Elderly Fall Detection and Warning System

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Abstract. Elderly persons falling while showering or bathing is currently common happenings. The fall is due to various reasons. The worst part is due to deadly attacks such as heart attack or what commonly is called as stroke where the elderly lose consciousness. If the attack is handled within a certain period, the elderly could survive and recover fully. Beyond that period there could be grave consequences. Due to age the agility and resilience of an elderly is limited and often need assistance in order to overcome the incident. Providing human assistance within a bathroom or its vicinity is not an easy matter due to certain limitation. This research strives to provide emergency warning system that can invoke justifiable human action to provide assistance. The assistance is often lifesaving within or in the vicinity of the bathroom where the accident is happening. The warning system uses a sensor that identifies movements within the confines of the elderly movement. The research object is a shower room normally found in a non-luxurious apartments or landed houses. As soon as no movement is detected a warning indicator is raised. To detect movement a common detector known as PIR is selected. The indicator from PIR is transmitted using LoRa as the communication infrastructure. LoRa will act as the sender and recipient of data from the sensor. The LoRa receiver will send an audible alarm and an SMS message as warning to the family member in charge. All system within the shower room use low voltage batteries. Electrical power must be avoided due the hazard it could cause. Measurements showed the most likely blind spots. The system functions as designed.

1. Introduction
A shower room often is often slippery due to water and quite often residue of soap even though it is kept dry. For the elderly the possibility of falling is reasonably higher compared their younger counterpart. The balance control of an elderly is already decreasing. Not only the balance control is less but there are also other causes that increase the possibility of falling in the shower room [1][2][3][4]. The most notable probable cause is due to common health problem such as diabetes, hypertension, or hyper cholesterol. These health problems increase the possibility of falling in the shower room due to unexpected circumstances that manifested in sudden losing consciousness and consequently balance. Certain losing consciousness is not fatal, but the falling and late detection for medical handling worsened the fall consequences. Medical personnel know about the golden moments that is believed can increase the possibility of complete recovery of the patient. Hence, it is of utmost important to detect a fall as early as possible. The fall fatality increases if in the shower room is cluttered with sharp edges, hard items and the shower room is locked from the inside.
According to WHO the number of elderly has reached 7% of world population, while between 28%-35% of those who are 65 years or above experienced falling at least once in a year. Monitoring will be necessary for the elderly that are highly vulnerable to falling while bathing or showering. Preferably whoever do the monitoring should be within the proximity [5][6][7]. Practically there are moments or conditions that this requirement cannot be fulfilled due to situations beyond human control or due to human nature that are easily distracted. It is therefore high technology can play a role in assisting human.

The technology that can support the monitoring of the elderly should be easy to use preferably fully automated. To achieve this requirement an appropriate sensor will be chosen [8][9][10]. It should directly or indirectly detect if a fall occurred. The detection result should be communicated for immediate help to the party in charge. It should also raise alarm within the premise by means of audible alarm.

Another requirement that is considered is safety due to the need of electrical power. The system is designed under the strict prohibition of using house power supply within the shower or bath room, especially where water is involved. The system would only use low voltage power supply or in this case batteries. It presents little inconvenience of regularly checking replacing batteries, but avoid the possibility of electrocution. Any other system outside the room can use normal house power supply [11][12][13].

As the sensor that detects fall will only send indication and other data, Low Power data communication infrastructure will be suitable for the purpose [6]. LoRa is chosen as the infrastructure to carry sensor data to the controller. LoRa based modules are widely available and reasonably priced. The necessary intelligence can be easily embedded into LoRa modules. LoRa itself is specified as low power and can be powered with batteries [14][15].

The major objective of this research is to develop a warning system of elderly fall detection in a shower or bath room. It is to mitigate the risk of late detection of a fall that could endanger the elderly. It will benefit of increasing the possibility of improving emergency handling of certain time critical cases and increasing the chance of recovery. The research is limited to a predetermined shower room or bath room usually found is common apartments or landed houses.

2. Previous works
The use of LoRa based solutions for various home automation and monitoring has been shown in published research. A published paper Lora Based Intelligent Home Automation System [15] shows how LoRa can be applied to access and control from Android based application to appliances and house facilities (Air Conditioner, Lighting, etc.) that are connected to the house intelligent system. Another paper A Solar Powered Long Range Real-Time Water Quality Monitoring System by Lora WAN [16] described how sensor through LoRa module transmits data to a gateway for storage to the database. The data will be displayed or processed using applications. Even though LoRa is sufficiently versatile but there are limitation that must be considered. A paper Understanding the limits of Lora WAN [17] showed that system capacity is limited to its duty cycle.

