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IoT BASED PATIENT FALL DETECTION

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Abstract

IoT enabled devices have made remote monitoring in the health care sector possible unleashing the potential to keep patients safe and healthy. In India the population of the elderly is projected to increase nearly 20 percent in 2050. According to WHO, falls are one of the dominant health related issues among elderly. It is reported that more than one third of 65 (and above) years old falls each year. A quick response on the incident might decrease the risk of serious injuries such as head traumas or brain damages. The proposed system will continuously monitor the vitals of the elderly and assist preventing the fall. The proposed system consists of accelerometer and gyroscopic sensor to detect the patients movement and orientation. The system also consists of additional sensors like pulse, sweat sensors which sense the patient's heartbeat rate, body temperature. The device can be worn as a band in patient's wrist which acquires the data and send to the nearby device like laptop or mobile and push it to the cloud server through telemetry. The vitals of the elderly can be monitored

Keywords: *Fall Detection, Telemetry, patient detection, IoT,Data analytics, health care, mobile cloud*

1. Introduction

According to the World Health Organization, falls are the second leading cause of accidental or unintentional injury death worldwide. Each year an estimated 646000 individuals die from falls globally of which over 80% are in low-and middle-income countries. Roughly 28-35% of people who are more than 65 years old fall and the percentage increases to 32-42% for those more than 70 years old[1].

This paper presents a fall detection system for the elderly. The system consists of two major components: accelerometer and gyroscope, a wearable device detects if a user is suffered from a fall, and a cloud application that automatically sends a notification in case of emergency. The main advantage of the proposed system is that the patient's relatives and the practitioner are able to monitor the patient's health condition each and every second.

The wearable device has the capability to detect the fall through accelerometer and gyroscope. The available literature states that measuring a person acceleration and orientation allows a electronic device to detect a fall. Therefore, this project measures the acceleration in 3-axis as well the angular position of the wearable device. What's more, vision-based methods are more expensive, as storing and processing the images needs large storage and high performance computer. However, the wearable sensor can avoid such defects. In this paper, we propose an algorithm with high sensitivity and specificity for fall detection, and implement a mobile or laptop cloud system with a wearable device and cloud server.

2. RELATED WORK

In recent years, many researchers have paid close attention to fall detection. Usually fall detection systems can be classified into three categories wearable sensors, vision based and ambient based. However, in this paper we just focus on the wearable sensor method.

Most of the fall detection systems uses accelerometer as a primary one to detect the person movement and orientation. Threshold-based methods are one of the most popular techniques for

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fall detection system using wearable sensors. Here , a fall is detected when an acceleration goes beyond a pre-defined thresholds.

Vision- based sensor methods

Vision-based sensor refers to the videos and images from the camera. They use a single mini-camera which captures the patients images and videos and they detect falls by analyzing the velocity change of the motion magnitude, human shape and orientation. However, on the other hand there are some defects such as problem of privacy, not flexible. Additionally, the capturing of images and videos are costly.

Ambient sensor based methods

The ambient sensors collect the information of the surroundings, such as radar, infrared ray, Wi-Fi, ultrasonic. In some methods, they implement the fall detection system with the Wi-Fi devices. It detects fall by comparing the top and side signals with the pre-defined threshold signals .However, the ambient sensor is not target-specific as it collects information from the surrounding. The privacy issues is also concerned in this method.

C. Wearable sensor based methods

Wearable sensor based methods usually uses primary sensors like accelerometer and gyroscope. The sensors can be placed in various places of the body to collect the data. The sensors will continuously monitor the person health condition and it will send an alert to the person's relatives and the particular practitioner when a value is reached beyond the pre-defined value. Wearable sensors are more flexible and also easy for implementation. Additionally, they are more target-specific and provide more private security.

3. PROPOSED METHOD AND SYSTEM

The system defines two main components. The first component is a wearable device acting as a wrist band, and the other one is a mobile application running on a cell phone. These two items will communicate with one another via Wi-Fi. The wrist band consists of accelerometer, pulse and sweat sensor that detects the fall and sends the notification to the person relatives and the practitioner.

