Elderly care through unusual behavior detection: A disaster management approach using IoT and intelligence

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This article attempts to provide a minimal disaster management framework for the elderly who are living alone. Elderly people are generally vulnerable to hazards and emergency situations. The proposed framework aims at developing an Internet of Things (IoT)-based intelligent, protective ecosystem for elderly that calls for help in emergencies such as floods, earthquakes, home fires, volcanic eruptions, and storms. This disaster system makes use of a range of calamity sensors in conjunction with in-house activities of the elderly subject. In the case of mishappening, the disaster relief authorities, community members, and other stakeholders will be instantly informed. All these sensors are powered through an uninterrupted electricity supply system, which will continue to work even in the case of power outages. The work carried out in this article is deeply inspired by the need to have holistic platforms that ensure a low-cost, robust, and responsive disaster alert system for the elderly (DASE) in place. Our objective is to overcome many of the shortcomings in the existing systems and offer a reactive disaster recovery technique. Additionally, this article also incorporates the need to take care of numerous important factors, for instance, the elderly individual's limited physical and cognitive limitations, ergonomic requirements, spending capacity, etc.

1 Introduction and motivation

A disaster is an unexpected, shattering event that dangerously disrupts the living of a society, village, or town and causes economic, environmental, and human losses that affect the ability of the community to cope through its resources [1]. A society is formed by its people who include children, adults, and elderly. Adults are capable of taking care of themselves. Children cohabit with their parents or guardians. Elderly who are living alone are the most vulnerable ones during disastrous situations.

The population of older adults in the world is growing day by day. The number of aged people (60 years and above) globally will get doubled in 2050, from 11% or 650 million to 22%, representing 2 billion people of the total humanity [2]. Particularly in India, according to the census of 2011, around 104 million people are above 60 years of age, which comprises almost 10% of the total population. Unlike developed nations such as the U.S., Australia, and Japan, which have a state-supported mechanism for elderly care, India and other developing countries including Thailand, Srilanka, Pakistan, Bangladesh, etc., do not even have a minimal support framework for elderly care. A disaster management support system for the elderly still seems a distant possibility in such developing countries. Elderly who are living alone are at a higher risk than those who are living with their families.

The occurrence of disasters is regularly increasing. Almost daily, reports of industrial explosions, extensive power outages, wildfires, earthquakes, nuclear reactor accidents, hurricanes, tornadoes, and floods dominate the national and international news [3]. Older adults are more at risk during all phases of a disaster, from life-threatening challenges during

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the evacuation to negative psychological consequences during the recovery period. Disastrous situations, social and economic disruptions, and structural damages make life much more challenging for socially isolated elderly persons. They require prompt and appropriate care. The severity of the impact of disasters on older people depends on the specific characteristics of the elderly and their environments, the type and severity of the hazard, disaster management systems, and interactions between all of these.

To help the public become aware of an emergency situation, an array of disaster surveillance and warning systems has been extensively applied. However, existing warning systems are not capable of collaborating with household appliances or embedded controllers. To be precise, they cannot provide enough time for evacuation and attentiveness, especially for disasters such as floods, storms, and earthquakes. Besides, the existing warning and surveillance systems are not responsible for calculating the threat on an elderly lying unconscious inside a house and generating help messages on his/her behalf.

Technology can play a significant role in managing disasters—proactively and reactively. Internet of Things (IoT) and state-of-the-art artificial intelligence (AI) and machine learning tools and techniques have proved beneficial in making emergency alert systems for the elderly [4]. Thus, for managing disasters, one can also count on IoT and AI [5]. IoT is a network of interconnected devices containing software, electronics, and actuators, allowing them to interact and exchange data. Note that the data by itself is often not useful until it is transformed into the information. In this article, we propose a system for creating a disaster alert system for the elderly (DASE) based on the cloud-based intimation services and the elderly behavior analysis.

In this article, routine data of the subject are collected through three sources: refrigerator door, bathroom door, and main door. Routine analysis is performed, and a decision is taken about the well-being of the subject in case of a disaster warning. If something unusual is detected, during or after the occurrence of the disaster, alerts are sent to the disaster relief authorities and other caregivers as well. The methodology that we propose is superior to many existing ones as it offers promptness, privacy, and correctness.

Section 2 presents a detailed literature survey of the existing methodologies and systems related to old-adult care, disaster activity monitoring, and relevant IoT-based systems. Section 3 comprises the overall system and the proposed architecture. Section 4 explains the proposed methodology in detail. Section 5 is about experimental setup. Discussions and results are presented in Section 6. Section 7 describes the conclusion and scope of future work.

