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A FRAMEWORK FOR REAL-TIME DYNAMIC RESCUING SYSTEM FOR INDOOR ENVIRONMENT

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ABSTRACT

Most current emergency operations employ manual find-and-rescue procedures. Consequently, people trapped in a building remain helpless in an emergency, unable to call out successfully until a rescue team come along which often may be too late. The work presented in this study proposes a dynamic real time rescue system approach to an emergency such as fire outbreak in residential multilevel building or apartment. The research focuses indoor environment, even though the idea is adaptable for outdoor environment as well. The study proposes utilizing automated reporting of disaster situation to fire service in the event of a fire outbreak, automated residents' roll calls to all registered occupants in a building, automated emergency status request push notification to all residents, and dynamic rescue combined with indoor pathway safest route guidance, to guarantee safer rescuing procedures. The dynamic rescue approach employs dynamic trapped resident information mining to deploy firemen proportionately to affected areas. The accuracy of the resident information mining is approximately 97.8 % for large datasets while 90% (9/10) for small datasets. The study proposes strategies to mitigate observed challenges with most of the previous rescuing systems. It is hoped that this study may provide a new direction for emerging smart buildings and future directions for rescuing and emergency situation.

Keywords: *Dynamic Rescuing System, Indoor Safety System, Emergency Response, Indoor navigation, Indoor Dynamic Localization*

1. INTRODUCTION

Fire is considered a good servant owing to its usefulness for everyday need. However, it is also regarded as a bad master due its potentially dangerous and damaging nature. Fire is the most frequent man-triggered disaster among the rest of the disasters. Causes of fire are quite diverse and require methods and techniques that adapt to the conditions and needs of each incident. The factors include the fire type which defines the nature of materials that catch fire, meteorological conditions such as wind, presence of flammable materials, structure of the house and the effectiveness of intervention that ensure how much can be controlled.

Most common causes of fire in buildings are due to electrical malfunction such as overloading or short circuit, mismanagement in pantry area which includes gas leakage and sparks from burning items or electrical gadgets or bad smoking habit such as carelessly throwing away cigarette butts. The conditions that often aid a fire to take shape and continue burning include availability of combustible materials, specific temperature that the material could burn, availability of fuel and most importantly the presence of air or oxygen. Fire does not only cause damage to properties and loss of lives but also release dangerous gases and fumes. The smoke can cause suffocation and poison due to carbon monoxide and carbon dioxide as a result of burning items. People often panic when there is fire incidence due to the realization that fire can kill within a short period, or cause injuries and permanent disfigurement as well as inexorably destroy everything in the vicinity (Masellis, Ferrara, & Gunn, 1999). The result of panic could cause more serious damage towards the residents themselves as well as anyone else around. The panic is worsened due to their inability most times to ascertain the exact

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spot of the fire, whether it is their floor or closer or a distant area of the building.

Again, currently in a situation of fire incidence in a building, residents are always unsure of the first steps to take to reach out to firefighters. This is primarily because the first thing in their mind is to get out as soon as possible from the building into a safe assembly point. This is understandably the wisest thing to do. However, while the above is vital, timely contact to fire service is equally crucial to forestall damage to properties and loss of lives. More often, people in neighboring buildings or passersby are most likely the ones that contact or dial fire service hotlines, which more often is an afterthought. When they eventually do, they may have to search for the hotlines in a situation where they do not remember the emergency number. Again, it is often difficult to provide the correct description or address of the location of the fire incidence due to anxiety or non-familiarity with the area, in cases where the caller is a passerby.

Furthermore, when firefighters eventually arrive at the scene of the fire disaster, they spend considerable time trying to assess the situation before commencing to extinguish the fire. In a situation where the building is considerably large, the firemen and rescue teams would have to seek assistance of individuals resident in the building to provide briefing and guidance before proceeding to commence rescuing operations. This window of time lost to delay in contacting fire service, likely wrong description of the address of the location by the caller, manual navigation to the location by the fire service, as well as assessment of the fire situation upon arrival at the scene of the fire, often times lead to increase of the inferno as well as aggravating the fire disaster, hence leading to loss of more lives and greater damage to properties which might have been prevented if timely actions have been taken.

Going from the aforementioned, this study proposed a framework based on disaster reporting system that can automatically be used to immediately contact the fire service, police as well as other related officers in the event of a fire disaster. The idea proposed in this work utilizes automated alarm triggered notification to fire service, automated emergency push notification to all residents, danger areas identification using data fusion from each floor surveillance cameras, automated occupant roll calls, as well as guided dynamic rescue combined with indoor pathway safest route recommendations. It is the believe that the novel framework proposed in this study might provide the insight for emerging smart houses fire managements.

2. DISASTER REPORTING SYSTEM

This related work section provides a general view of disaster reporting systems commonly used for all forms of disasters including natural as well as fire outbreaks. This is intended to provide an understanding of the general guidance and strategies employed for disaster management and reporting. During disaster, people may be trapped inside a building and may not have sufficient time to decide what to do to ensure their safety. The problem is worsened due to the fact that the victims are often in panic hence confused on the appropriate actions to take. The following subsections examine different forms of disaster management or reporting systems.

2.1 Natural Disaster Reporting Systems

In recent years Google and Facebook released approaches that could report the status of disaster victims especially for larger scale. Google built up a team called Google Crisis Response that seeks to make critical information more accessible around natural disasters and humanitarian crises. The team responded to previous natural disasters such Haiti earthquake in 2010, Pakistani floods between 2010 to 2011, Christchurch earthquake in 2011, Tohoku earthquake and tsunami in 2011 and other related events. Five tools have been utilized by the team, namely; Google Person Finder, Google Maps, Google Earth, Google Fusion Table and Google Sites.

