources are shown in Table 2. In Figure 5 the results of patient assignment to these three hospitals at the shortest distance are shown. For

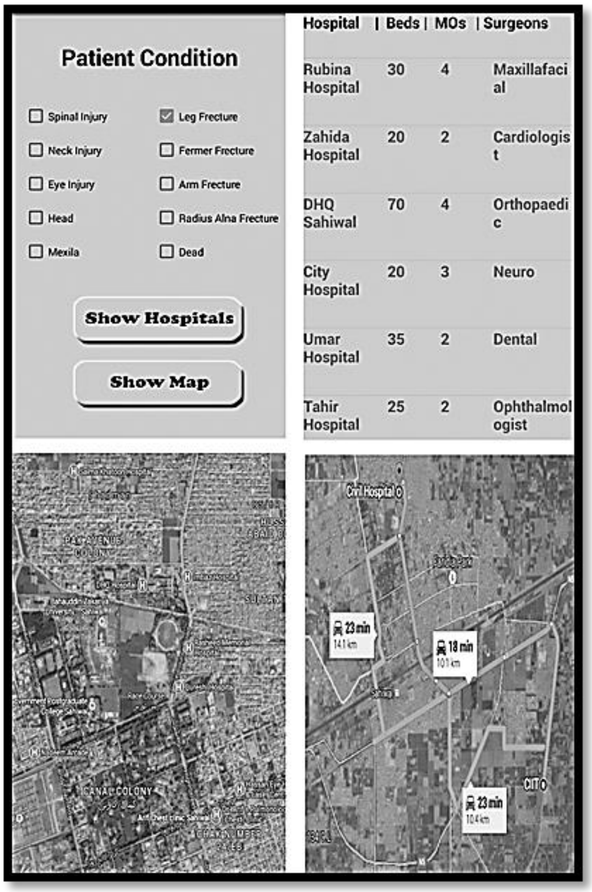

Figure 4. Smart Resource Allocation Application Screen Shots

this example, we varied the total number of patients from 300 to 500. The load did not reach the threshold value of 200 and 250 patients for all the hospitals. As the results for 200 and 250 do not cause any migrations of patients so these results are not presented. The hospitals were slightly overloaded when the number of patients reached 300. The algorithm for patient migration now executes reducing the load on these hospitals. When the number of patients increased to a total of 500, migration was required so a few patients were shifted from H1 to H2, balancing the load on hospitals. When all the hospitals are overloaded or lightly loaded, no transfer of the patient is required. No action is needed to balance the load when the hospitals are lightly loaded. However, in the case of overloading in all the hospitals, the research can be expanded and the algorithm for Extended Distance can be used to find additional hospitals in nearby areas. The results show that transfer of patients from one hospital to another hospital is not required when the traffic is balanced in all hospitals. This saves time for patient and delay in treatment is reduced.

The hospital H1 is located at 23.9 km and H3 is located at 15.2 km. If it takes 18 minutes to travel form disaster location to hospital H1 and 10 minutes to H3. In a disaster, mostly the nearest hospital is chosen by traditional systems for faster transportation and treatment but the suitability of hospital for victim per injuries is neglected. Some victims may require a treatment that is not available at the chosen hospital. These victims then require a retransfer to another hospital. Now, as H3 is at the shortest distance. In a traditional system, for a victim transferred to this hospital, the required treatment may not be available and retransfer will be required. This consumes 10 minutes for traveling to H3 and an extra 18 minutes for traveling to H1. This is a time taking process and may also lead to the death of the patient. The proposed system selects the hospital with capacity and resources. A hospital is allocated to a victim if it has the required treatment facility per patient condition. It selects H1 for the victim as required treatment is available here and the time will be reduced from 28 minutes to 18 minutes. There are more chances that treatment will save the victim's life.