2 Literature survey

As per the records of the Emergency Events Database (EED), natural disasters have cost around 3 trillion dollars of financial losses, and 1.3 million life losses with more than 4.4 billion individuals injured during the last 20 years [6]. The occurrences of such catastrophic events are mostly due to natural factors or sometimes human-induced factors, which results in extensive destruction of environment and infrastructure.

A High Power Committee on Disaster Management identified 31 different types of disasters in five categories: water and climate-related disasters; related geological disasters; chemical, industrial, and nuclear-related disasters; accident-related disasters; and associated biological disasters [7]. These catastrophic situations pose a severe threat to human security and well-being. Apart from life casualties, these hazardous events spread diseases, damage the social services, displace disaster victims from their homes, and disrupt livelihoods. Elderly and disabled are the most susceptible population who suffer a lot during any natural disaster.

A considerable change has been noticed in the recent disaster-management-related research works. Now, these studies are shifted from the hazard paradigm to the vulnerability paradigm [8, 9]. The hazard paradigm covers and promotes hazard-centric disaster research, where the focus of research and analysis remains on phenomenal features of natural or human-induced hazards and the physical circumstances in which disasters occur [10]. In contrast, the vulnerability paradigm promotes societal condition research works concerning various natural disasters and hazards. The vulnerability can be defined as an outcome of societal, political, and financial pressures, which are forced on persons and, thus, hamper their ability to deal with disasters [11].

Recent disaster studies have paid attention to disability and aging [12]. Disasters result in the loss of human capital, which includes injuries and damage to body parts. For example, as a consequence of the Haiti earthquake in the year 2010, around 200,000 people suffered body impairments out of the three million people [13]. Reinhardt et al. [14] found that elderly and people with pre-existing physical or mental health disabilities are more prone to acquire impairments than individuals without disabilities in times of disaster.

Statistical data from disasters and crises in recent history point toward a higher vulnerability of elderly people; the age-specific death rate of older people is relatively more than any other age bracket. The possibility of occurrence of such disastrous events in any part of this aging world means that several elderly people will be dying out. For predicting various natural disasters/hazards and their management, researchers and practitioners have proposed and constructed a variety of disaster prediction models. Some popular models include Rapid Flood Spreading Model [15], Swift [16], Landslide Hazard Assessment for Situational Awareness model [17], Prometheus [18], KanaiTajimi [19], and Dilatancy-dilusion [20] model for earthquakes and many others.

The technology has placed its feet in all sectors, from agriculture to automotive, and from new product forecasting to mobile phone industry, to improve the efficiency of the different businesses and society at large [21–24]. Alternatively, some researchers, to make this field more efficient and convenient, have also explored the role of information and communication technology (ICT) in disaster management [25]. The use of ICT is fairly acknowledged all through four stages of a disaster, including disaster prevention, disaster preparedness, disaster response, and disaster recovery [26]. The sound technological construct of ICT allows developing early warning systems, which can assist rescue teams in saving lives. ICT can play a vital role in the collection of information from multiple sources during the incident of disasters and outline operational plans during the emergency. The use of satellite remote sensing, monitoring, and alerting tools has made natural disaster management more effective. With the advent of Geospatial technology [27], it becomes possible to monitor the natural parameters of the Earth and its environment. Geospatial science gathers, records, processes, and analyzes geographical data from divergent regions of the world.

The evolution of web-based applications and people's flair for using network-centric web apps to share important and lifesaving information encourages researchers to find solutions based on them [28–30]. The geographic information system is also being utilized widely in conjunction with other technologies, such as web, mobile, etc., to identify the potential risks and dangers of any natural disaster in a particular geographical location or any vulnerable area for effective post-disaster planning [31]. For the last two decades, natural hazards and calamities have been monitored through wireless sensor network (WSN) technology. The availability of a large number of sensors along with telecommunication systems and mobile computing offer the development of an inexpensive, quick, and flexible WSN that effectively and efficiently monitors the possibility and occurrences of natural disasters [32, 33]. A WSN-based system is used for multiple purposes, for instance, disaster prevention, post-disaster search, and rescue missions. However, the use of wireless sensors introduces some complexity and challenges of transmitting and storing extensive data in support of the search teams when required [33].

With the increasing Internet bandwidth in different areas of developing countries, the evolving technology of the IoT has become popular among researchers. The IoT-enabled disaster management system consists of devices/sensors that can send and receive real-time and live data to and from the cloud through connectivity. When the cloud gets the data, designated software processes it and subsequently decides to act, for instance, sending an emergency alert without human intervention [34]. Ujjwal et al. [35] aggregates various challenges in disaster management research trends and presented a solution in terms of a theoretical cloud-based framework for more effective disaster modeling and management.