There are various types of sensors that can detect movements such as vibrations [8][9]or other methods [10][11][12][13]. Within a shower room visual detection such as camera is not advisable among other due to privacy, thus to detect movement a sensor known as PIR (Passive Infrared Receiver) is selected. PIR provides signal that indicates the presence of movement within its coverage. It detects human body infrared radiation [18]. Infrared detection has been implemented for various applications that involve detection of movements or presence of bodies emitting heat [19][20][21][22][23]. A PIR module generally consists of some parts such as Fresnel lens, Infrared filter, Pyro electric detector, signal Amplifier. A PIR can only receive infrared radiation. Infrared radiation will be detected by piezoelectric detector. Pyro electric detector is made of gallium nitride, cesium nitrate and lithium tantalite. It produces electric current as it detects infrared radiation. It will detect the infrared radiated by the human body that has different temperature from the ambient temperature. The pyroelectric material will produce electric current due to the presence of
infra red radiation. Within the PIR module there is an amplifier to amplify the electric signal and comparator to providing indicator as output. Fresnel lens increase the sensor coverage.

3. Methodology

3.1 System Diagram

The warning system consists of two modules, a detector module and a controller module. The controller module functions as a receiver and gateway. Both modules use a micro controller with ESP and LoRa sub modules. The detector module is installed in the shower room. It must detect whether the elderly that is showering does not fall. A fall is indicated if there is no movement and no infrared is detected within a predetermined area or coverage footprint for a certain time period.

ESP receives data from PIR which functions as a detector for human being movement. As long as human being movement being detected indicated by the presence of infrared radiation, no data is being sent. If there no infrared detected then an indicator will be sent to the gateway. The ESP with PIR as the sensor module is placed in the shower room. This research will determine optimal location of the sensor. The experimental shower room has a width of maximum 1.5m and length of maximum 2m. The elderly maximum elderly height is 2m, while the ceiling maximum height is 3m. Based on these parameters the system must operate reliably. The detector module will send its data using LoRa to its gateway that is within the controller module.

The controller module is placed outside the shower room. Controller module interpret the data received from the detector and proceed with actions required such as starting the audible alarm, sending SMS through GSM module to warn the parties that could handle emergency situations.

3.2 Operations algorithm

This Elderly Fall Detection and Warning System is only operational if the shower room is used by the people who need monitoring. In the current design it must be manually turned on. Upon turning on it will check if the battery power is sufficient. A voltage less than 7.1V will trigger LoRa to send an indicator to the receiver cum controller for follow-up. PIR will be initialized to detect movement. A reference time for timing purposes is started. Any movement indicated by the presence of infra red radiation will be compared to the reference time. No movement detection beyond a certain time, the transmitter will send an indicator through LoRa to the controller. The controller itself is basically also a LoRa receiver.

Depending on how many detectors are being used, the controller unit which houses LoRa gateway can be powered all the time. Gateway can use the normal net power instead of battery. It is placed outside the shower room. Gateway is normally placed to monitoring mode. Before entering monitoring mode it initialize GSM and LoRa sub modules. GSM sub module will need SIM card in order to enter the cellular network. The receiver is programmed to send SMS messages to one or more numbers depending on what indicators it received.

The receiver, which is a LoRA receiver, waits for data from the transmitter. This Elderly Fall Detection and Warning System is programmed that if PIR does not detect any movement within 120 seconds, transmitter will send an indicator. The indicator is received by the controller. It than turn audible alarm on and send an SMS warning to programmed number.

3.3 Parameter measurement

The system performance depends on how reliable it can detect if a fall is happening. The detector operational work has certain coverage area where it can receive body infrared radiation. The coverage area should cover the human body entirely because the detector only provides warning if no infrared radiation is detected within its coverage area. The coverage area is similar to the radiation pattern of a parabolic antenna. It will receive the best radiated power if the infrared power hit line of sight the detector. The detection pattern is similar to a cone with an apex at the detector. A line of sight is defined as radiation power coming from an object of having height and located less than the acceptance angle of PIR. The acceptance angle is defined as the maximum angle infrared radiation can
be detected. It is assumed that the object height is minimum 1m and maximum 2m. Thus is an elderly falls it is the radiated power source will have a height of less than 1m. The radiated infrared will not be detected and after certain grace period a warning signal will be invoked. Within the shower room the blind spots will be identified in order to adjust the detector location to eliminate or minimize the blind spots.

