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Article

Long Range Based IoT Search and Rescue System, a Human-Computer Interaction Preliminary Study and Implementation

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Abstract: Nowadays, IoT has been introduced in different aspects of our lives giving solutions to several problems, one of which is the Search and Rescue (SAR) operations. People that suffer from dementia or people with disease in the autism spectrum tend to elope from their caretaker's attention, a fact that can lead to serious problems. Thus, a system that takes into consideration of the multiple requirements is of paramount importance. In this paper, a LoRa based SAR system is proposed in order to help in the localization of people with high risk of going missing. In contrast to most of the related systems, in this research article a different approach has been followed. Instead of focusing on the technology, in our approach a human-centered design has been used, leveraging the knowledge of Human-Computer Interaction (HCI) domain. Thus, the technologies used, are an outcome of the initial study. Finally, the system is evaluated using heuristic evaluation and questionnaires.

***Keywords*:** IoT, LoRa, LPWAN, UX, HCI

1. Introduction

Many dementia sufferers face the danger of walking off of their supervisor's attention and getting lost. These persons might get injuries that would require special care and cause stress for both the victims and their relatives and caretakers. Thus, a Search and Rescue (SAR) system could be proved quite beneficial. Approximately 60% of dementia patients may become disoriented and go missing. Furthermore, research found that roughly half of autistic children attempted to defy parental control at least once before eventually going missing while walking and suffering similar consequences for themselves and their caretakers [1,2]. But even healthy people may get lost as well, in different scenarios. Children becoming lost in huge places, like amusement parks, where parents may find hard watching their children in the crowds, is one possible scenario. Another scenario could be the accidents that occur in mountainous sports, e.g., skiing, as the athletes can go missing usually due to an accident. All the aforementioned scenarios highlight the significance of having a system in place that can assist SAR personnel, as well as caregivers for individuals with conditions like dementia, in finding and rescuing these individuals in the event that they go missing.

In this regard, the Internet of Things (IoT) can greatly assist SAR operations. The growing usage of fitness trackers, GPS devices, smart watches, and other portable IoT devices provides up new opportunities for improving protection and care for those who are at risk of going missing. The goal, use, and technologies of these devices vary, ranging from gait and behavior analysis to evaluate physical activity, to warning systems that monitor slips and to GPS trackers that aid in the location of the missing. As a result, in order to be effective, such systems must meet certain requirements. The fundamental prerequisites are a) the communication

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technology and protocols, b) the localization accuracy, c) the energy consumption and d) Human-Computer Interaction (HCI).

As far as the communication technologies are concerned, different wireless technologies can facilitate such systems. Each wireless technology posing different advantages and disadvantages. For outdoor monitoring systems, a new class of wireless technologies known as Low Power Wide Area Networks (LPWAN) has been developed, with the major characteristics of low energy consumption, long-range communication, and low cost. One of the most important technologies is the Long Range (LoRa) technology. When it comes to the localization process, GPS technology is commonly employed since it delivers great localization accuracy, but this accuracy comes at a cost in terms of energy consumption. Thus, using LoRa with a LoRa-based localization process rather than GPS may open up new possibilities for SAR systems.

Given that there are numerous stakeholders, such systems contain a lot of characteristics that impact the user experience from an HCI standpoint, such as the person who wears the portable device and, the supervisor who uses the interactive interface through which the location is monitored. HCI is an interdisciplinary field of study that focuses on computer technology architecture, especially the interface between humans (users) and computers. HCI, which began with computers, has now expanded to embrace practically all areas of information technology architecture, including, in our case, IoT systems.

Many systems have been proposed for SAR operations. support in paper [3] the authors studied a LoRa based system focusing on localization algorithms using LoRa. In contrast to the above works, in this paper, we focus on the HCI aspects of such a system. Paper [4] describes two Received Signal Strength Indication (RSSI)-based localization algorithms that deal with noisy outdoor environments, using LoRa devices. Paper [5] study the localization using LoRa but in contrast to [4] use Time Difference of Arrival (TDoA) based algorithms noting that grouping of the received LoRa packets can deal with noisy environments. The authors of the article [6] employ IoT in conjunction with an Unmanned Aerial Vehicle (UAV) for SAR missions. Specifically, the usage of UAVs provides supporting information to rescuers. In this paper, the focus is given on wearable device-based localization monitoring, without the costly UAV technology employed. The authors in [7] provide a study on the feasibility of machine learning algorithms used to GPS data to anticipate the potential paths of dementia patients. The authors propose that prediction models for each individual may be generated based on the frequency with which the user wears the wearable device, and therefore GPS data is gathered. In addition, in the article [8], the authors built a GPS-based fall detection system in order to broadcast the position where the individual fell. The primary drawback of the works [7,8] is that, in contrast to LoRa, GPS quickly consumes the battery of the IoT device.

The goal of this project is to create a SAR system based on LoRa using wearable devices. In contrast to other similar systems [9], in this paper, a human-centered approach has been followed in order to understand the stakeholder's requirements and needs, following the Norman Interaction Model and Design Thinking frameworks. Moreover, heuristic evaluation and a small-scale experiment was conducted with the number of participants that helped us to improve the system and to detect usability problems. Also, some algorithms of energy consumption were integrated from our previous works such as paper [9,10,11,12].