Google person finder was utilized to enable several victims from Tohoku earthquake and tsunami reunite with their family members. Google maps supplies critical information of the disaster. This helps the public by providing information such as the areas covered by debris from the disaster, blocked roads, resources and medical stations. By using the map, several broadcast stations are able to make real-time updates of a disaster. Google earth works in a similar fashion to Google maps but it is able to present virtual globe with extensive customization. Google earth has been used by *Doctors Without Borders* to visualize cholera case origins. Google Fusion Table gathers, visualize and share data online with response organization and constituents. This application is crucial in identifying patterns and making decisions. During riots in London in 2011, this application was used in creating maps which showed indices of deprivation and riot locations. Google sites facilitate creation and updates of a website with critical response information available from anywhere in the globe at any point of

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time. Its highlight being that it can be created or updated without the help of web developers or any knowledge of HTML programming making it easier to use.

In 2014, Facebook introduced Safety Check. In modern days, the rates of immigration and emigration are increasing due to job opportunity, better quality of life or even marriage. In time of disaster or crisis, people are concerned of the situation of the loves one such as family and friends. Sometimes, calling directly to them is not an option and we could only turn to social media to check the updates. Facebook wants to provide helpful tool that people can use when major disaster strikes. Safety Check allows a person's family and friends to know that they are safe, check on the infected areas and mark their friend as safe (Gleit, Zeng, & Cottle, 2014).

There was a real-time crisis mapping of natural disasters using social media proposed in 2014. The area affected with natural disasters were mapped and they are linked to the geo-passed real-time tweet data steams using locations from gazetteer, street map as well as volunteered geographic information (VGI). The real-time crisis map was created using statistical analysis. Not only that, benchmarking the geo-passing outcome was done against the available published work and it was assessed across multi-lingual datasets. This proposed system uses *Twitter* and its objective included refining geo-parsing accuracy of street-level tweet regarding reported incidents and also to notify the accuracy of existing social media crisis maps during natural disaster situations (Stuart, Lee & Stefano, 2014).

Dual Mitigation System is another real-time database system which combines the Indonesia Tsunami Early Warning System (INA-TEWS) and Automatic Packet Reporting System (APRS) to manage disaster mainly in the Malang Southern Coast. When an earthquake or tsunami happened, a warning system will be sent by the INA-TEWS that has microwave sensors. These sensors will greatly respond to wave that is potentially to be tsunami. Meanwhile, APRS works as a system of digital data delivery and it is a system from GPS. Locations details based on the geographical coordinate will be sent through APRS. Hence, Dual Mitigation is able to present evacuation route map, position of each team evacuation, evacuation route, number of victims based on text messages as well as evacuation post situations based on text messages. Dual Mitigation is presumed to function effectively, not just during a natural disaster happens, but also before and after the incidents (Aji et.al, 2015).

Social media such as Facebook, Twitter, Whatsapp and Instagram are very well-known and favoured in this period of time. Information shared through the use of social medias can be widely spread and go viral within a second. Many disasters had happened in the recent time and many had been on the trending topic on different social media platforms due to the users' updates or sharing. Thus, this has risen to be a developing and useful method to ameliorate the management of natural disasters or natural emergencies. This social media-based identifier for natural disaster is composed of a Secure Place Locator (SPL) which will be able to assist the activity of Disaster Management (DM) by making use of the social media. This software is then able to notify the disaster location as well as the safe point for casualties evacuation based on the Geographic Information System (GIS) in real-time (Slamet et al., 2018).

Geographical Information System (GIS)

Many of the disaster reporting systems incorporate GIS for mapping disaster location accurately. This GIS is a system whereby it is patterned to catch, keep, manipulate as well as analyze the geographic data. A case study was done following a flood risk in Vietnam and GIS was used in the mapping. Local knowledge, GIS and maps are very important and have to be integrated into the operation of disaster risk management. This is to ensure that the disaster risk identification can be done by a hazard map which plays the vital role as well as it is a successful tool in making local knowledge to be known. Not only that, to manage a disaster risk, it is crucial to have local knowledge whereas GIS is important to have conventional maps. With the GIS technology, the location of houses that are built either on raised platforms or close to ground level can be shown in the thematic map. This information will give better sign on the flooding risk inside the houses in within the different locations (Tran, Shaw, Chantry & Norton, 2008).

Infrared Camera

Infrared camera in mobile phone could be the next leap in technology as it is beneficial in situation such as disaster. Infrared Camera allows a person to view through thermal imaging and night vision. Thermal image and night vision is manipulation of wavelengths of color that can perceive. CAT Phone has released a Smartphone with built-in thermal camera. CAT Phone has built Flir's standalone thermal camera into the body of the phone (Warren, 2016). Even though the image resolution is limited to VGA (640x480) this is the first step in developing

Smartphone that have thermal imaging feature especially for emergency. If there are no built-in thermal camera in a Smartphone, user can use external thermal camera that can be mount onto a Smartphone. After the camera is mounted onto the phone, the user can use an application called Therm-App and for now it is only working for Android Smart phones. Therm-App claims it can detect a person from 500 meters away and it can do night vision as well (Allain, 2014).

Infrared thermography using drone and FLIR camera has also been used in disaster management. In searching and rescuing process are being done, long range drone can be used as to shorten the time taken because the longer the time taken, the victims will be in a more dangerous situation. A night vision technology used mainly in the desert storm war as well as for tracking namely, Forward Looking Infrared Radar (FLIR) is also used. FLIR is used together with Unmanned Aerial Vehicle so that the design is light and portable. Human heat signature can be sensed using the drone and TIR cameras during the search and rescue process (Divageer, Bhaskar, Sathish, & Ganesan, 2018).