4. Measurement Results
4.1 Sensor placement
In order to detect movements the sensor must be placed somewhere in the shower room. In this research the shower room has width of 2.1m, length 1.5m and ceiling height of 3m. PIR will be placed at the wall where it can cover the most probable movement of the elderly. The shower room being researched has a layout as depicted in Figure 1.

The sensor will be placed at the determined location at its length (L1, L2, and L3) and width (W1, W2, and W3). Measurement from each location will be taken. Sensor with its transmitter will be placed to at each location individually for coverage measurements. The sensor height will be 1.3m above the room floor. For measurement purposes there are 16 points that a subject must move. The sixteen points are coordinates where the elderly is assumed to move during shower. The meaning of move is not necessarily walking around but also could be standing. As long as a sensor detect changes that it consider as movement no alert will be issued. The test will consist of sensing standing at the indicated points and sensing while moving along or around those points, Transmitter will sent an indicator if PIR sensed movements and no indicator being sent if PIR concludes that there are is no movements.

Testing sensors placed at the wall along the width and length of the shower room with the subject movement covering the sixteen test point will give a map of coverage. There are six sensor placement points being tested as shown in Figure 1. According to the technical specification the infrared radiation capture angle is 100°. Measurement was performed more than 20 times.

Figure 2 gives the coverage map of each sensor placement along the width of the shower room. If the sensor is directly facing the shower where the elderly will be showering, the sensor does not have a blind spot. It can cover the whole area of interest. Placement of sensors away from line of sight showed the existence of blind spots that must be considered.
Figure 2 Map of Sensor Coverage along Room Width

Figure 3 is the coverage map if the sensors are placed along the length of the shower room. It showed that there are more blind spots that should be considered.

Figure 3 Map of Sensor Coverage along Room Length

Table 1 shows the average of repeated measurements. The process was repeated for each sensor position placement.

| Test Points | Sensor L1 | Sensor L2 | Sensor L3 | Sensor W1 | Sensor W2 | Sensor W3 |
|-------------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1           | Y         | Y         | Y         | Y         | Y         | Y         |
| 2           | Y         | Y         | Y         | Y         | N         | Y         |
| 3           | Y         | Y         | Y         | Y         | Y         | N         |
| 4           | N         | Y         | Y         | Y         | N         | N         |
| 5           | Y         | Y         | Y         | Y         | Y         | Y         |
| 6           | Y         | Y         | Y         | Y         | Y         | Y         |
| 7           | Y         | Y         | Y         | Y         | Y         | N         |
| 8           | Y         | Y         | N         | Y         | Y         | N         |
| 9           | Y         | Y         | Y         | Y         | N         | Y         |
| 10          | Y         | Y         | Y         | Y         | N         | N         |
| 11          | Y         | Y         | N         | Y         | N         | N         |
| 12          | Y         | Y         | N         | Y         | N         | Y         |
| 13          | Y         | Y         | Y         | Y         | N         | Y         |
| 14          | Y         | Y         | N         | Y         | Y         | N         |
| 15          | Y         | Y         | N         | N         | N         | Y         |
| 16          | Y         | Y         | N         | N         | N         | Y         |

Y = sensor can sense movement  
N = sensor cannot sense movement

4.2 Environment Impact

The previous measurements were performed only to see the sensor coverage under idle shower room condition. It is of interest to find how the sensor will perform if the environment is approaching shower room under use. In tropical countries people could shower with cold water or heated water. The
previous process was repeated with to see if there is any impact to the sensor performance. There is no impact to the result.

5. Conclusions
PIR sensor that is used is this research can perform well in a shower room of 2 m long and 1.5 meter wide with ceiling height of 2.5 m. It can cover the space of interest. Any movement or lack of movement can be detected. The principle being used is non movement is equal no change being detected within a pre-determined time. Alert is then raised. The alerts are audible sound and SMS message. The height of the sensor is 1.5 m above the floor. Environment ambient temperature and humidity do not affect the sensor performance. The research result is valid for shower water between 30˚C and 45˚C. PIR sensor being selected has a capture angle of 110˚. Coverage distance beyond 2m was not investigated.

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