The structure of the paper is the following: Next section explains the motivation of the work, Section 3 gives an overview of the IoT concepts and explains the wireless technology that is used. Section 4 gives an overview of the SAR domain, for a better understanding of the reader about the scenario used. Section 5 provides information about the HCI based procedure of the implementation. In section 6, we presented energy consumption issues related with the proposed system. In section 7 the system parts and architecture are presented together with the evaluation process of the interface. Lastly, in section8, the conclusion and the future work are presented.

2. Motivation

Alzheimer's disease (AD) and other causes of dementia are major public health concerns. There are reportedly about 5.4 million people in the United States who have dementia, with 70-80% of all people with dementia in the United States being cared for at home by a family member [13] with 15 million nurses providing an estimated 18.2 billion hours of treatment annually. It is projected that 60% of dementia patients will wander [13]. Wandering is a general concept that can be described as "a syndrome of dementia-related locomotion activity expressed in lapping, random, and/or pacing habits, some of which are synonymous with eloping, eloping attempts, or getting lost unless accompanied" [1]. Wandering can occur as a result of a person with dementia, such as Alzheimer's, being unable to recall his or her name or address and becoming disoriented even in familiar surroundings. Wandering and getting lost can happen during the mild, moderate, or serious stages of

AD and can be risky (leading to falls and injuries, institutionalization, and death) as well as stressful for families and caregivers [13,14]. Having dementia over a longer period of time, the severity of dementia (though wandering can occur at any stage), the prevalence of a sleep disorder, deterioration in day-to-day functioning, and behavioral disturbances such as anxiety and depression are all associated with wandering [2]. Having this said, we can conclude that is of paramount importance to monitor the people suffering from such diseases, in order to find them when they get lost, as it can be dangerous for them and very stressful for their caretakers.

Furthermore, one out of every 59 children in the United States have Autism Spectrum Disorder (ASD), a neurodevelopmental illness characterized by chronic impairments in social cognition and social contact, as well as restricted and repetitive patterns of conduct. Some persons with ASD engage in maladaptive behaviors, such as wandering/elopement, which is defined as leaving a safe, controlled setting without the approval or authorization of a caregiver. It is estimated that over half of children with ASD aged 4 years and older have eloped at least once, and of those who have eloped, around one-quarter went away for an extended amount of time, which disturbed caretakers. As a result of this activity, children with ASD are at a higher risk of catastrophic injury or death. Drowning was shown to be one of the major causes of death among people with ASD, with roaming being the most common behavior that led in drowning deaths. A convenience study of 1218 children with ASD aged 4 to 17 years revealed that 24% had a history of elopement and were at risk of drowning [2].

According to the 2011 Pathways study survey [15,16], more than 25% of parents of children with ASD employed fences, gates, locks, alarms, or other barriers to prevent elopement in the preceding year, and 3.5 percent of parents used an electronic tracking device for their newborn. Tracking systems are portable devices that employ technologies such as GPS, wireless networks, Bluetooth, or radiofrequency communications to pinpoint a child's whereabouts in real time. Any monitoring system may be customized to designate safe zones, allowing parents to be notified if their child enters a potentially unsafe location, such as a swimming pool. Although these technologies cannot physically prevent elopement, they are likely to improve parents' quality of life by providing them with peace of mind in knowing that they may be able to respond to elopement episodes more readily and find their children. In a 2019 article [13] assessed the effectiveness, burden, and cost of different elopement prevention interventions in a group of children with ASD. They revealed that just 6% of homes had ever used GPS trackers, and they confirmed that GPS trackers were viewed as less dependable, more difficult to implement, and more expensive by parents than some physical measures. They did, however, just look at GPS trackers, while this type of device might employ a variety of technologies. Furthermore, their sample of GPS-enabled users was small (n=534), limiting the accuracy (and probably generalizability) of their findings. In paper [2] investigated a large countrywide group of children with ASD and a history of elopement. The researchers observed that employing an electronic tracking system was associated with lower elopement incidence and duration, a lower risk of serious injury as a result of elopement and an increase in household quality of life indices. Many impediments to such systems have been identified, such as poor fit or child discomfort, as well as the weight of usage.

Furthermore, in terms of sporting activities, one example of a sports category is winter mountain sports, which are quite widespread across the world. Rapid localization of the person(s) involved in the accident is required for a successful SAR operation in the case of an accident. Unfortunately, mountain-based SAR missions are widespread. For example, in 2012, the French National Mountain Safety Observation System recorded 5389 operations [3]. Two frequent situations account for 62 percent of mountain SAR operations: 1) the missing hiker and 2) the avalanche. Hikers are responsible for 59.41 percent of mountain SAR operations, with 37 percent of these operations focused on locating missing people. When it comes to winter sports (such as skiing and snowboarding), the majority of deaths are caused by human-caused avalanches, with over 150 people dying each year in North America and Europe alone [17,18]. The rapid localization of people buried under snow is critical in these situations, as 60% of them die within the first 30 minutes [19,20].