2.2 Fire Incidents Globally

This section focuses on fire incidents globally especially to underscore the importance of this research. Data analysis is carried out using several different datasets from the CTIF World Fire Statistics Center (Brushlinsky, Ahrens, Sokolov, & Wagner, 2018). CTIF collects statistical official data from every country that supplies data for each respective year. However, when the comparison of the statistics data of each country and city is done, there is a reminder that each country has its own regulation on announcing the fires, fire deaths or injuries that might change from time to time. The report from CTIF World Fire Statistics Center includes the number as well as rates of fires, deaths or injuries due to fire. Figure 1 shows the overview of fire problem worldwide from 1993 to 2016. From the table, it can be seen that the highest number of countries reported in the fire incidents' analysis was in the year 2000 with 57 countries. The data shown from 1993 to 2007 fluctuated and it gradually declined from 2008 to 2016. Less number of countries were reporting their fire incidents in the past years. Consequently, the data provided may not give a full picture of the overall worldwide fire incidents. The number of emergency calls due to fire outbreak, the number of fire incidents, the number of civillian deaths due to fire outbreaks, civillian fire injuries based on the countries in the world are presented in the figure. Only 39 countries reported their fire incidents' data in 2016 to the fire centers or services in 2016, with overall population of around 1.2 billion, out of which there were 3.0 million fire cases, 18.0 thousand civillian fire deaths as well as 58.7 thousand civillian fire injuries. The countries with the highest reported cases were USA followed by Russia and Vietnam. Malaysia was ranked at the 10th place in the number of reported cases, showing that fire incidents have been a huge concern and requiring something urgent should be done.

The trends in fire outbreaks in the countries of the world from 2012 through 2016 shows that USA ranked first, followed by Bangladesh and Russia. The mean rate of fires per 1000 people per year in 2012 to 2016 was 2.1. The trend in civilian deaths due to fire incidents from 2012 to 2016 shows ranked India first with the highest civilian deaths of an average of 20,668 per year, followed by USA, then Bangladesh. The mean rate of fire deaths per 100, 000 persons per year from 2012 to 2016 was 1.5. Fire injuries on the other hand among the countries reported from 2012 to 2016 ranked USA highest with an average number of 15 692 per year followed by Bangladesh and Russia. Overall, the mean rate of fire injuries from 2012 to 2016 per 100,000 persons per year was 5.0. Firefighters and service men have also been reported to suffer deaths or injuries during rescue operations. From 2012 to 2016, Austria ranked first on firefighters deaths or injuries, with an average number of 3/1045 per year. Belarus ranked second while Belgium ranked third.

In Malaysia, the Fire and Rescue Department of Malaysia (FDRM) in 2013, had cases of 33,640 fire incidents all over the country with an average of 92 cases per day. Continous increase of fire outbreaks from 2007 to 2013 have been reported. In 2013, approximately 33,000 cases of fire incidents were reported with an approximately 70 deaths and 165 injuries, even though, the number of deaths in 2013 was still considered the lowest compared to the lasts seven years but recorded the highest injuries (Rahim, 2015). However, in a recent newspaper article reported, in 2018, about 36,043 calls over fire which was very alarming as compared to the 28,853 calls in 2017 was reported (Bernama, 2019).

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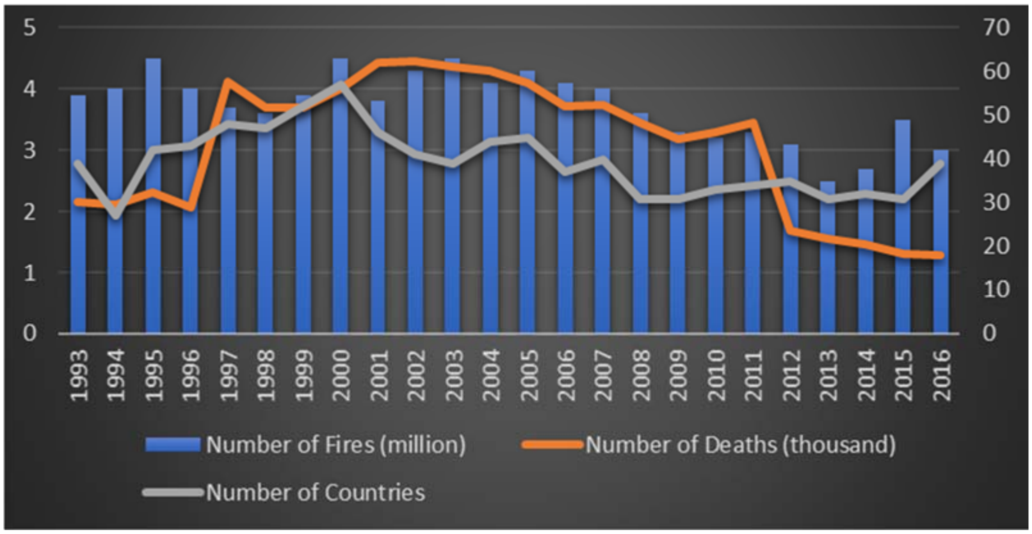

Figure 1. Statistics on fire breakouts in the world, 1993-2016

2.3 Intelligent Fire Safety System for Indoor Environment

Serious destruction or harm which includes loss of lives are caused by fire hence making fire detection a tremendous research attraction in the past recent years. Previous study by Saeed et al., (2018) proposed an IoT-based intelligent modeling of smart home environment for fire prevention and safety. Fire detection is important as an early detection of a fire event can considerably reduce the number of deaths and property damages. Early detection is also crucial as it initiates an escape from a dangerous, fiery location to a safe location. To detect fire, lodging a fire alarm system is the best way. Fire detection and sending alert to people can be done using the fire alarm system as it works through visual and audio appliances. The most widely used technology in fire alarm system is the wireless sensor network (WSN). This can be used to interconnect services and enable a wide range of numerous different applications namely target tracking, localization, healthcare, smart transpiration, environmental monitoring, and industrial automation. The function of WSN includes gathering and observing autonomously or with the help of users which can supply real-time fire detection. Moreover, Global System for Mobile Communications (GSM) is also used to alert the user at an initial stage when the sensors send a report of a fire occurring.

