Faster Evacuation after Disaster: Finding Alternative Routes using Probable Human Behavior

Anurata Prabha Hridi[1]
anurata23@gmail.com

Dipto Das[1]
dipto.cse.buet@gmail.com

Md Monowar Anjum[1]
monowaranjum@gmail.com

Tanmay Das[2]
dastanmay84@yahoo.com

[1]Department of Computer Science and Engineering, Bangladesh University of Engineering and Technology.
[2]Department of Civil Engineering, Sonargaon University, Dhaka, Bangladesh.

ABSTRACT

This poster presents an app that can help disaster affected communities find efficient and safe evacuation routes to reduce the loss of human and resources, both during and after a disaster has hit. This proposed app will navigate people seeking evacuation through suitable routes based on geographical condition, structural vulnerability, disaster severity, traffic density, human mobility, etc. The choice of most effective and safe evacuation paths primarily relies on stochastic probability of human movement and requires frequently updated data. In order to achieve this, the app uses real time GPS data by simulating the movement pattern of its users connected to network as well as their previous movement patterns when they are found offline. This simulation process will find out the less congested and safer routes for faster traversal. Users can use these path suggestions to safely drive themselves out of the disaster stricken area. In case of a user being offline, this app will use data stored on the device to suggest evacuation routes based on human mobility pattern. The implementation of this idea will help the app users evacuate safely and quickly, thus minimizing human casualty due to disaster fatality.

CCS Concepts

•Human-centered computing → Interaction techniques; Empirical studies in ubiquitous and mobile computing;

Keywords

Disaster evacuation, stochastic human behavior pattern, shortest path algorithm, disaster risk mitigation, mixed logit model.

1. INTRODUCTION

Bangladesh is affected almost every year by some form of natural disaster, be it floods, torrential rains, erosion, or cyclones. Of the 508 cyclones that have originated in the Bay of Bengal in the last 100 years, 17% have hit Bangladesh, amounting to a deadly cyclone almost once every year. Of these, nearly 53% percent does have claimed more than five thousand lives Bangladesh (2008).

For a country like Bangladesh, it is sad but true that scarcity of information and corresponding communication can be a huge obstacle towards achieving any goal specially when it comes to disaster evacuation. The first thing that shatters the community is that they are without any fruitful information regarding evacuation to safety. This causes much loss of life and resources. And this loss becomes almost an inevitable outcome whenever a disaster hits Bangladesh. This app targets to navigate app users to safety at the fastest possible time using real time data of their locations and mapping their probable behavior on the face of emergency [2]. Mobility of a panic stricken community depends mostly on their situation around and their immediate response for evacuation [1], based on simulation on data obtained. Thus this app aims to achieve maximum way outs in faster and safer way, using minimum resources available.

2. MOTIVATION

Bangladesh, being a calamity prone country, faces a disruption in communication when a disaster strikes. Therefore, a large number of lives is in constant uncertainty with a great scarcity of food, shelter, clothing, etc. due to the occurrence of each disaster. However, this situation can be improved by an effective and well managed disaster evacuation planning. Whenever, a natural calamity, i.e. flood, cyclone etc. strikes, getting real time data about people's mobility or possible way-outs becomes quite a challenge. Most of the time, data collection about the movement of people in distress during that period is hardly possible because they are scattered and since the government runs a survey as a whole, location of each individual remains out of reach. Moreover there is panic all over and probable estimation on people's response to emergency is all that can be done [3]. This app plans to maintain a central database with frequent updates and map human behavior, which represents a pure stochastic event, for further simulation to find out the most preferable route to safety.

3. OVERVIEW OF OUR STUDY

For post disaster evacuation, it is assumed that data about condition of Roads and Highways and also circumference of calamity affected area; which are updated monthly, have

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already been collected in normal mode of operation. By default, through the use of GPS (Global Positioning System) it is possible for the server to store data of an user's day-to-day movements. Against each user in a particular area, real time data of distance and direction of the user covered are being stored. In this way, a graph can be plotted for each user showing the most probable path he/she chooses to pass from his source to destination and based on daily usage, this piece of data is being updated every 24 hours. And with all these sorts of information, it can be easily summed up which roads are burdened with people seeking shelter hence, more congested and dangerous with respect to geological condition; and which ones, being under-used, are comparatively more preferable to use.