3. Internet of Things

There is a lot of talk these days about numerous developments in the realm of computer engineering and informatics, one of which is the Internet of Things (IoT). The purpose of IoT is to make the world smarter and make life easier by conserving time, energy, and money. Using this technique, expenses in a variety of sectors may be reduced. As a consequence of large expenditures and various studies, IoT has become a growing trend in recent years. We may describe IoT as the communication network of a collection of gadgets, household appliances, automobiles, and other objects that have electronic means, software, sensors, and network connections to allow data connection and exchange. Otherwise, we might argue that the fundamental goal of the

Internet of Things is to link all electronic devices to one another via a local network or to equip electronic gadgets with the potential to connect to the Internet.

Because IoT is primarily multi-parametric, a variety of technologies, protocols, and prototypes are utilized to support the concept of IoT. The communication range, energy consumption, and other characteristics may be used to categorize wireless technology. Thus, wireless technologies may be divided into four types: short-range communication technologies, cellular technologies, long-range technologies such as Low Power Wide Area Networks (LPWAN) and satellite communications.

LPWAN solutions bridge the gap between short-range communication technologies and cellular technologies by focusing on energy efficiency, long-distance communication, and cheap cost while sacrificing latency and throughput. LPWANs are designed to interact with current short-range radio and cellular IoT networks; however, the user or application must choose which network(s) to utilize based on the needs and requirements of the application.

To begin, it is vital to research the application requirements. In many applications, such as agriculture, IoT devices must be put in rural or suburban locations. As a result, most microcomputers are powered by batteries and do not have access to a regular power supply. Battery replacement takes time and energy, and when applied to big networks, the expense becomes exorbitant. Paper [9] estimated a node's battery life in decades, whereas [17] calculated it to be "10 years or more." The goal battery life for End Devices (EDs) is established at ten years based on these claims. Because LPWANs are wide-area networks, they must communicate across vast distances. In Line of Sight (LoS) circumstances, LPWANs are often acknowledged to have a target range of a few kilometers in urban areas and tens of kilometers in rural regions. Path loss, shadowing, multipath fading, and other kinds of signal deterioration are caused by obstacles, infrastructure, moving objects, and other types of signal deterioration. LoRa is an essential LPWAN technology.

LoRa technology is a wide term that encompasses two major components. The first is LoRa, which specifies the physical layer of the technology as well as the modulation technique. The other component, known as Long Range Wide Area Network (LoRaWAN), refers to the open specification protocol established by the LoRa Alliance, an inclusive community in which any individual or organization is invited to join. In contrast to Sigfox, which has a subscriber business model, and NB-IoT, which runs in licensed spectrum, LoRa is primarily a manufacturing-driven business strategy, with Semtech transceivers being the only ones accessible [21]. While only Semtech may produce real transceivers, any hardware manufacturer can include them in their products as long as the LoRa standards are met [21].

4. Search and Rescue

The needs for hardware and other requirements are explained in this section. First and foremost, the wearable end user device must be worn by the individual. This device should support a technology that allows it to connect to the internet, and in many circumstances, such as in suburban areas where broadband or cellular wireless technologies are unavailable, other and new technologies should be employed. Furthermore, this device should support all relevant sensors that aid in the determination of an emergency situation, such as heart rate sensors, etc. Furthermore, all networking components and technologies like as cellular towers, femtocells, and LoRa Gateway (GW) should be present, or the operator of such a SAR system should take particular precautions so that the wearable device can have supplemental modules that support multiple technologies.

Another critical component in such systems is the accuracy of localization. A difference in localization, especially in the outdoors and in hilly areas, might be expensive to SAR efforts. This can happen because a 500m miscalculation might cause rescuers to climb a hill or descend a canyon, squandering both expensive resources and, more crucially, vital time since the person who has gone missing may be in danger. The data rate is also significant. In instances when the missing person, for example, has ASD, the individual can travel freely, which creates a new problem: the necessity for near-real-time surveillance. The well-known and frequently used GPS technology is one that can deliver real-time localization with great precision. The GPS, originally known as Navstar GPS, is a satellite-based radio navigation system owned by the United States government and operated by the United States Space Force. It is one of the Global Navigation Satellite Systems (GNSS) that provides geolocation and time information to a GPS receiver anywhere on or near the Earth when four or more GPS satellites give an unobstructed line of sight. Obstacles such as mountains and buildings hinder the GPS signals.

One disadvantage of using GPS for SAR scenarios is that it consumes a lot of energy. Despite its great accuracy, the GPS module significantly reduces the battery life of energy-constrained wearable devices. Examine the study [3] to grasp the significance of the long battery lifetime and, as a result, the energy usage. The study [22] investigates the existence of a criteria for selecting SAR operations depending on search time length, with the goal of maximizing the rescue of surviving missing individuals. The average search length for a significant number of survivors (n = 1439) is 7.9 hours, with a maximum duration of 323 hours, or almost 13 days. Specifically, at an expected cut-off point of 51 hours, virtually all survivors had been found, and by 100 hours, nearly all lost victims, dead or alive, had been found (but not rescued) [22]. As a result, the battery life must be sufficient to provide rescuers ample time to find and rescue the people. It is worth mentioning that even if the wearable device's battery is not completely charged, it is critical for SAR operations to maintain "contact" with it.