Another group of researchers, Dewi et al., (2018) proposed a design of web-based fire warning system using Ethernet Wiznet W5500 where they designed a system prototype using a number of integrated modules and sensors such as smoke sensors, temperature sensors as well as GPS that works as a coordinate detection. Not only that, Arduino Uno was used as a data processing element and Ethernet W5500 as the output that sent data to the server regarding information about fire location. In the study, experiments were conducted regarding the process of collection and relaying information to the server for processing. It works by sensing the smoke and temperature rise using the smoke and temperature sensors, the data collected is thereafter sent to the server which generates the location details regarding the fire incident via the browser. The location information is presented in the coordinate formats for locations based on Google Maps. It displayed the detail such as the condition of the fire and the temperature at the fire location.

2.4 Existing Related Rescue Systems

Several systems have been proposed in the past to serve the purpose of aiding firemen, rescue workers and emergency teams as well as to provide better rescue procedures and services to victims of a fire incident. In this section, a brief summary of their functionalities and weak points are discussed to identify the necessary challenges still envisaged in the rescue procedures. This is needed to provide a clear vision of what are the required improvements to advance the procedures and approaches for indoor fire rescue mission.

As can be seen in table 1, a list of the existing rescue system or app is presented. The names of the systems, their features, advantages and limitations are highlighted.

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Table 1: Existing Safety Apps Comparison

	Features	Advantages	Limitations
Facebook safety check (Mota, Sugianto & Rizal, 2014)	• Uses user's personal information and location • In case of disaster, Facebook will notify users asking if they are safe. • Whole personal network will be notified about the users' status once the questions are answered. • If the users are not in the disaster-affected area, they can notify if they are outside the area.	• Able to be accessed online using Facebook.	• No map to show the users the highly affected area or the safe exit point.
SmartRescue App (Lazreg, Radianti & Granmo, 2015)	• Upon turning on the app, it will begin to send sensor and victim's location. • Feature fire prediction and indoor localization. • Feature a node that acts as the statue of fire in a room at a previous time step. • A map of the building with a heat map which illustrates the state of the fire in each room fasten firefighter's interventions. The map is updated per second. The intensity of the fire is represented by the colour (from green to red).	• Use smartphone sensors and artificial intelligence technique to assist firefighters' process in an indoor fire. • Uses Phoenix to share sensor data between devices in the affected area. • Uses Wi-fi signal strength instead of GPS for localization.	• Some victims might not have their smartphones with them at the moment, thus it will be very difficult for them to on the app. Thus, sensors such as temperature and smoke can be incorporated on the smartphones. • No navigation system that can assist the victims to exit the building safely.
I React (I-React, 2018)	• Available for citizens and responders (firefighters) (News anchor). • Citizens can immediately take picture if they encounter any hazard and it will be geolocalized. Citizen can then select the type of hazard and add other important details regarding the hazard. The citizen's report will be mapped onto a real-time risk maps for others to view. • As for responders, they are also able to take picture of the hazard and add other details regarding the hazard as well as send the report to be generated intro real-time risk maps. The citizen's report will be able to be validated by them too. Not only that, a bespoke augmented reality glasses are used to visualize real-time maps, reports and images captured by drones. Wearables are also available which has oxygen sensor to inform them when they level is low.	• Free disaster-resilience app • Uses satellites, drones, weather forecast and historical data to gather information. • Provide wearables and bespoke augmented reality glasses for faster interventions.	Not considerably low cost

3. METHODOLOGY

This proposed real-time dynamic rescuing system consists of five main components, namely automated alarm triggered notification to fire service, automated emergency push notification to all residents, danger areas identification using data fusion from each floor surveillance cameras, automated occupant roll calls, as well as guided dynamic rescue combined with indoor pathway safest route recommendations. These components are utilized to provide appropriate notifications, safety report, navigation, and real-time situation update for the residents and other stakeholders such as apartment management in-charge persons, firefighters as well as ambulance and emergency service. The prototype is implemented in form of an app developed for smart phones.

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3.1 Automated Alarm Triggered Notification to Fire Service

The first crucial component of the proposed disaster reporting system is to gather and autonomously sends notification to the fire service department and building security guards or building management in-charge persons. Firstly, the system provides the location details alongside the fire incident notification as well as providing map information by integrating with Google maps to the firefighters. This immediately provides the firemen the location and navigation information to quickly reach the fire site.

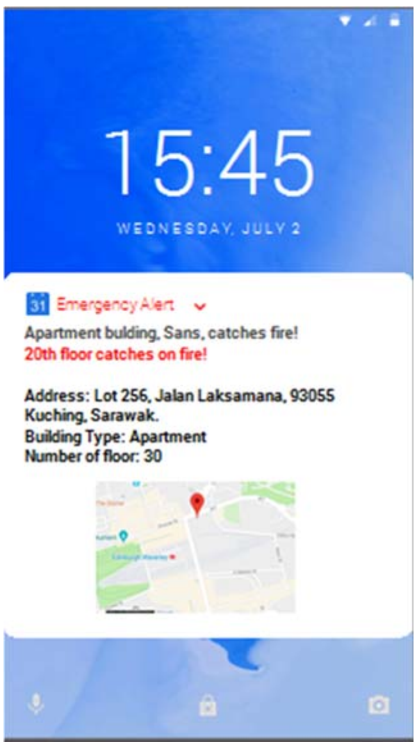

Figure 1: Emergency Alert Notification to Fire Service Department

The system also provides the house descriptions, building type, number of floors and on which particular floor was the fire started. All house descriptions are pre-inputted at the registration of the house for the apps configuration/registration except the particular floor in which the fire started which is triggered and determined by the house alarm system and/or captured by surveillance cameras. These details thereby give the firefighters first-hand information on the likely challenges ahead and thereby envisioning a tentative appropriate strategy to adopt based on their prior experiences and trainings. The system equally provides immediate connection to management in-charge persons to continue situation report before the arrival of the firemen. The prototype interface for *Alert Notification to Fire Service Department* is as seen in figure 1.