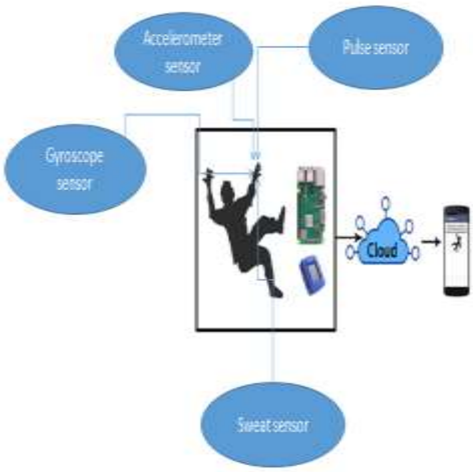

Fig.1.Proposed wearable fall detection system

Accelerometer

Accelerometer sensor is the most widely used sensor that detects the fall and also the body motion .Accelerometers are feasible, more effective, easy to operate, light weight, simple and cost-effective to detect the falls .A study was conducted using accelerometer sensor and also without using accelerometer sensor. It concludes that the study made without accelerometer sensor is not much accurate when compared with the study made by using accelerometer sensor.

By applying different signals on the accelerometer, the fall can be detected. The main feature obtained by accelerometers is the Signal Magnitude Vector (RMS) which is given as

$$RMS = \sqrt{x^2 + y^2 + z^2}$$

Where x, y and z are the acceleration values along X, Y and Z axis. Most acceleration based studies uses the threshold-based algorithm for fall detection. The placement of the sensors is also an important concern for detecting the falls. By using accelerometer method, the battery will get drained soon as it needs high sampling rate.

Gyroscope

The most important feature that results from the gyroscope sensor is the magnitude of the resultant angular velocity(w), which is given as

$$w = \sqrt{w_x^2 + w_y^2 + w_z^2}$$

where w_x, w_y and w_z are the angular velocity along the X,Y and Z axis of the gyroscope. Through study it was said that more accuracy can be achieved by using gyroscope sensor than accelerometer. Since, the accelerometer measures only the linear motion in specified directions.

The main disadvantage of low cost gyroscope is that they suffer from time varying zero shifts. Thus ,errors will be occurred when calculating the angular acceleration and angular position, by using differential and integral operations. The error will be increased when the noise is high. The gyroscope is also only available in high grade smart phones.

C .Pulse sensor

Pulse sensor is well designed plug – and – play heart-rate sensor. It has a main advantage that it can be used by students, artists, athletes, makers, and game and mobile developers who want to easily incorporate live heart rate data into their projects, also includes an open-source monitoring app that graphs our pulse in real time.

In our proposed system ,a pulse sensor is used that detects the persons heart rate. Due to high pulse rate many actions like heart attack may occur that may even lead to death. Thus, the sensor will continuously monitor the persons pulse rate and once if the rate exceeds the normal value, then a immediate notification will be sent to the persons relatives or practitioner.

D. Sweat sensor

By tracking how fast the sweat moves through the micro fluidic, the sensors can report how much a person is sweating, or their sweat rate. However, the wearable sensors can detect what's in your sweat. Moreover, it is known that due to high sweating a person may lead to some sort of unconsciousness and also diseases like asthma can occur. Therefore, in our proposed system the sweat sensor will continuously monitor the water content of the human body and if any fault is detected ,a notification will be sent immediately.

4. PROPOSED ALGORITHM

Initially, the mobile application and the wearable device is connected. Once a fall is detected, the wearable device sends the notification to the mobile or laptop.

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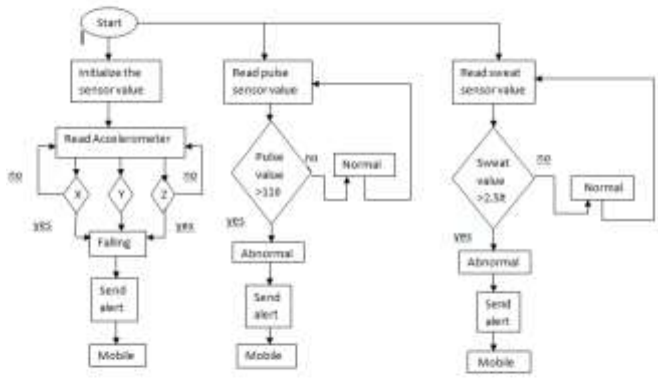

Fig.2.Proposed Algorithm

The above diagram is the work flow of our proposed system. There are three main components in the system: 1)Accelerometer sensor, it is mainly used to detect the persons movement and orientation.2)Pulse sensor, it measures the heart rate of the person. 3) Sweat sensor, it measures the body temperature of the person. Once all the parameters are detected the cloud sends the notification to the mobile or laptop.