Here might arise a question of storing a plethora of data that can be generated for a single user on regular basis. A trade off is made here between resources needed and accuracy desired. In order to ensure optimum battery and space consumption, this app will preserve movement data of past seven days for each user. From user end, necessary data are collected and sent to the server. These cached data will be simulated to bring out a particular pattern for a user which might not be 100% accurate; however, this probabilistic calculation will let this app work more correctly.

For putting a hierarchy on R&H, these parameters were closely estimated:

- Quality of infrastructure
- Location of water bodies
- Position around sea shores
- Presence of large trees
- Presence of tall structures
- Human habitation
- Community movement

When a disaster strikes a region, disaster mode is turned on. While simulation is performed on data collected, this priority level was maintained:

- GPS information of an app user seeking evacuation route
- GPS location data obtained from other users' input
- Previously cached data and other relevant info stored

These data are simulated using dynamic adaptive routing technology [6]:

- Mimics the reactive route choice behavior of the evacuees.
- Dynamic route choice:
  1. Evacuees update their routes based on the prevailing traffic condition.
  2. Update their routes based on Logit splitting model applied to the k-shortest paths:

$$p_{ij}^{t} = \frac{exp[-\theta F_{ij}^{t}(l)]}{\sum_{f} exp[-\theta F_{ij}^{t}(f)]}$$

  where i is the current node, j is the destination node, θ is a model parameter, $F_{ij}^{t}(l)$ is the disutility of path l at time t.

There can be multiple random events possible which are thoroughly narrated in Figure 1. Notifications can also be sent using real time data for users online while for offline users probabilistic approach is used.

Online users Based on real time data of the users, there might be three scenarios:

- If GPS of a user represents an area away from the attacked boundary, this app considers that the user is safe and does not include his/her activity in this procedure.
- If GPS of a user is inside a disaster-stricken area but gives stagnant locations for a while and has no interaction with the server, then it is assumed that he/she has already found a safe shelter and does not desire our intervention.
- If a user is very much into the risk zone and seeks a way out, using data and modeling his stochastic event of traversal, this app produces a solution and suggests it to the user.

If from GPS observation, it is noticed that a large number of people are making a retreat, server takes it for certain that, the particular route is no longer usable. So, it crosses out that route as an option to evacuate. Thus, faster and safer evacuation takes place.

Offline users Offline users do not have any connectivity to internet i.e. GPS. They might not have any kind of mobile connectivity either, which apparently leaves them all alone in middle of a disastrous situation. Therefore it is incredibly challenging to design a methodology that can actually help users even if they are in offline state. This is where the innovative part of this methodology lies. A way to help the offline users find a safe navigation route which leads out from the disaster stricken area is being designed here. In all the previous implementations being talked about, it was always assumed that the user is connected to network, which is very much unlikely, considering severity caused by a disaster.
App version of this idea will always have the following data:

- Stored data of the previous 14 days movement pattern. To be precise, endpoints covered with respect to time.
- Stored data of the quality of the roads around that area.

Based on the stored data of the past seven days, a user's behavioral model is constructed. Using that model this app can deduct which routes are more likely to be used by the user during a catastrophic disaster. Using the predicted routes which will be found from the behavioral model and road safety data already available to the app, the app will construct a graph and assign different values to the edges maintaining the parameters defined.