The mobile devices and the applications that reside on them are getting so popular that the plethora of research is available on improving the app building process itself [36–44]. The role of smartphones and other supporting devices in disaster warning and management is increasing day by day. Smartphones are accompanied by an array of sensors such as global positioning system, cameras, accelerometer, etc., which can widely be utilized in conjunction with other technologies [45, 46]. Besides the effective disaster management, feature smartphones also provide easy interfaces to cope with the after-effects of disasters by engaging people in the process of disaster management [47]. The growing role of social media applications allows people to exchange information regarding the disasters and the related safety precautions.

Health wearable devices are also broadly utilized for the remote monitoring and emergency notification of elderly people [48, 49]. Wearable sensors are supposed to generate more accurate information on various health parameters of elderly such as heartbeat, blood pressure, muscle movements, and respiration. Pidd et al. [50] introduced a prototype simulator, which was capable of providing spatial decision support to emergency planners. The authors achieved it through combining the geographical information within the simulator. Keoduangsine and Goodwin [51] explored the existing flood warning systems and their challenges in the context of developing countries. The article also presented a framework called an appropriate flood warning system (AFWS), which utilized GPRS and SMS as a key technology for flood warning. One more experimental study was conducted on early warning systems for developing countries by Basha and Rus [52]. The study was focused on river flooding, challenges, and solutions.

Several pieces of research have been carried out that offer a wide range of disaster management services using different concepts, tools, and technologies. The summary of various research works carried out using these tools is presented in **Table 1**.

After reviewing the literature related to various phases of disaster management, it is apparent that regular collection of information is required while reacting to the occurrences of the disastrous event. A few researchers have addressed the facilitation of an assortment of services prior to, during, and after the occurrence of a disaster. It is also evident that elderly people are vulnerable to disasters and emergencies. Those suffering from severe medical problems such as dementia, heart disease, progressive loss of function, etc., can have difficulty acclimatizing to challenges and surviving with disruptions. A few gaps are identified, which are mentioned as follows.

Table 1 Summary of research works in the area of disaster management.

Authors (Year)	Target Area/Aspect	Key contribution	Reference
Shah et al. (2018)	Disaster warning and measuring system	An IoT based flood warning system that detects the water level and measures its rising speed. Different sensors are used to sense the water level, and alerts are sent to individual residents through SMS.	[54]
Rossi et al. (2017)	Early warning system	A service-oriented cloud-based architecture, which utilizes an Azure Blob service for storing the user data and issues early warnings to the authorities during the events of disasters. Data from various sources are collected for efficient observation.	[55]
Kurnianingsih et al. (2016)	Emergency Alert Prediction	The work investigated the performance of three supervised learning algorithms, namely k-NN, LVQ, and deep learning, to predict emergency for older adults. Deep learning found to be 99.57% accurate.	[56]
Kharde & Kumar (2015)	Tsunami Identification and Alert system	Custom-developed floating sensors and acceleration sensors are used. The seismic response is recorded and measured through an accelerometer. A low power readout ASIC circuit is used for extended battery life.	[57]
Chun-Yen Lin et al. (2014)	Disaster response System	The work describes the design and implementation of a proof of concept prototype named as active disaster response system (ADRS), which automatically performs emergency handling tasks when an earthquake happens.	[58]
Kalabokidis et al. (2013)	Early warning and effective communication	A web-based platform VirualFire issues early warnings to the general public in the event of fire hazards. It also provides coordination among fire-fighters to apply better fire fighting efforts.	[59]
Rahman et al. (2012)	Disaster warning and evacuation system	Location-based early disaster warning and evacuation system on mobile phones using OpenStreetMap.	[60]
Adam et al. (2012)	Decision support and alert generation	Authors investigated the combination of spatial computing and social media for efficient disaster management. The system provides multiple services, including data streaming, alert generation, location services, and data services.	[61]
Li et al. (2011)	Disaster communication	A cloud-based platform for effective collaboration of self-scalable and community-based cloud computing environment. In this information sharing portal, various stakeholders can contribute resources, like knowledge, data, storage, and computing platform to the cloud.	[27]
Wei Duan (2010)	Decision support and Emergency Management	Utilized GIS in conjunction with web-technology for hosting the decision support system for disaster management. The key feature is the easier user access to the system.	[32]

1) Many existing disaster management systems provide a way to alert residents of a particular area to take sufficient measures for protection. Such systems do not offer any provision for those who are living alone and unable to protect themselves such as physically disabled people, elderly, etc.
2) Most of the existing systems focus on a specific disaster event such as flood, storm, or earthquake.