The wearable device is worn on the person's wrist. It will be continuously monitoring the health conditions. The sensor value is initialized first, and the accelerometer value is read, based on the three signal values (x, y and z) notification will be sent. Simultaneously the pulse sensor value is detected , if it is greater than 110 (>110) then it is referred as abnormal state and an alert is sent. Likewise the sweat sensor also measures the water content of the body and if it is more than 2.5 liters then an alert is sent.

5. THRESHOLD METHOD

In this method, the tri-axial accelerometer sensor data is collected as x, y and z. The threshold method is used to roughly filter out the suspicious falls. The threshold method is chosen in the mobile stage, because it is light-weighted but a useful way to filter out the activities of daily life with less storage, and it can also be easily implemented in the mobile device. The RMS value is collected from threshold, the system will continue to run in the mobile stage. The acceleration data will be transmitted to cloud server, and an extract features are received from cloud server.

$$RMS = \sqrt{x^2 + y^2 + z^2}$$

Acceleration(v)	Time(s)	x-axis	y-axis	z-axis
6	4	0.1	4.1	11
4	5	0.9	4	9
2	6	-1.3	5.7	8
0	7	0.2	5.5	9.9
-2	8	-1.8	4	9.7

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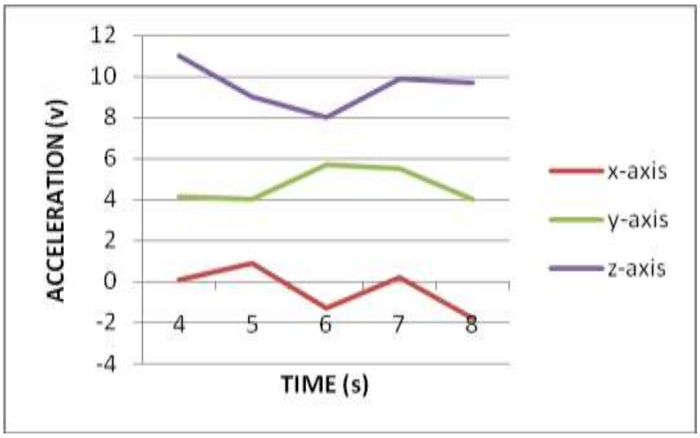

Fig.3.Acceleration Vs Time

The above graph represents the accelerometer graph for the 3-axes.Accelerometer sensor detects the movement and orientation of the person. The above analysis was made when the person is under any action such that the acceleration changes according to the time.

Algorithm 1 Threshold

Input: threshold, x, y, z

```
function THRESHOLD (threshold, x, y, z)
    √(x² + y² + z²) → RMS
if rms < threshold then
    continue to run in the mobile stage;
else
    turn to the collaboration stage;
end if
end function
```

Fig.4. Threshold method

The above algorithm represents the fall detection algorithm of the project. The accelerometer and gyroscope are measured, once the wrist band is connected to the mobile. If the acceleration goes beyond the normal threshold value, the device checks the gyroscope variation. If the change in direction exceeds the threshold value, then a 5 seconds timer is started. Once it is over, the direction of position is checked again. If it exceeds the threshold value then a fall is detected. Then a 30 seconds timer is started, if the position remains same then a notification will be sent to the mobile application.

Pulse sensor method

The following graph represents the data of pulse sensor Once when the accelerometer and gyroscope is measured the heart rate is also measured along with them. For adults 18 and older, a normal resting heart rate is between 60 and 100 beats per minute (bpm), depending on the person's physical condition and age. For children ages 6 to 15, the normal resting heart rate is between 70 and 100 bpm. When the wearable device is connected with the mobile application it measures the pulse rate and once if the value goes above or below the normal rate, a notification will be sent. An optional heart-rate are mostly monitored by pulse sensor. The different wavelengths of light from optional emitters interact differently with the blood flowing through the patient's wrist. The measurement of heart-rate through analyzing light refracted off flowing blood. The pulse should be monitored continuously in the form of heart –rate.

Sweat sensor method

Sweat potentially contains a wealth of physiologically relevant information, but has traditionally been an underutilized resource for non-invasive health monitoring. In wearable sweat sensors have overcome many of the historic drawbacks of sweat sensing and such sensors now offer methods of gleaning molecular level insight into the dynamics of our bodies. The potential value of sweat-based wearable sensors, examine state-of-the-art devices and the requirements of the healthcare monitoring. The fall may be either accidental or dramatic changes in patient's body. Sweat sensing is emerging as a technology capable of providing continuous access and monitoring.