3.2 Automated Emergency Push Notification to All Residents

This component is activated concurrently with the previously mentioned module in the disaster reporting system. The system automatically sends a broadcast message to all registered residents providing them details of the fire incident. The most important set of information include the floor where the fire started and suggestions of safe exits from the building. In a smart home, the system is also designed to trigger open all exits and adjoining doors to allow faster passage of residents out of the building.

3.3 Danger areas identification using data fusion from each floor surveillance cameras.

The next critical component of the disaster reporting system is the identification of danger areas and exits for safe navigation guidance from the building. This is crucial due to the fact that safest, nearest and shortest distance exits are highly required to ensure residents are guided out of the building as fast as possible.

Figure 2: Danger Areas Identification & Notification to Firefighters & Rescue Team

This is achieved using data captured from the surveillance cameras on each of the floors combined with residents' attendance roll call, thereby the system is able to identify which floors are safe, as well as nearest exits dynamically suggested to be proportionate with the number of residents at different locations within the building.

Figure 3: Danger Areas Identification & Notification to Firefighters & Rescue Team

To achieve this, one of the main requirements of the system is the ability to read and observe every floor and pathway using the floor surveillance cameras. This makes it easy for the system to determine which floors are affected by the fire as well as the safety status of each floor and exit to be consequently relayed to the residents to aid their exits from the building.

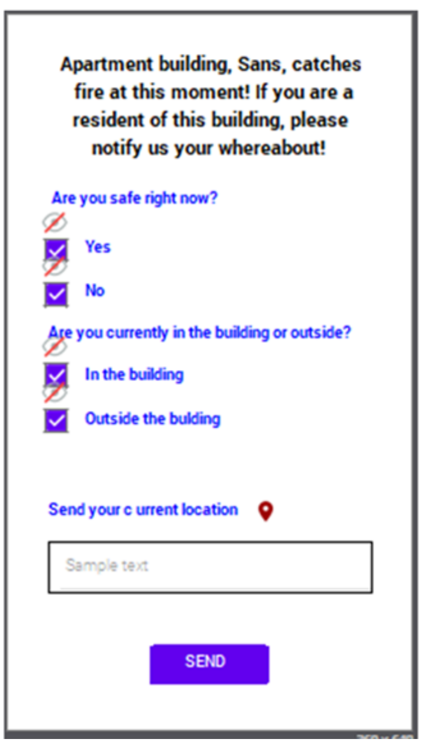

Figure 4: Occupant Roll Calls for Firefighters & Rescue Team

Figures 2 and 3 give the prototype interfaces for this module.

Often, most trapped people in fire situation are stuck due to closed doors and windows, hence, it is suggested that all doors are immediately flung opened to allow people rushed out of the building.

3.4 Automated Occupant Roll Calls

The system also sends automated head count notification to each resident to signify whether they are safe and arrived at the assembly points or any other safe zones or whether they are still within the building. The user is only required to press one of the options presented, namely, “Safe” or “Not Safe”. This should make it easy immediately for rescue team to ascertain the number of people remaining inside the building and those that are either safe or not safe. Management in-charge persons and firemen will continue to receive notification from the residents.

Figure 5: Occupant Roll Calls for Firefighters & Rescue Team

The interface allows firemen to have a quick situation summary of the residents in the building.

3.5 Guided Dynamic Rescue & Indoor Pathway Safest Route Recommendations

This component is divided into two modules. The indoor pathway safest route recommendation is sent immediately from the first notification to all residents as a guide to avoid the area(s) or the floor(s) as well as dangerous exit(s) likely affected by the fire.

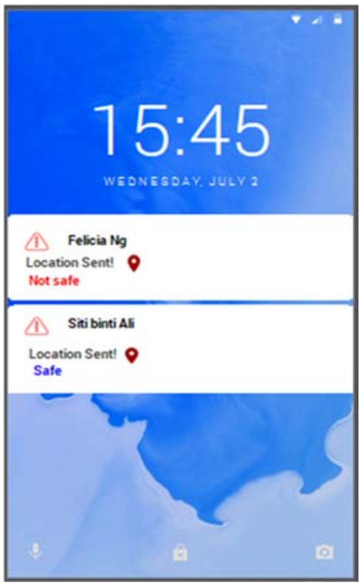

Figure 6: Safe/Trapped Notification to Firefighters & Rescue Team

This recommendation continues as the process progresses focusing on the residents that respond with "Not Safe" button on their mobile gadgets. Indoor localization via self-notification, surveillance camera or wireless localization is utilized here to determine their locations as well as to propose appropriate guidance for firefighters and rescue teams to provide assistance for the residents still inside the building.