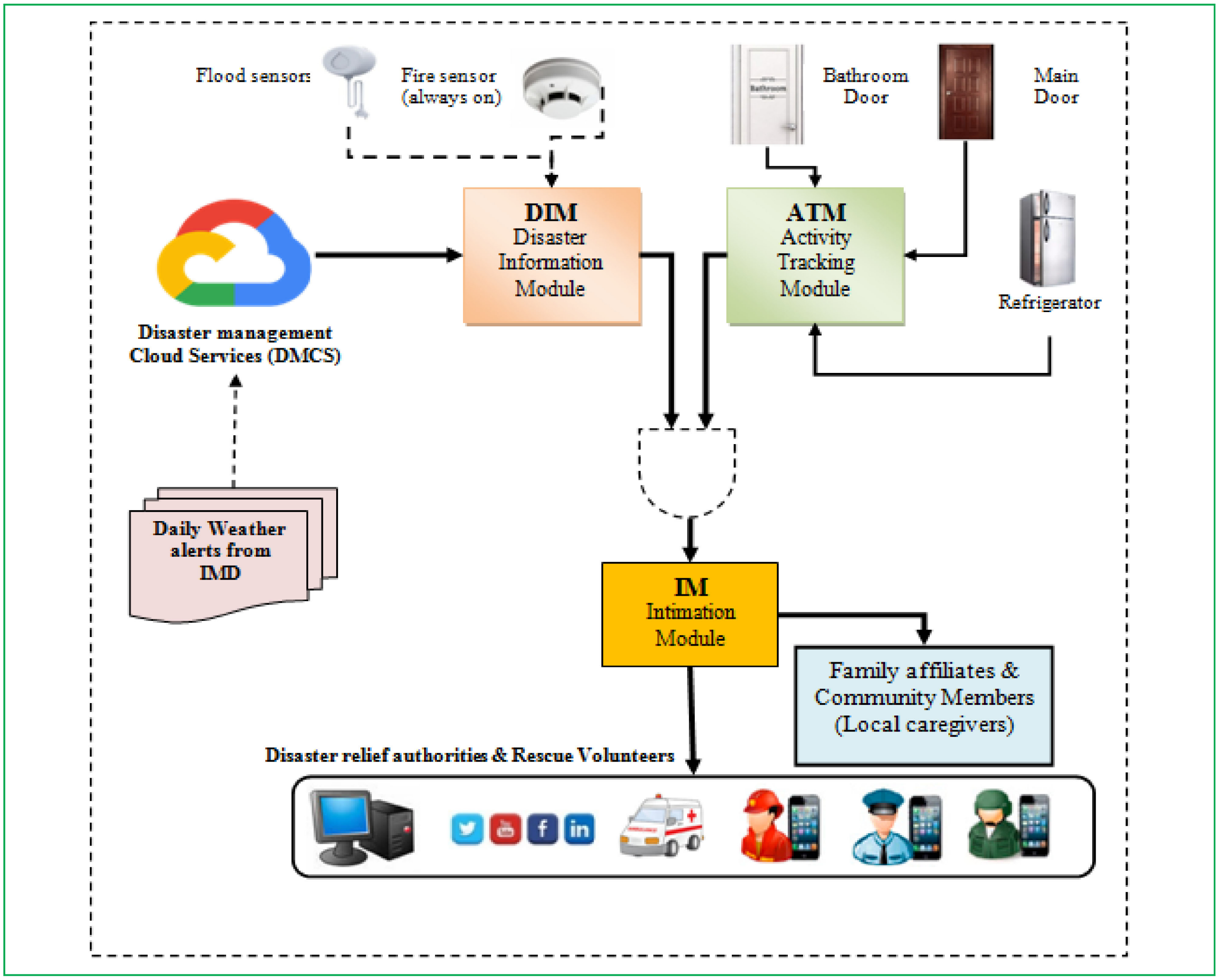

Figure 1

Overall DASE.

None of the existing systems provide a general solution to manage rescue from any kind of disaster.

3) Existing elderly care systems necessitate wearing of gadgets or sensors on the body for vigilance. Elderly often resist wearing devices, for they find it troublesome and irritating. Also, due to forgetfulness, the elderly often forget to wear such devices.

This article presents a disaster support system for the elderly who are living alone and cannot protect themselves in case of disasters. The proposed system attempts to overcome the identified issues in the existing systems and uses technology intervention to provide a correct, prompt, and privacy-preserving solution in disaster management.