The patients are transferred to hospitals via an optimized route. The route is chosen based on distance. Hospital with the shortest distance having required facilities for the patient is allocated to the victim. All the possible routes from the disaster location to the assigned hospital are searched and distance is calculated by executing the algorithm. The route which takes less time for traveling to the hospital is chosen for shifting the patient. The possible paths are shown to rescue workers who can choose a path for delivering the patient to the hospital. In severe cases like internal injuries or bleeding surgical intervention is required. If such a patient is not managed properly complications may occur. So, transportation of patients suffering from severe injuries as fast as possible becomes a priority. As some injuries can cause patients to weaken very rapidly so keeping the time between injury and treatment to a bare minimum is ideal. The survival rate for traumatic patients decreases dramatically after primary hours. The chances of survival increase if patients get treatment on time. If the shortest path is followed there is a greater possibility that a patient will get treatment in a golden hour during which it is highly possible that given medical treatment will prevent death.

Thus, the victims of disaster get timely treatment and more time is available for survival with "smart resource allocation and information system for victims of catastrophic disasters".

Table 2: Health Center Ranking

Health Centre	Distance	Treatment Rank
H1	23.9 Km	3
H2	28.3 Km	1
H3	15.2 Km	5

CONCLUSION

The main issue in a disaster situation is that rescue teams do not have updated information about nearby hospitals and resources available there. In this paper, we have developed an android application for disaster casualties. This application aims to quickly transport disaster patients to the hospitals having facilities required for disaster patients and have the shortest distance from disaster location. The application tracks the resources of the hospital in terms of capacity limit, facilities, specialists, equipment and rooms at hospitals. Information about casualty condition is relayed to the hospital prior to transportation so that the hospital can prepare resources for the coming patients. This way patients will get timely treatment and retransfer of patients from one hospital to others will not be required as the patient is transported after checking that hospital is not overcrowded and facilities and specialists

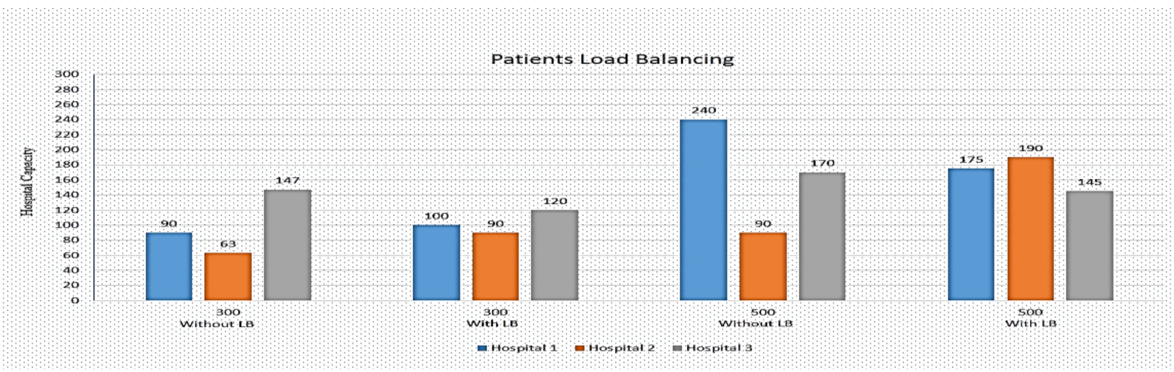

Figure 5: Patient load balancing

are available there. So, the application allows timely treatment and better resuscitation services for catastrophic victims who can't wait to be examined and provides a solution for patient load balancing and patient load migration, better utilization of available resources, especially in resource constraint scenarios. Additional hospitals can be found by an algorithm of extended distance if the number of patients in a disaster exceeds the early estimate. The patient with less critical injuries can be shifted to these additional hospitals. So, the application allows timely treatment and better resuscitation services for catastrophic victims who can't wait to be examined and provides the solution for patient load balancing and patient load migration. It allows for better utilization of available resources, especially in resource constraint scenarios.

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