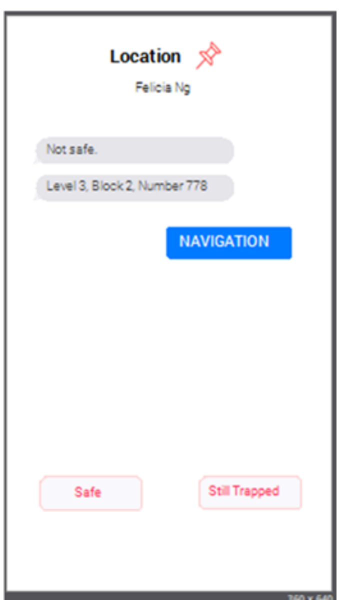

Figure 7: Trapped Guided Navigation to Firefighters & Rescue Team

The system is also designed to provide dynamic priority based guidance using residents' information mining. This module utilizes critical variables such as proximity to the source/areas already covered by the fire, age, type of disability. This is considered a requirement of the system to give preference to people with special needs as well as relative higher numbers of residents stuck in different sections of the building with a view to prioritizing rescue operations. The data of the residents with "Not Safe" statuses are automatically extracted from the system and reprocessed using dynamic mining to provide prioritized rescue operations based on nearness to danger spots as well as users' context and attributes such as disablility, blindness or visually impaired, infants, old, and available number of firefighters. This is discussed in detail in section 4 – prioritized dynamic mining section.

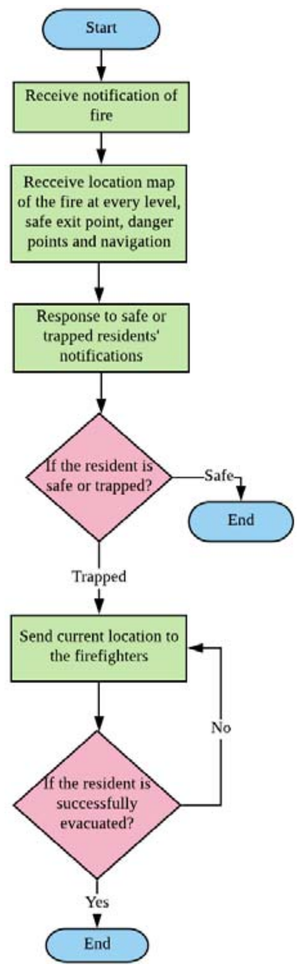

Figure 8: Flowchart for residents' system

The flow of the operation of the disaster response system from a resident's view is shown in figure 8. The available firefighters and rescue workers are

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dynamically distributed to the danger zones to help the trapped residents. This is achieved by combining manual inputs of the number of firefighters and rescue workers deployed to the scene with the extracted data from the system for dynamic mining processing.

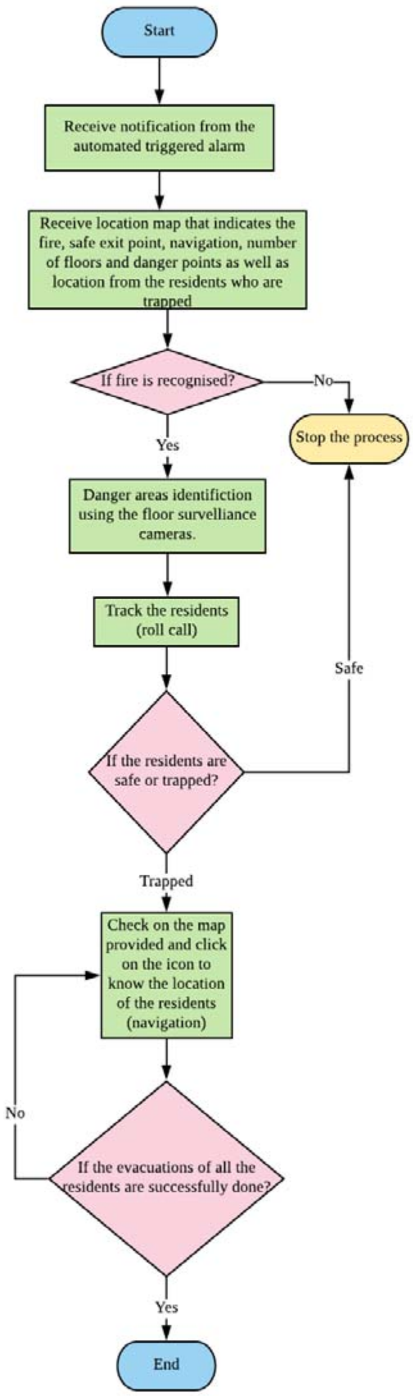

Figure 9. Flowchart for firefighters system

The firefighter flow of operation is as shown in figure 9. As can be seen from the figure, once the notification of the outbreak of fire has been received, the fire service contacts the in-charge person at the house/building to ascertain whether the fire has been extinguished in a situation where the fire incident was a trivial case, otherwise, they move rapidly to the site of the fire outbreak, following the location map provided by the system via Google map. At the site of the fire outbreak, they can examine the danger points, exits and track residents to rescue the trapped residents accordingly. The dynamic guidance provided by the system is then adopted to speedily dispatch the firefighters and rescue workers into the building using a priority-based approach.

4. PRIORITIZED DYNAMIC MINING

This section provides a description of the real-time dynamic rescuing system. To adequately formulate rules for the prioritized dynamic system, hypothetical residents' data were simulated.

```
Begin

For every resident
Input Users' Location, Age, Disability, Level
AND For every location, count #Number of
residents
While #number of residents =: 0
  If Location = NotSafeExit,
    OR Level = SameFireFloor AND Disability =
    Handicapped AND Age = Minor THEN assigned
    Priority = Highest

  Else If Level = SameFireFloor THEN assigned
     Priority = Higher
  Else If Location = SafeExit AND Level =
  AboveFireFloor AND Age = Aged OR Disability
  = Handicapped THEN assigned Priority =
  Higher

  Else If Location = SafeExit AND Level =
  AboveFireFloor THEN assigned Priority = High

  Else If Level = BelowFireFloor AND
  Disability = Handicapped OR VisuallyImpared
  THEN assigned Priority = Higher

  Else If Level = BelowFireFloor AND
  Disability = Able THEN assigned Priority =
  Low
  End If
End For
Repeat
End
```

Figure 10. Prioritised Dynamic Mining Rule Generation

The attributes considered for the residents dynamic rescue mining module, namely *Location*, *Level*, *Age*, *Disability*, *Number* and *Priority* are discussed subsequently. The purpose of the dynamic mining module is to assign and communicate priority level regarding the residents to the fire fighters as a guide for their cause of action. Table 2 shows the confusion matrix of the dynamic rescue mining based on 500 simulated residents' datasets.