3 Overall system and proposed architecture

In this section, we provide an overview of the proposed DASE (see **Figure 1**). The system makes use of an Android device, which is easily available, to receive disaster warnings from authentic disaster intimation services, for example, India Meteorological Department (IMD). Upon receiving the notification, the local ecosystem of IoT devices becomes functional, and the intimation module (IM) starts computing the risk of threat associated with an elderly living alone in his/her house. Note that mere disaster warning does not push intimation services to begin functioning. The intimation services get started only after receiving a red flag from both the disaster information module (DIM) and activity tracking module (ATM). For example, in case of flood and downpour warnings from the weather forecasting agencies, the proposed system will be

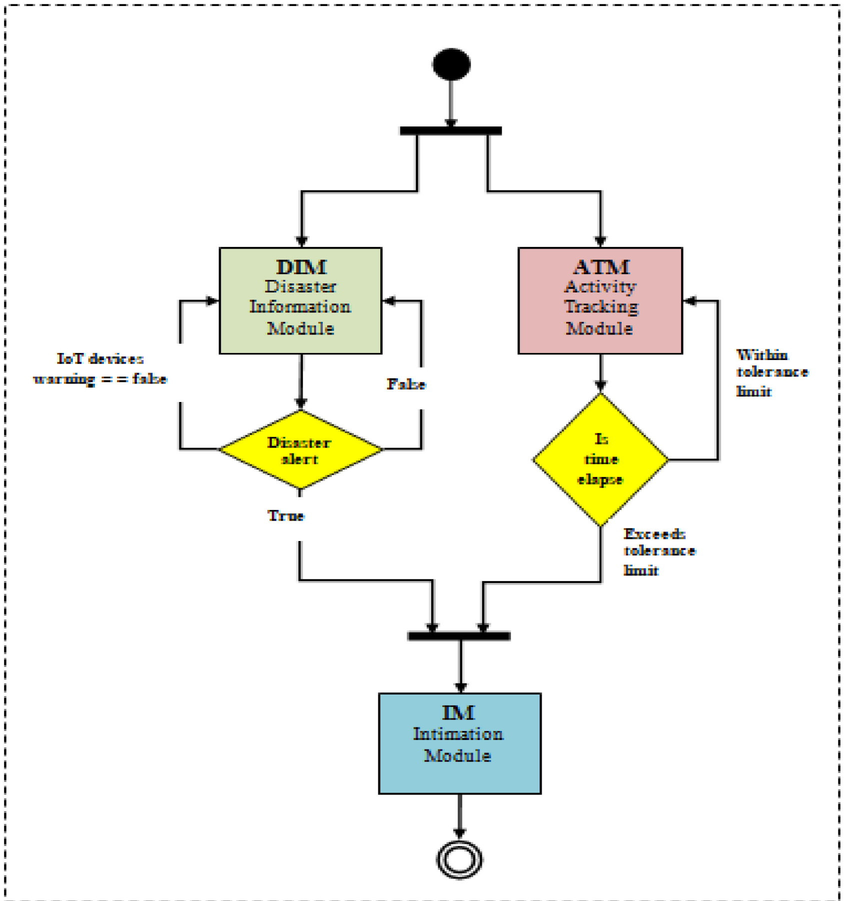

Figure 2

Activity view of the proposed system.

activated and start sensing the local conditions through flood sensors and intimate only after analyzing that the risk becomes realized.

The system requires three door sensors fixed to a bathroom door, main door, and a refrigerator door. These sensors sense the opening or closing events of the door. Door events (opening and closing) are sent to the ATM running on a local Android device in the same WiFi network with door sensors.

We realized this system by using an Arduino microcontroller chipset and ON/OFF switches. A mobile phone with Android Jelly Bean 4.3.1 is used to receive and further process the data to convert it into useful information. The same or a different Android device is also used for running the DIM. The output of the DIM and ATM goes to the IM, and intimations are sent to the local caregivers by their preferred mode. The IM is available as a service on the cloud, to which many disaster relief agencies can subscribe. In case of emergencies, all the relief forces will be informed, and they can be kept in sync during the response. The logic behind capturing door events is to make sure that the elderly are functional during or after the occurrence of a disaster. If the proposed system learns no activity, the authorities are immediately informed to send the relief.

The DIM is simple to understand. It receives disaster warnings from the services to which it is subscribed, then the DIM sends an alert signal to the appropriate local IoT devices, such as flood sensors, storm sensors, etc. Note that fire sensors are always kept in an alert mode. Once it receives emergency alerts from the local IoT devices, it informs the IM, and its responsibility is over.