5. System Architecture

In this section, the system architecture is presented. The system consists of 4 main parts: a) End Devices (ED), which in this study the wearable is based on Dialog’s DA 14861 [23] platform with a LoRa module integrated. The ED can be into two states: Normal state: the individual carrying the ED is not in danger or Emergency state: The individual carrying the ED is in danger. The ED includes a button with which the user may put the ED to the emergency state or cancel the emergency state and return to the regular state. b) The GW, which is a device responsible for translating the packets transmitted through LoRa to Internet packets and vice versa. The GW relays the LoRa packets to the respective Network Server (NS). c) The NS is a server responsible to supervise and set the network parameters. d) The Application Server (AS). In Figure 1, a typical deployment of LoRa system is presented, showing each LoRa component. Figure 2 shows a DA 14864 wearable device incorporating a LoRa module and a LoRa GW that is placed on the University of Patras Campus.

As far as the web application is concerned, the main technical aspect of the application is the web framework called Flask [24]. As far as the front-end development is concerned HyperText Markup Language 5 (HTML) [25], Cascading Style Sheets 3 (CSS) [26], Bootstrap 4 [27], JavaScript ES6 [28], and jQuery 3.5.1 [29] were used. For the Relational Database Management System (RDMS) the SQLite 3 [30] technology has been used. As far as the maps in the web application are concerned the Leaflet [31] has been used. The Leaflet is an open-source JavaScript library for creating mobile-friendly interactive maps. Figure 3 shows the homepage of the web application.

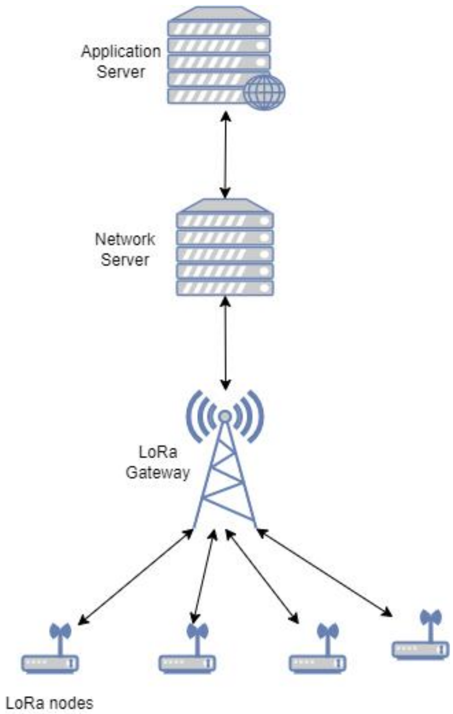

Figure 1. LoRa deployment architecture.

Figure 2. Left: a DA 14861 wearable device. Right: A LoRa GW in the University of Patras campus.

The basic scenarios that the system provide to the user are the following: a) The user logs in to the system, b) Definition of the allowed region, c) Location monitoring, d) Set the wearable device's state to an emergency/normal state, e) See past packet information.

Figure 3. The homepage of the web application.

When a person visits the website, the homepage is the first item that appears (Figure 3). When the user signs in, a page with a customized message notifying the user about the last selected ED is displayed. The user is then sent to the Dashboard page. On this page, the user will discover a leaflet map displaying the user's most recent position with the wearable device, as well as a tooltip displaying the user's current condition (e.g., normal state or emergency state) and the timestamp of the most recent LoRa packet. Furthermore, a table is given below the map with the most recent information from the user as well as sensor measurements such as the HR and the pedometer. Figure 4 depicts the Dashboard page.

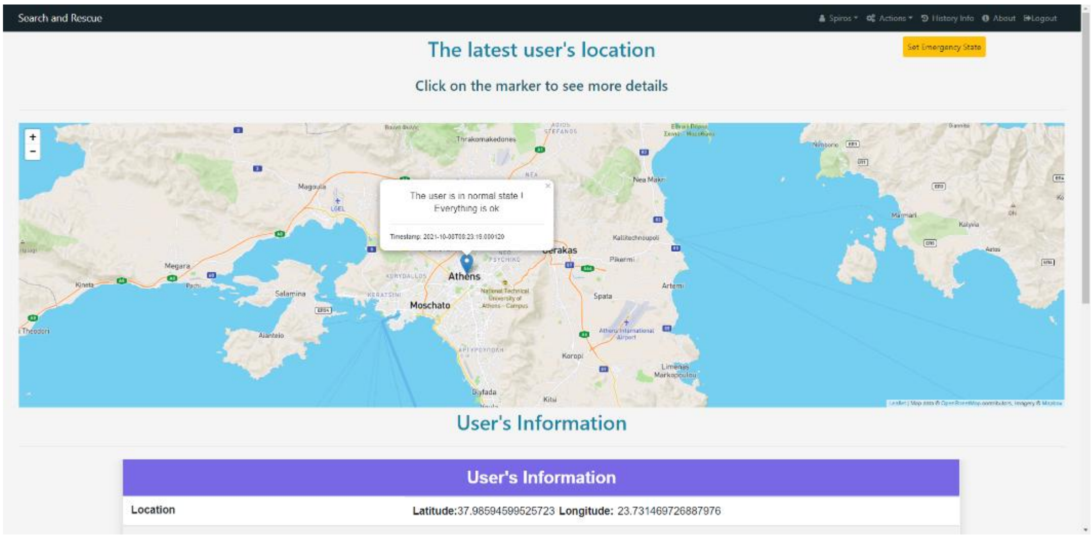

Figure 4. Dashboard.