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	=== Confusion Matrix === Correctly Classified Instances 489 97.8 % Incorrectly Classified Instances 11 2.2 %			
	Highest	Higher	High	Low
Highest	111	9	0	0
Higher	2	203	0	0
High	0	0	75	0
Low	0	0	0	100

Table 2. Confusion Matrix for Optimum Prioritised Dynamic Mining

Each of the attributes is discussed thus:

- ✓ *Location* – this attribute refers to where a resident is located at an instant in a multilevel building or apartment, specifically whether they are close to a safe exit or not. Two attribute values were considered in this case, namely *SafeExit* and *NotSafe*. *SafeExit* for residents close to a safe exit pinpointed by the navigation system and *NotSafe* when there is no close by exit that the resident may use to get out of the building immediately.
- ✓ *Level* – the level in the building where the resident is located at the instant, whether on the same level as the floor where the fire started, *SameFireFloor* or above, *AboveFireFloor*, or below the floor, *BelowFireFloor*. If the fire started in floor 10, residents in floor 10, should be of highest priority, followed by those above level 10, and then those below level 10.
- ✓ *Age* – this attribute refers to the age group of the resident, specifically whether they are *adults* or *minors* or *aged*. This is necessary to prioritize rescuing operations focusing on more vulnerable residents.
- ✓ *Disability* – another important criterion is ability or disability of the residents. A resident with disability should be given priority before others in a given emergency situation. The disability attribute values considered include *Blind*, Acute *Visually Impaired*, and *Handicapped*.
- ✓ *Number* – this refers to the relative number of residents in a particular spot compared to the numbers of residents in other spots. This information is computed based on localization clustering algorithm to determine how to allocate firemen. Higher number of residents should be assigned relatively higher priority. Three comparative classes were assigned, namely *High*, *Medium* and *Low*.
- ✓ *Priority* – this is the eventual priority level assigned to the resident based on the above stated attributes. Four priority levels have been considered, namely *Highest*, *Higher*, *High*, and *Low*.

Various algorithms such as decision tree, and bayesian network, were applied repeatedly with pruining to extract the optimum rule for the dynamic rescue system. The first overall optimum rules mined can be seen in figure 10. A dataset of 500 residents were simulated initially which was dynamically reduced based on the priority levels. The optimum rules gave an accuracy of 97.8% after repeated processing. Optimum rules derived from subsequent reduction in the datasets based on dynamic removal of the residents gave accuracy of 100% as can be seen in table 3.

```
Begin

For every resident
Input Users' Location, Age, Disability, Level
AND For every location count #Number of
residents
While #number of residents =: 0

  If Level = SameFireFloor THEN assigned
  Priority = Highest

  Else If Location = SafeExit AND Level =
  AboveFireFloor AND Age = Adult AND
  Disability = Handicapped OR Age = Aged THEN
  assigned Priority = Higher

  Else If Location = SafeExit AND Level =
  AboveFireFloor THEN assigned Priority = High

  Else If Level = BelowFireFloor AND
  Disability = Handicapped OR VisuallyImpared
  THEN assigned Priority = Higher

  Else If Level = BelowFireFloor AND
  Disability = Able THEN assigned Priority =
  Low
        End If
End For
Repeat
End
```

Figure 11. Prioritised Dynamic Mining Rule Generation

As can be seen from the optimum rules generated in figure 11, the highest priority is assigned to *NotSafe* locations. Those residents in such spots are attended to first while fewer firemen may be sent to the other spots with lower priorities to guide and assist them out of the building.

Other scenarios simulated included removing different clusters such as mining next higher priorities when *Highest* priority residents are removed. Thereafter, a reevaluation of the dataset was carried out, the optimum rules derived from these reduced datasets of the residents yielded a performance of 100% as seen in table 3.

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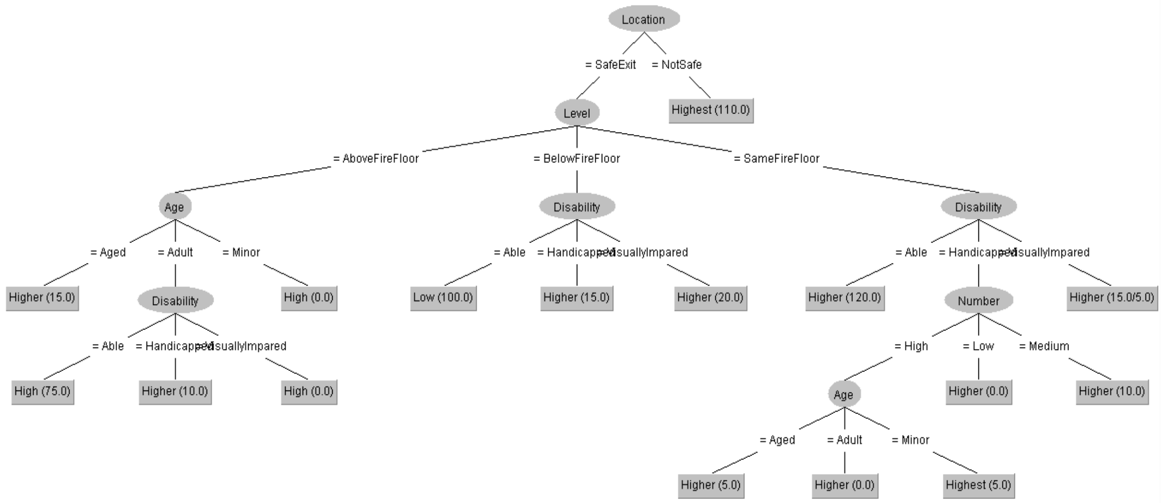