The IM module assesses the current conditions; if there is a red signal from both the DIM and ATM, the IM informs the local caregivers and disaster support groups of the location and status of the elderly in need. The working mentioned above is pictorially presented through an activity diagram in **Figure 2**. The architecture of the ATM is

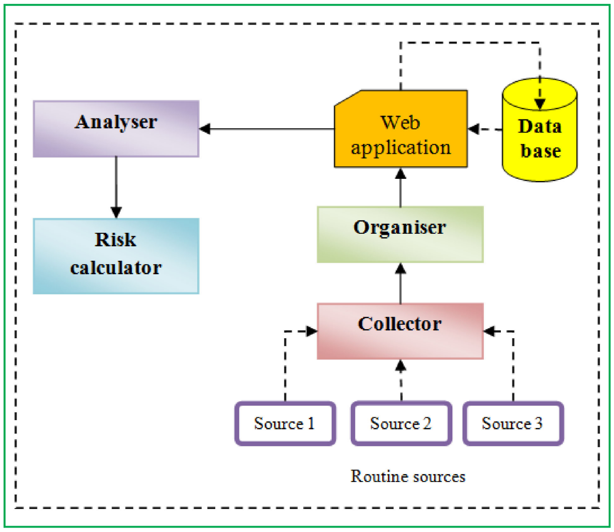

Figure 3

Working of ATM module.

Table 2 Central tendency calculation for a single day.

Duration	No. of activities	Time elapses between consecutive activities	Mean of the times elapsed between consecutive activities	Tolerance limit
12 AM – 3 AM	4	74 min - 32 min - 42 min	49 min	49 + 10 % of 49 = 54 min
3 AM – 6 AM	5	62 min- 24 min- 45 min- 20 min	38 min	38 + 10 % of 38 = 42 min
6 AM – 12 PM	26	-	24 min	24+ 10 % of 24 = 27 min
12 PM – 6 PM	21	-	27 min	27 + 10 % of 27 = 30 min
6 PM – 9 PM	18	-	36 min	36 + 10 % of 36 = 40 min
9 PM – 12 AM	7	-	41 min	41 + 10 % of 41 = 45 min

described using **Figure 3**. The ATM is made up of four subsystems: collector, organizer, analyzer, and risk calculator.

The collector collects incoming data from several sources (refrigerator, main door, and bathroom door) and stores them inside some data structure such as a list or a stack. The organizer arranges the collected data according to some criteria (more on this in Section 4) and stores it on a suitable medium (database, for example). The analyzer performs some statistical analysis on the organized data, which is further used by the risk calculator to assess the risk.

4 Methodology

The collector stores data as received from different sensors with a timestamp. The proposed system uses three door sensors, and their door open event is captured with the timestamp. For example, a typical string sent from an Arduino device attached to the bathroom door looks like: "ref_door_used->15-07-2019@10:10:10." Such data are stored in a list, which is to be used by the organizer module. The organizer iterates over the list and segregates the event and timestamp values. The organizer further stores these extracted values in a relation of the form "ATM (eventsource, date, time, time-frame)." The analyzer computes the central tendencies of the time differences between consecutive events for a given time frame. However, if "*n*" day's data are to be taken for analysis, the analyzer calculates the mean of each day's mean for a given time frame. The proposed system uses six time frames in a day. The time frames considered are 12 AM–3 AM, 3 AM–6 AM, 6 AM–12 PM, 12 PM–6 PM, 6 PM–9 PM, and 9 PM–12 AM. For simplicity, we took the arithmetic mean as a measure of central tendency. The risk calculator compares the time between the last activity (of the elderly) noticed and tolerance limit. If no activity is noticed within the tolerance limit, the risk calculator signals red. The red signal from the ATM alone is not sufficient for the IM to alert disaster relief services—it needs a red signal from the DIM too. The DIM on receiving a warning from the reliable disaster warning service commands the local IoT devices to start sensing. Once a red signal is received from the IoT devices, the DIM also signals red to the IM, and the IM intimates the disaster relief authorities. **Table 2** shows typical central tendency calculation for the time differences in consecutive events for a single day.

The tolerance limit indicates the maximum delay that can be tolerated in noticing an elderly activity after the subject last performed an activity. If, for example, during the 12 AM–3 AM time frame, the subject has not done any activity for the last 52 min, the tolerance limit is said to be crossed.

If the tolerance limit is crossed, the risk calculator of the ATM indicates red to the IM. It should be noted that the ATM does not necessarily take all stored information into analysis. It can choose the last 10 days' data, the last 100 days' data, or just the previous day's data for central tendency calculation. It is also possible that for the one time frame, the ATM takes mean as the central tendency, while for the other time frame, it assumes median.