If the user wants to add a new zone in which the person suffering from dementia or ASD can move, and if this person exits this region, then the emergency state is triggered. The user should click “Actions” -> ”Set permitted Area”. On this web page, there is text giving guidelines to the user on how to add a permitted area (see Figure 5). Following that, there is a map on which the user may draw a circle to symbolize the authorized region. The user is then given with a tooltip-style form in which they may enter a Title and a Description. Furthermore, the user can check the previously added permitted areas through the “Check your permitted areas”. On this page, the user can see in the map the boundaries of the permitted regions, and by clicking on the circles the user can see the respective details and information. Also, the user can check the packet history via the “History” webpage. On this page, the user can see the history of the packets received in a tabular. In the navigational bar, the user can spot and click the option “About” where the user can see the Frequently Asked Questions (FAQ). Lastly, the user in order to logout has to click on the logout option in the navigational bar. When the user selects the logout option, a popup modal appears, requesting confirmation from the user.

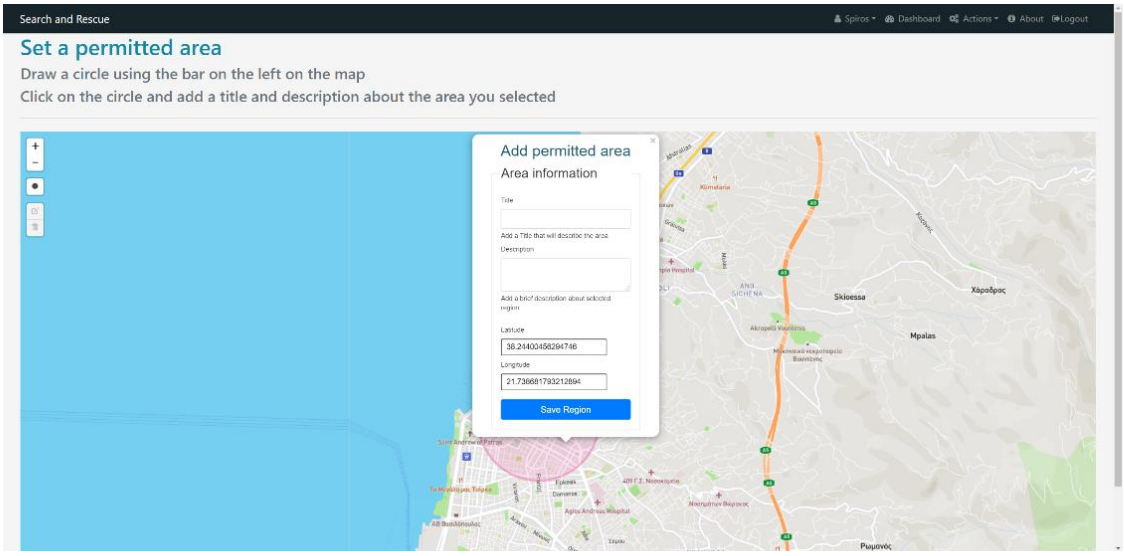

Figure 5. First page in the "Add new allowed region" scenario.

6. Energy Consumption Issues

The use of sensors is one of the concerns that affects the energy consumption of current IoT devices' batteries. As described in [32], one element influencing power management is the introduction of the concept of operating states into such solutions.

It becomes clear that it is critical to dynamically adjust the operational status of the sensors based on the user scenario and demands. The authors' model assumes that sensors such as accelerometers and medical sensors are built within the ED.

To achieve energy efficiency on the nodes, we define the following four states:

- Off: the ED, in this state is switched off.
- Hibernate: no sensor is working in this state. Only the accelerometer is operating and triggered. The ED includes a button with which the user may put the ED to the emergency state or cancel the emergency state and return to the regular state. We monitor the accelerometer in order to monitor a possible sharp fall of the person wearing the w ED (as far as possible) in order to give an alarm if necessary. There is an option in order to disable the accelerometer sensor.
- Normal: in this state, the sensors are taking measurements and transmit the measurements through LoRa to the application server.
- Emergency: in this state, all the sensors are turned off, apart from the sensors that help for the detection of the person that got lost.

Furthermore, the pace at which sensors gather and deliver data is an essential aspect that influences energy usage for IoT devices. As a result, the rate at which data is transferred must vary depending on the user's state as well as the mobile device itself. All of these modifications are taking place on the application server. To preserve battery life, the application server transmits to the node the state in which it will be configured, blocking or activating components of the ED. Many parameters may be analyzed on the cloud, including the battery level. When the battery is low, for example, the transmission frequency should be reduced to extend the battery life.