The following five tabulations and their corresponding graph shows various relation between different contents of sweat with parameters like current, time, activity, sensitivity etc..,

Current(amps)	Time(s)	Sweat rate
75	200	56
75	300	56
75	400	57
75	600	57
75	650	57
75	1050	56

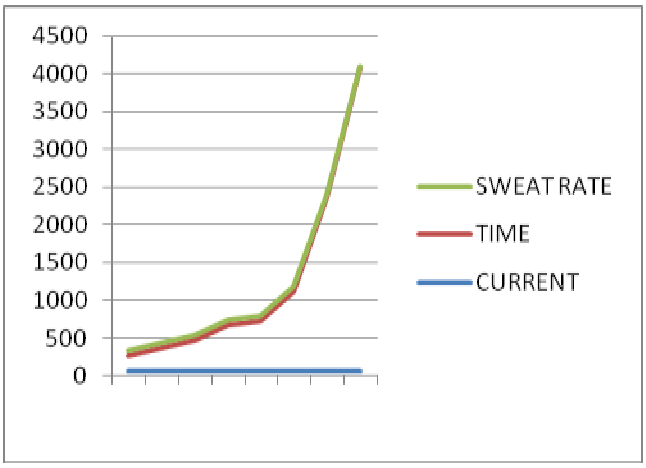

Fig.5.Current Vs Sweat rate

The above graph represents the relation between current, time and sweat rate. It is observed that, as the time increases the sweat rate decreases, whereas the current is constant.Therefore, the time and sweat rate are inversely proportional to each other.

Elements	**Sensitivity**	**Activity**
Pottasium Phosphate Buffer	**0.6**	**100%**
Phosphate Buffered Saline	**0.6**	**42%**
Yellow Buffer	**4.8**	**90%**
Water	**0.7**	**60%**
Sweat(no salts)	**0.7**	**64%**
Salty Sweat	**0.2**	**35%**

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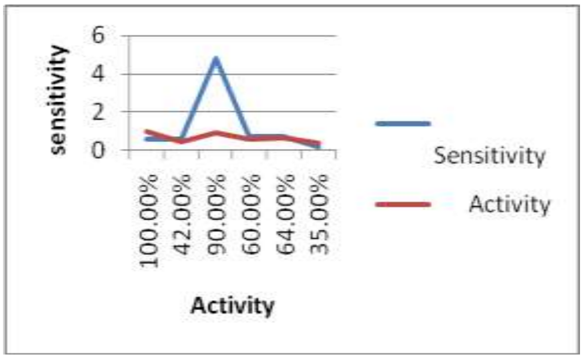


Fig.6.Sensitivity Vs Activity

The above graph is the relation between sensitivity and activity, as it is a important parameter in sweat. As the sensitivity decreases the activity also decreases accordingly.Different elements have various sensitivity and activity as shown above.When the person is highly sensitive the activity also becomes high.This analysis is made when diseases which causes high sweat such as heavy fever,high blood pressure takes place.

Elements	Current
No Salt	20
40mM Nacl	19
15mM Kcl	21
6.5 mM NH4Cl	23
5mM CaCl2	19
80µM MgCl2	18

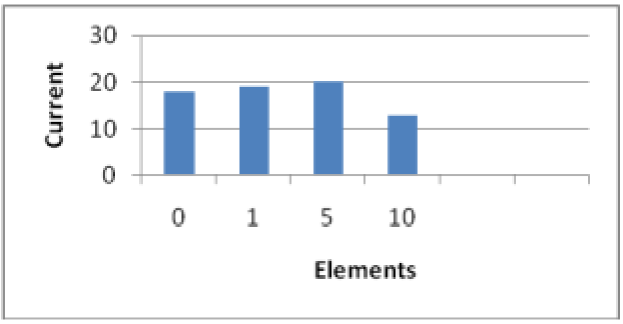
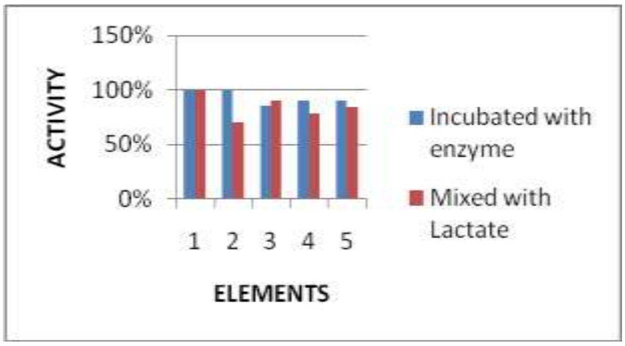