Figure 10: Dynamic Rescuing Mining Flowchart

	=== Confusion Matrix === Correctly Classified Instances 380 100 %		
	Higher	High	Low
Higher	75	0	0
High	0	205	0
Low	0	0	100

Table 3. Confusion Matrix for Reduced Dataset Prioritised Dynamic Mining

The flow of operations based on the priority levels is as seen in figure 10. The system also tested small scale scenarios such as 100, 75, 60, 50, 40, 30, 20 or 10 residents, the performance of the rules mined is presented in table 4. The datasets were selected from the original 500 datasets simulated using random sampling. Overall, the accuracy of the system is above 90% even when the datasets are considerably small.

Rule Performance for Smaller datasets				
No of Residents	Correctly Classified Instances		Incorrectly Classified Instances	
100	95	95%	5	5%
75	70	93.30%	5	6.70%
60	57	95%	3	5%
50	48	0.96	2	4%
40	39	97.5	1	2.5
30	28	93.3	2	6.70%
20	18	90%	2	10%
10	9	90%	1	10%

Table 4. Prioritised Dynamic Mining Rules' Performance for Smaller datasets

5. REAL-TIME DYNAMIC RESCUING SYSTEM

This section provides an overall description of the real-time dynamic rescuing system. Firstly, it opens with the characteristic features of the system, which was subsequently followed by the rationale for the design of the features. Lastly, critical issues and limitations from human factors perspective that may pose challenges to the system are identified.

5.1 The features of the Real-time Dynamic Rescuing System

The first fundamental feature of the system is to be able to send notifications to the building in-charge person or the admin/management as well as the fire service. The notification information to fire service should include the address of the building, the google map navigation to the site, the level in the building where the fire started and other basic information. However, for the management or in-charge person(s), the point where the fire started, and all the safe exits should be identified and immediately provided. The duty of the building management or in-charge person(s) is to confirm the severity of the fire and continue to communicate with the firemen on the status of the fire before their arrival. In a situation where the fire is trivial and has been successfully extinguished, the in-charge person(s) can update the firemen to return, since the situation has been brought under control.

The second important feature of the proposed system is the auto notification to all residents in a fire incident, informing them of the level or the spot where the fire started and offering guidance on how to get out of the building through the safe exits. It also updates them on the status of the fire or whether it has been brought under control or extinguished.

The system should provide guidance to firefighters by detecting priority and concentration of victims as well as analyzing the danger levels. The indicators or variables for the danger levels include the proximity of the victims to the fire spots, the number of people trapped in a particular location, whether the victims can move out safely on their own or trapped as well as whether the victims are normal or handicapped, blind, aged or infants.

When under the same danger level, areas with higher numbers of victims will be recognized by the system as higher priority as the firefighters can dispatch more men to them. The users are required to update attendance roll call or head count immediately after receiving emergency broadcast alerts. Users are identified by user ID, name, location, safe or able to move, trapped, or injured. All this information is provided through the resident's view of the dynamic rescue system.

While the system provides mechanisms to navigate victims out, victims can also update their situation by clicking fire spots that haven't been detected by the centralized fire alarms or sensors. Trapped victims can give extra (secondary information) via update in the system regarding any spot that caught fire but not detected by the system.

If the victims are not responding, centralized management office may try to detect their locations through GPS and ping their cells to confirm if they are able to respond to provide information regarding their states. Fire sources or spots are updated into the system dynamically through fusion of the floor cameras, while the locations of the residents may be provided by the users themselves or through the floor cameras, which is subsequently mined to prioritize rescuing process. In future work, facial recognition may be implemented to auto detect residents faces and help with identification and head count, by utilizing camera placed at each safe exits. As can be seen in the previous discussion, the purpose of the indoor navigation system is to help the residents to choose pathways that avoid the fire spots. Future work may include navigation system aided with thermal imaging or night vision and augmented reality for enhancement. Thus, augmented reality and sensors such as temperature and smoke can be incorporated on the systems which residents can access from their smart phones.

6. CONCLUSION

This section provides a conclusion of this study on the real-time dynamic rescuing system. The basic functions of the system is to provide immediate notification to fire service and other related entities such as policemen and rescue workers, hospitals and first aid teams. The fire service teams are the first to be contacted. Information of the building such as address, Google maps navigation to the location based on fastest pathways, contact to the resident in-charge persons for situation updates to aid firemen's preparedness and strategy ahead of arrival to the locations, automated roll calls of the occupants, floor information to identify danger spots as well as to provide dynamic rescue operations utilizing relative context or situation awareness of the trapped victims.

For this system to be effective however, the following limitations envisaged must be further investigated. Firstly, in a disaster situation, it may happen that a few of the victims might not be in the possession of their mobile devices at the time of the outbreak and any delay due to searching for their smart-phones may further endanger their life. In this case, this study proposes a "add a friend" module where another user may add a registered member to the safe list, hence, the system does not consider them missing. This would ensure that safe list can still be updated for those who were not able to use their immediate mobile devices themselves. Again, many users running away from danger may not remember to update themselves on the "safe list". Hence, it might be necessary to push alert notification to confirm their status. This proposed system presents a navigation system that can assist the victims to exit the building safely as well as provide dynamic guidance for firemen to aid their rescue operations.

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