5 Experimental setup

The proposed system was tested for around six months on an identified elderly male subject. The subject was living alone and was mostly the sole user of his refrigerator and door facilities. The only purpose of testing the system on a real

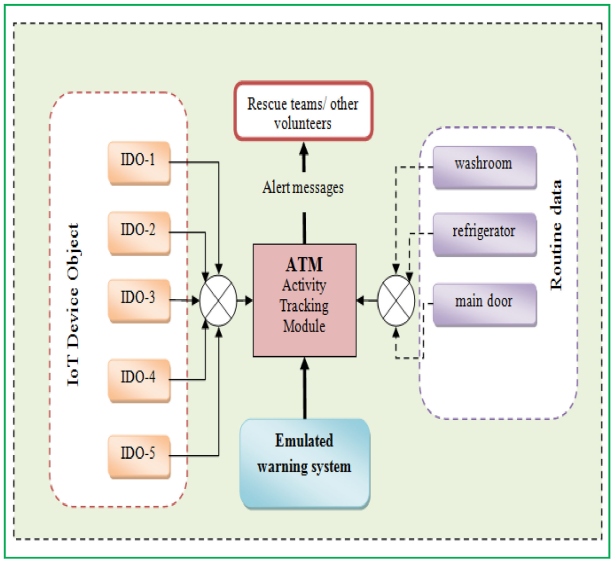

Figure 4

Experimental setup.

subject is to capture the changes in elderly routine, which depend on their health, cultural, and other external factors. Installing the response of IoT devices on corresponding triggers is emulated without requiring actual devices and sensors.

Three door sensors (ON–OFF switch along with an Arduino chip) are attached each on the main door, bathroom door, and refrigerator door. One additional CMOS laser sensor is installed just before the main door exit to ascertain whether the subject is inside or outside the house. In case the elderly subject is outside his house and some disastrous situation occurs, the emergency alerts should not be generated. The ATM, IM, and DIM, all subsystems, run on an Android device.

The organizer of the ATM populates a database table "ATM (eventsource, date, time, timeframe)" from the data collected by the collector. The web API to connect to the Oracle database server is written in Node.js and consumed into the Android app. The PL/SQL procedure to compute time frame from the time value is executed through the web API. The procedures to calculate time-framewise mean of time elapses between consecutive activities for a particular day, and the mean and standard deviation of the same for *n* days in succession are also created. The risk calculator of the ATM compares, in the present, the time elapsed after performing the last activity by the elderly subject and time tolerance limit. The risk calculator then sends the appropriate signal to the IM. The DIM gets warnings through an emulated SMS-based disaster warning system. The emulated warning system gives a random number of warning messages (warning_ON and warning_OFF) in a day

Table 3 ATM table containing initial test values.

Eventsource	Date	Time	Timeframe
bathroom	15-03-2019	00:07:33	1
refrigerator	15-03-2019	02:07:33	1
maindoor	15-03-2019	02:07:33	1
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refrigerator	15-03-2019	23:21:55	6
bathroom	15-03-2019	23:45:23	6

**sequence does not matter; any three IoT devices should signal a true-the value does not matter*

and at random time frames. Upon receiving a warning, the shared state object is set to the state "ON."

Similarly, on receiving a warning_OFF SMS, the shared object is set to "OFF." The IoT devices are also emulated using five simple Java objects each returning a random Boolean value: true or false. We used to mean as a measure of the central tendency and a margin of $2.5^{*}\sigma$, where σ is the standard deviation of the distribution of the mean of time deviations in a particular time frame for "*n*" number of days, as the tolerance limit. The experimental setup is explained pictorially using **Figure 4**. Initially, some dummy entries are made into the ATM table, as listed in **Table 3**, for testing the installation. Then, the experimental system is tested against different configurations, and the test suite is listed in **Table 4**.

6 Results and discussion

The system did pass the test suite, and it was observed that the system did not produce disaster intimation until a democratic decision by the local IoT devices was not made in favor of disaster occurrence. Merely an emergency signal by the DIM also did not ascertain a call to the disaster relief team—elapse of elderly inactivity time beyond the tolerance limit was also essential.

The proposed system was first tested in a five-day run over ten days' collected data. Note that the data collection was stopped after the first ten days to be resumed again after the testing for five days. We observed a total of 21 intimation alarms in five days. If the elderly routine analysis had been done accurately, and the routine itself had been constant, no disaster intimations by the IM unit would have been generated. We further tested the proposed system for five days over 25 days' collected data, and the observed disaster alarms fell to 16. After that, for 50, 100, 125, and 150 days, the number of false alarms was decreased to 11, 3, 3, and 4, respectively. It was noted that analysis on the past 100 days' data was a reasonable choice. By increasing the data collection days any further, no significant improvement was noticed.