Figure 6 depicts the method through which the ED transitions from one state to another. Because the off state is supposed to indicate the condition where the ED is totally switched off, it is disregarded in transitions from one state to another. If we start with the hibernation state, it transitions to the regular state as follows: the ED shifts from hibernate mode to normal mode every X seconds and then back to hibernate mode. Every Y seconds, the hibernation mode returns to normal, and the values are relayed to the LoRa gateway. The X and Y values are computed experimentally in each network since it is critical to account the ED's individual use case, hardware, and so on [9,10,12].

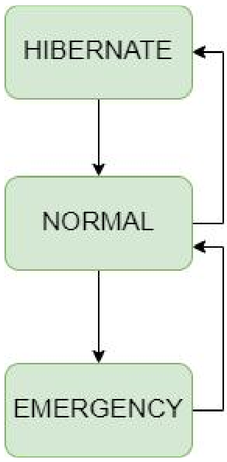

Figure 6. State transition in ED.

Following data transmission, the ED opens two downlink windows to receive packets from the gateway. In an emergency, the ED sends the sensor data to the LoRa gateway, which subsequently delivers the packets to the Application Server. After transmitting the data, the ED waits for further packets before entering hibernation mode.

From normal mode the following transitions are made either in hibernate or emergency mode:

- After the X seconds, the ED go from normal to hibernate mode.
- After pushing the emergency button, detecting a user fall, detecting a high heart rate, or locating the user outside of a predetermined region, the ED sends a message to the Cloud to transition from normal to emergency mode. We monitor the heart rate to monitor the health of the individual wearing the ED (as much as feasible) and to provide an alarm if necessary. The decision to switch to emergency mode is made by the cloud, after receiving the message from the ED. The Application server sends a downlink message to the ED. The message is stored in the GW where when a downlink window opens the message is sent to the ED. From the emergency mode, the following transitions are made to normal:

- By sending an appropriate message from the cloud, the ED goes into normal mode, e.g., in the case the user returned back to the predefined area.
- After pressing again, the emergency button, the ED returns to normal mode.

Furthermore, aside from the ED statements (whether the user is in an emergency scenario), one aspect that is taken into account is the battery level. When the battery is low, the sensors should be turned off for an extended length of time. The values of the parameters X and Y change dynamically in response to the user's condition and battery level. The next part explains and describes how to extend the battery life. The algorithm's pseudocode is shown below.

Pseudo code of the algorithm

```
Cloud sends downlink to the node
 If (BatteryLevel >= BATTERY_HIGH)
    If (state = EMERGENCY)
          Y = Y_emergency_high_battery; X =Y / value_emergency;
      Else
           Y =  Y_normal; X=Y / value_normal
 Else If (BatteryLevel >= BATTERY_LOW)
       If (state == EMERGENCY)
              Y = Y_emergency_mid_battery; X=Y;
      Else
              X = Y / value_emergency;
 Else
    If (state == EMERGENCY)
          Y = Y_emergency; X=Y;
     Else
          X = Y;

If state == EMERGENCY:
   suspend(unnecessary sensors for localization)
Else:
   activate(unnecessary sensors for localization)
```

A detailed evaluation of the above-mentioned algorithm is presented on [12].

7. HCI Approach and Evaluation

The primary purpose of computer systems is to be developed in a user-centered manner so that people can use them successfully and easily. For the development of a system, it is necessary to understand the users' requirements. The simplicity of a system and the fact that the users should be independent without the guidance of an expert is also an important aspect of the development [33].

System designers must know how to translate user's needs into system capabilities and the first step in this process happens with a good design of a system interface. A well-designed interface allows people to interact with the system and deal with any difficulties without external help while at the same time they have full control of the machine. For this reason, the topic of user-centered design has become the most important concept in the design of interactive systems. The keyword, in this case, is the term usability [9].

7.1 *Usability Criteria*

The following ten usability criteria were isolated from work by Nielsen [34].

- The first principle is the visibility of system status.
- Match between the system and the physical world.
- User control and freedom.
- Consistency and standards.
- Error prevention.
- Recognition rather than recall

- Flexibility and Efficiency of use.
- Aesthetic and Minimalistic Design.
- Help users recognize, diagnose and recover from errors.
- Help and documentation are the last principles.

Based on Nielsen's core heuristics, new heuristics were discovered by analyzing assessment techniques, testing website prototypes, and searching for ideas in working websites. The goal was to include some additional relevant heuristics in the research to see how well they were followed and to maintain the system up to speed with developments in the website design field. These were the heuristics: durability, reduction, and navigation, user privacy, beauty, and responsive design.

When it comes to website design, navigation is crucial. It is how designers employ various tools such as buttons and links to assist website visitors in navigating around the various pages. It functions as a road map for website visitors to locate information and materials provided by the site. A common rule is that every visitor to a website should be able to locate anything within three clicks. People will stay on the website longer if they can traverse it more easily. Therefore, even in terms of website aesthetic design, navigation comes first. Because not everyone thinks the same way, a navigation menu must be clear, concise, and provide a variety of options. [21].