Fig.7.Current Vs Elements present in sweat

The above bar chart represents the value of various elements present in the sweat.Sweat has various elements associated with it.The above analysis was made when the person sweats due to some diseases. We can observe that sweat with no salt content has current value of about 20Amps.Whereas sweat with 80µM Mgcl2 has current of 18Amps.

Elements	**Activity**
	Incubated with enzyme, mixed with Lactate
No Salt	**100%, 100%**
40mM Nacl	**100%, 70%**
15mM KCl	**85%,90%**
6.5mM NH4Cl	**90%, 78%**

5mM CaCl2	**90%, 84%**
80mM MgCl2	**90%, 88%**



The above bar chart is relation between the activity and sweat with enzyme and lactate.It was analysed whether the sweat is mixed with some enzymes or lactate.The enzyme and lactate content varies according to the type of activity the person undergoing.

CaCl2(Mm)	**Current(μA)**
0	**18**
1	**19**
5	**20**
10	**13**

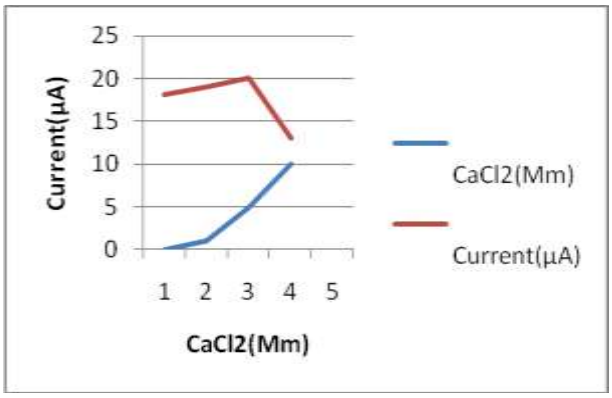


Fig.9.Current Vs CaCl2 content in sweat

The above diagram represents a relationship between the current and calcium chloride (CaCl2) present in the sweat. It is clear that as the current increases the calcium chloride content increases.Therefore both are inversely proportional to each other

CLOUD STAGE

The cloud stage is implemented in the cloud server side, which has more computing resources and ability to give higher sensitivity and specificity detection result. The cloud server receives the fall data information from smart IOT Gateway and store them using Mongo DB. Once a fall occurs, the model is again created and trained in the cloud using the API REST, for its subsequent be locally instantiated in the gateway. In fall detection system, cloud server is used to retrieve, preprocess and analyze data remotely in a cloud, which provides a huge amount of computational power and storage. A mobile phone or wearable device as intermediary devices can be used to send data to the cloud. The data stored in the cloud can be used for long term analysis. The analyzed result is sent back to a mobile device to inform the user. The model was able to detect falls with an accuracy of 85% in the case of activities like moving.

DATA ACQUISITION

The acceleration sensor uses acceleration and velocity to get the value and with help of these we can detect whether the fall is occurred. At this step with the help of action done by the volunteer and the actions like position and orientation. Whenever, there is a changes in the body posture, the sensor sends the alert with the help of acceleration data. For each activity the acceleration value are stored. Each position has different values that are used to detect whether the fall is occurred or not. The value goes high when standing up and acceleration value comes and the difference between maximum and minimum and the difference obtained is thrice of the value.

6. CONCLUSION

In this paper, the different fall detection systems that exist were discussed and analyzed, where each one has their own advantages and disadvantages. The accuracy of the system depends on the sensors used and the type of classification. The wearable sensors are the most popular ones when compared to camera-based and ambience sensors. Ambience sensors are highly influenced by environment. The wearable sensor include the use of smart phones and the system also sends notification when a fall is detected. Camera-based sensors, main disadvantage is that the limited coverage and the performance being affected by objects in the environment. The wearable devices main disadvantage is that it is intrusive and the placing of the device on the human body is uncomfortable. Wearable sensors are preferred method as it is practical and allows for continuous monitoring , and can be used to collect real data in a cost-effective approach. A smart phone can be used as a wearable device since a lot of people have them, and it is not intrusive.

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