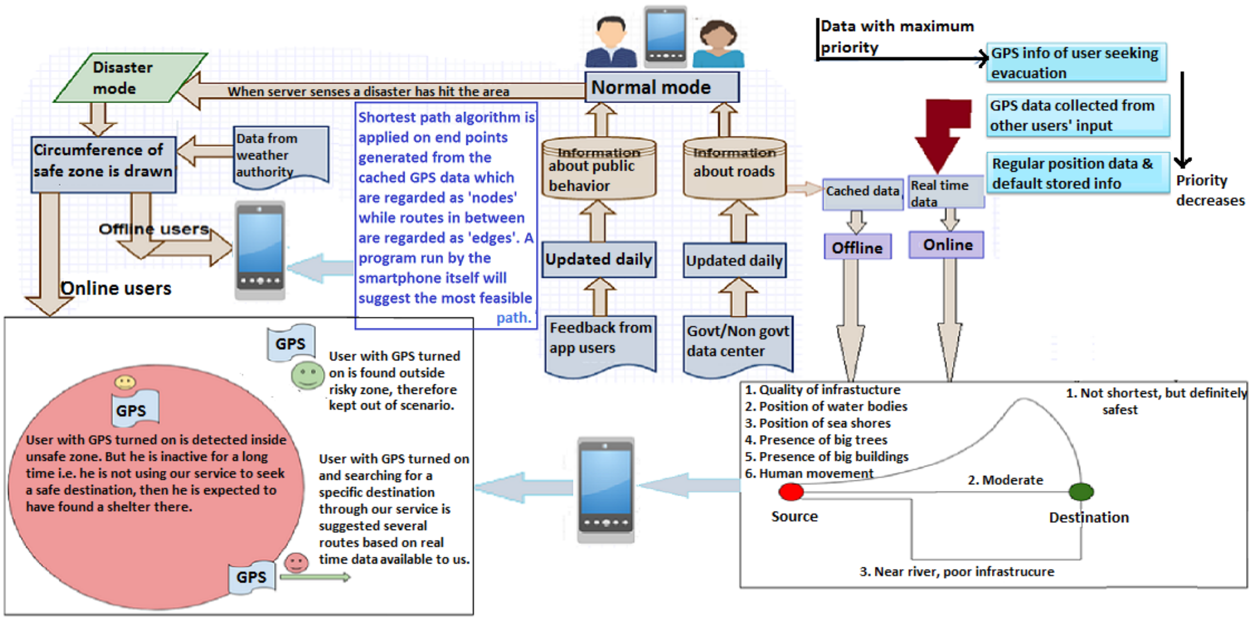

Figure 1: Flow of mechanism of proposed idea

The safest but the least known evacuation route may have least value in the graph constructed by the app. A well known route which is particularly prone to eventual damage or has more probability of being congested in a disaster scenario will be given a greater value in the constructed map. Then our app will run a shortest path algorithm on the graph multiple times and find out all the evacuation routes. The evacuation routes will be sorted according to their safety and also user's behavioral pattern, which is actually mapped by the last updated cached data.

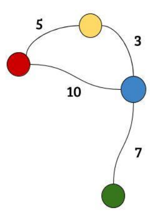

Figure 2: Applying shortest path algorithm on GPS endpoints

For example, from Figure 2 there are two possible routes for evacuation to safety. Routes have safety parameter value of 3,5,7,10 respectively. The less the value, the safer it is. There are three endpoints which gradually advance to safety. From danger zone to a lesser critical one, this algorithm would recommend route marking 5 and 3 rather than 10. Here a trade off between shortest and safest possible path is made so that the user can utilize the output of the app and choose a route to safely reach a zone which is away from the disaster affected region.

Besides, the server is also aware of the fact that a certain user is not connected to it at that moment. However, analyzing his/her movement history, server will emulate the actions of the app and make an assumption which routes are more likely to be used during disaster scenario as advised. It will then take steps to reduce congestion by suggesting the online users alternative routes which are more likely not to be used by offline users and thus empowering faster evacuation.

As this app deals with a large amount of GPS data of its users, ensuring privacy is a great concern. Therefore, for the sake of anonymity, k-anonymous locations are calculated from the GPS endpoints extracted [4] and along with road description, these are stored so that a user reaches safety without his/her privacy getting disrupted. The endpoints will be properly masked using encryption techniques which won't let any other intruder get hold of any individual data. In this way, this app can provide privacy preservation facility to its users and make them feel secured anyhow.