The term "privacy" refers to the information that the site requires from the user. It is critical that any information provided by the user be deemed personal data and protected by law. Furthermore, when a user creates an account on a website, the password and username must be unique, and only the proper person can enter with the credential. In addition, every website must provide a privacy statement that defines the owner's legal rights to the user's data. Of course, when a user views and uses a website, he or she must be aware of and agree the privacy policies [35].

An evaluation based on fundamental heuristics and the new can provide significant information about website usability and how to improve an existing one's usability and user-friendliness.

Heuristic evaluation is a usability engineering approach that assists designers in identifying design flaws and usability issues. A small group of evaluators from various backgrounds is required for the assessment problem in general. Each evaluator is given enough time to evaluate the design in the form of mock-ups or prototypes, identify usability issues, document them in a catalogue, and recommend a modification. When all of the evaluators' evaluations are completed, they are free to speak with one another and discuss their results. This technique is critical because it ensures that the review process is impartial and independent. Table 1 lists the difficulties as well as the heuristics that were broken in each one.

In May 2021 the evaluation process of the SAR prototype took place in the office of the Laboratory of Distributed Systems and Telematics at Rio, Patras. The evaluation team consisted of three people: two HCI Master level graduates and one engineer specialist on monitoring systems with a background in Business and Management Administration. Each evaluator had a specific arrival time, and in 40 minutes it had to evaluate the prototype alone, with just the website's creator acting as an observer. The review took place on prototypes rather than merely mock-ups since prototypes allowed for modifications across different sections of the website to get the sense of a real operating site.

Evaluators were provided a heuristic evaluation sheet with information on the ten heuristics. They could make a note of any concerns or problems that arose, and then provide recommendations on how to improve the interface in the following frame. They might also record the severity score for each of the heuristics on the left side of the sheet. The severity is graded on a specific scale:

- 0-I don't agree this is a usability problem at all.
- 1-Cosmetic problems only needed not to be fixed unless extra time is available on the project.
- 2-Minor usability problem: fixing this should be given low priority.
- 3-Major usability problem: important to fix, so should be given high priority.
- 4-Usability catastrophe: imperative to fix this before the product can be released.

Table 1. List of the errors during the heuristic evaluation.

Problems	Heuristic violated
1. First screen	Aesthetic and minimalistic design
2. Menu actions	Connection between physical and digital world
3. Set a permitted area	Aesthetic and minimalistic design
4. Check the permitted area	Consistency of the system
5. Add permitted area	Help and documentation + navigation
6.Registration of new area, wearables list and addition of wearable device	Error prevention
7. History	Aesthetic design
8. Emergency button	Connection between physical and digital world
9. Emergency state	Visibility of system status
10. Window segmentation	Minimalistic design
11. Redirecting between pages	Navigation
12. Design of pages and menu	Responsive design

In Table 2, an example of the problems found in the heuristic is presented, and particularly the ninth problem is presented. In Figure 4 the screen after the heuristic evaluation is presented.

Table 2. Problem No. 9.

Issue	When the user presses the emergency button, the system triggers an alert, indicating that one of the persons using the ED has been misplaced. In its prototype iteration, the system alerted viewers by turning the entire screen red on every page (Figure 7). This adjustment irritated all of the participants who did not comprehend what the red hue meant. This activity violated the heuristic of system status visibility, as well as consistency and standards. Users are bothered by the red screen when the emergency mode is activated.
Problem Severity	5
Recommendation	Find an alternative way of showing danger and emergency Figure 8

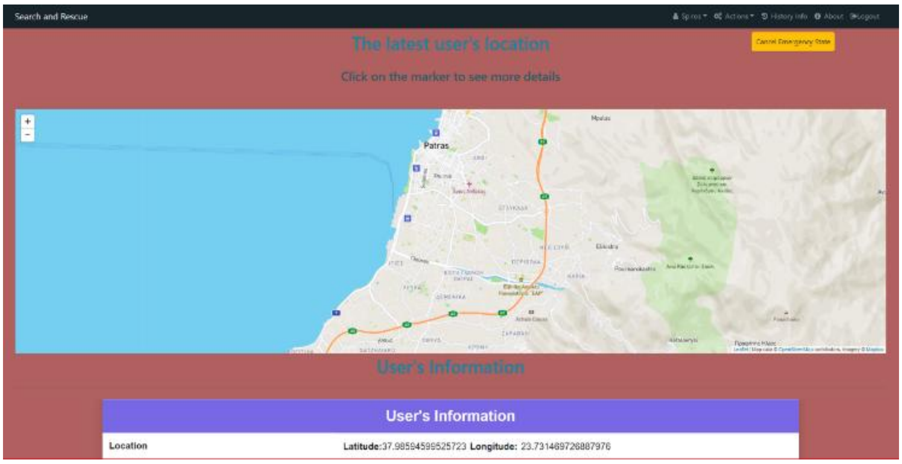

Figure 7. Initial emergency state case.