The elderly subject was being asked about the reasons as and when disaster intimation was generated. We came to

Table 4 Test suite for testing experimental setup.

Test Case #	State Object	IoT Device 1	IoT Device 2	IoT Device 3	IoT Device 4	IoT Device 5	ATM	Time-Frame	Elapsed Time	Tolerance Limit	Expected	Observed
1	off	-	-	-	-	-	-	-	-	-	false	false
2	on	true*	true*	true*	-	-	true	2	100 min	>100 min	true	true
3	on	false*	false*	false*	-	-	-	-	-	-	false	false
4	on	-	-	-	-	-	false	-	-	-	false	false
5	on	true*	true*	true*	-	-	true	5	68 min	>68 min	true	true
6	on	true*	true*	true*	-	-	true	6	79 min	>79 min	true	true
7	on	true*	true*	true*	-	-	true	1	122 min	>122 min	true	true
8	on	true*	true*	true*	-	-	true	3	61 min	>61 min	true	true
9	on	true*	true*	true*	-	-	true	4	70 min	>70 min	true	true

know that during the first three days of installation, the elderly was unwell and often slept more than his usual routine, which caused intimations generated. For capturing the elderly daily routines, we used six cycles in a day, and it works well. The choice of six cycles in a day was a well-thought-out decision and coincided with the cultural and religious obligations of the subject. For a different subject in some other part of the world, eight cycles might do the work. Alternatively, the Jenks natural breaks algorithm [61] could have been used as well, which provides a more general system of breaking classes based on inherent differences in the data. We also tried the system with five cycles in a day as suggested by Jenks algorithm, but observed five disaster intimations. However, for making a generic and ready-to-use device, Jenks algorithm is the right choice. We used three sources (refrigerator, main door, and bathroom door) to capture the behavior of the subject, which depends on the frequency of their use. Different or more sources could have also been used as per the needs.

We experimented in a virtually built environment, where the actual calamity sensors were replaced by the software programs throwing disaster detection status as “true” or “false” randomly. In a real setup, not all IoT devices have to be “always ON.” Some devices that sense the situations such as fire or earthquake have to be active always, as there are still no ways to forecast an earthquake or local fire breakouts. While other devices for flood sensing, storm sensing, etc., may be activated upon getting a warning from the reliable metrological services, to save power. Electricity failure, on the other hand, is a significant problem that occurs during disastrous situations. To overcome this, all the IoT devices can be powered through a battery, which would make the system work at length even during a power cut.

An in-house routine analysis of this kind could also be used in health monitoring of the elderly living alone. If the bathroom usage is growing more than the average, then it may be an indication of prostate issues or irregular bowel movements. Similarly, if bathroom usage is declining, then possibly the subject suffers from constipation or urinary tract obstruction.

7 Conclusion and scope of future work

Even the trivial incidences of disaster are deadly for older adults living alone. This article proposed an IoT-based routine analysis system for elderly that keeps a watch on the elderly daily activities, which involve bathroom usage, refrigerator use, and main-door activities. These three sources, if not being used as per the expected pattern during high-alert times, would indicate the disaster response teams. The mean of the means of time deviations per cycle is a simple enough metric to understand, and it proved equally useful in capturing the routing behavior of an elderly subject. The proposed system was tested for five days in different intervals based on 10, 25, 50, 100, 125, and 150 days learning. We observed that the correctness of the disaster intimations increased with learning up to the 100 days mark, and later no significant improvement was achieved. A possible reason behind this may be that after around three months, the change in facility usage habits of an elderly subject occurs, which is entirely possible due to health deterioration when one attains an age of 69 years, as per Indian health standards.

Apart from the elderly vigilance during disaster times, the proposed system offers other advantages too. The system does not require an elderly to wear any device on their wrist or other body parts. Elderly usually do not like to wear anything as it irritates them, or they may also forget to wear devices. Thus, the proposed system offers 24/7 unnoticed and hassle-free vigilance of elderly living alone. The proposed system also captures the routine behavior of an elderly without compromising their privacy, as no video surveillance was used. The system promptly and correctly reports probable emergencies during disastrous situations.

Even though the system successfully avoided the wrong disaster intimation alarms, it still could not prevent all, which was mostly due to the change in the routine of the elderly subject. Thus, working on the ability to capture daily routine changes of an elderly correctly is a challenging problem to solve shortly.

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