And it is to be mentioned that, this app can be used as a typical **Traffic Navigation App** in absence of a disaster to locate the safest and least congested roads to use on regular basis, using the user data and other resources stored.

4. FEASIBILITY AND IMPACT ANALYSIS

Feasibility analysis can be observed from Table 1 which is very much attainable by any disaster prone country. For example, as a pilot project, an overall estimation was done on Cox's bazar, a coastal area of Bangladesh and total worth of operation would be around $18000.

This app can also go a long way in addressing many vital issues at national level. Since operation of this app demands extracting a large scale of information from government, in return it will give it back a huge chunk of real time data which can be used further for later improvement in different sectors. Security personnel can be deployed correctly on those localities to ensure proper organization and manage-

Feasibility sector	Resource required	Comments
Technical	Server configuration: 16 GB RAM Working memory: 40 MB Task completion time: 5 ms Map API: Google Map	Technically speaking it is a web based and GPS dependent app with massive server side processing. All the technologies that are required to develop the system already exists. Therefore, the system is technically sound.
Financial	Number of total servers: 4+2 (backup) Per server cost: \$514 Total server cost: \$3084 Total system setup cost: \$15500 Operating and maintenace cost: \$3000 Cost for dedicated professionals: \$15000 Operating cost per year: \$18000	Disaster test case: Cox's Bazar, Chittagong, Bangladesh Population: 0.4 Million, Usage: 40% Total number of app subscribers: 0.16 Million Server processing capacity: 8000 requests/sec Total handling capacity: 40000 requests/server Delay metric: 5 seconds, approximate failure rate: 20% Probability of simultaneous disaster strike: 5 nearby districts
Socio economic	GPS service at user side is preferably activated Easy to use & needs no effort to look for escape Simple & requires least technical knowledge Complex jobs are mostly carried out by server	Most of the people in our country prefer lightweight apps for minimal usage of bandwidth and their user friendly nature. It will attract people at distress to use this app because panic stricken people will surely gain confidence after receiving a guideline from this app which makes this design socio economically stable.

Table 1: Feasibility analysis

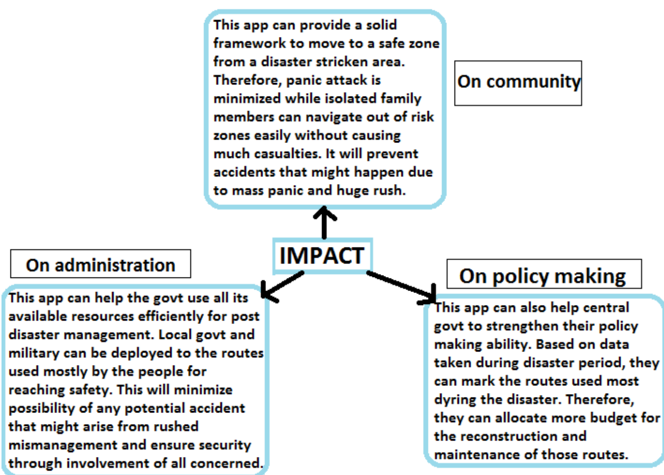

Figure 3: Impact analysis

ment without causing unnecessary life loss or panic. Budget can be allocated in a more planned way for exclusive renovation of those roads as part of post disaster management. Figure 3 makes an elaborate discussion on it, taking help from [5].

5. CONCLUSION

Natural disasters are outside the realm of control of human technology. However, disaster management is surely within. After natural calamities hit, first and foremost concern is to maximize the number of affected people evacuated into safety through optimization of resources available. By ensuring a solid framework to follow during disaster periods, this app can help minimize panic and unnecessary loss of lives and resources. Privacy is also perfectly preserved as only GPS endpoints rather the total route, are taken into account. The constraint being huge data versus inadequate space and power may hamper accuracy. However, this is a growing research field. By integrating artificial intelligence based techniques to predict human movement, big data techniques to analyze disaster period data this app can provide even more accurate route suggestions to online users and prediction about situation to offline users. We hope that we shall address these issues in the future versions of our app development phase.

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