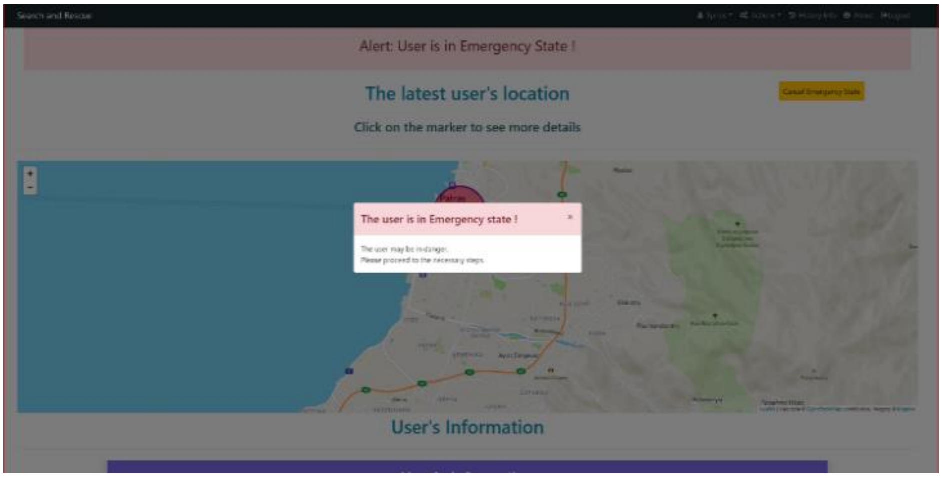

Figure 8. Emergency state alert after evaluation.

After the heuristic evaluation, the necessary improvements were made. After this, another iteration was made, but at this time a usability questionnaire was given to each one of 10 random participants, who are frequent internet users that were called to test the prototype online, and then they answered the questionnaire. This happened in order to test if there are more problems with the interfaces. The study uses a standard questionnaire that could help with the formulation and validation of the questions. More particular the questionnaire that was used was the SUS questionnaire (System Usability Scale) [36].

The goal of the project was not to do a statistical analysis, but to use the questionnaire as an extra tool for evaluation. After all, as previously said, the number of participants was tiny. In light of this circumstance, the solutions offered are the most typical. In the first question, 50% of participants agreed that they wished to employ a system like SAR more frequently because of the purpose it serves, with the remaining 50% divided between neutral and disagree replies.

The fact that 30% of participants received a score of 3 or above suggests, in conjunction with the comments received throughout the assessment process, that 1) some users were unfamiliar with a technological website aimed at a specific purpose. The heuristic assessment technique produced excellent results because the majority of users believe the system is not difficult. Something that comes up in the answers to questions 8 and 9. In eighth all of the ten responds were neutral while in the ninth only 70% of the participants strongly agree (5) about how confident they were with the use of the website when only 30% of the answers were divided into neutral and disagree. The fact that they were engaged with internet websites it was sufficient enough to make them feel confident about the use of this particular website. Then we calculated the score of the questionnaire, and the score was 72.5. The general guideline for SUS questionnaires classifies it with grade B, which means that the designed system is good and is also greater than the average grade of 68 [36,37].

8. Conclusion and Future Work

As mentioned in the previous sections, the need for an IoT-based SAR system has been understood and explained, in order to save the lives of people that have a high probability to go missing. The advantages of such a system can be critical for the missing person, as well as for the peace of mind of caregivers and those responsible for the persons, as in the case of people suffering from dementia or ASD. Furthermore, emerging technologies like as LoRa technology, which can broadcast over vast distances while consuming little energy, can aid in the development of SAR systems.

Future studies will include an investigation of various wireless technologies such as Sigfox and 5th Generation networks. In addition, after the COVID 19 epidemic is finished, ethnographic research in facilities for persons suffering from AD or dementia should be planned. Finally, another aspect that can be studied and examined is the legal part of the system that concerns people who are not fully aware of legal concepts, such as a person suffering from dementia, who cannot practically agree or disagree if the person in charge of safety has the right to monitor the position and other vital personal information.

Conflict of Interest

There is no conflict of interest for this study.

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Appendix

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to Search and Rescue website today.

		Strongly disagree				Strongly agree
1.	I think that I would like to use Search and Rescue website frequently.	1	2	3	4	5
2.	I found Search and Rescue website unnecessarily complex.	1	2	3	4	5
3.	I thought Search and Rescue website was easy to use.	1	2	3	4	5
4.	I think that I would need the support of a technical person to be able to use Search and Rescue website .	1	2	3	4	5
5.	I found the various functions in Search and Rescue website were well integrated.	1	2	3	4	5
6.	I thought there was too much inconsistency in Search and Rescue website .	1	2	3	4	5
7.	I would imagine that most people would learn to use Search and Rescue website very quickly.	1	2	3	4	5
8.	I found Search and Rescue website very cumbersome (awkward) to use.	1	2	3	4	5
9.	I felt very confident using Search and Rescue website .	1	2	3	4	5
10.	I needed to learn a lot of things before I could get going with Search and Rescue website .	1	2	3	4	5