Portable Automatic Conjecturing and Announcing System for Real-Time Accident Detection

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Abstract- In this paper, we propose the portable automatic conjecturing and announcing system for real-time accident detection. There are six sensors with 3-axis accelerometers and the ZigBee transmission standard mounted on the patients' specific region. After being transmitted to the mobile device through the ZigBee devices, the data are analyzed immediately. When the accident occurs, the mobile device could get the user's location with Assisted Global Positioning System (AGPS) and transmit the information of accident to the medical staff through the 3rd-generation (3G) network. The medical staff will make a careful check of this accident with the patient again. In order to improve the limit of Regional Health Network (RHN), the environment constraints, the mobile computing capability, the power consumption and the device portability are considered in this system architecture we proposed.

Index terms*: ZigBee, 3-axis accelerometers, Accident Detection*

I. INTRODUCTION

With advancements in medical technology, most can receive good medical care, and recently, there are increased studies on senile care systems. Moreover, issues concerning e-Healthcare have become an important focus [1] [2] [3] [4]. At present, handheld devices are growing in popularity worldwide, and have sufficient operational ability to cope with proper and complete operations, and the integration of portable devices with a real-time health care system program is an inevitable trend [5] [6] [7] [8] [9]. Hospital expenditures on medical staff are mandatory, and many patients have to pay large amounts in medical expenses for personal care. Thus, an e-health care system could assist medical staffs to carry out efficient monitoring, in order that medical resources could be applied more efficiently. More importantly, portable devices could expand the movable range of users, so that they are no longer restricted to a specific region. In case of accident, medical staff can utilize portable device, collect users medical records, giving medical staff advanced knowledge and understanding of the users' situation and efficiently enhancing medical service quality [10] [11] [12].

To accurately control user status, this study affixed six tri-axial accelerators at important locations of a body in order to determine accidental occurrences, and directly recognize the occurrence of an accident [13] [14]. Wireless transport protocol, Zigbee, sends sensing data to a portable device, and based on analysis and evaluation by an Accident Analysis Algorithm, the portable device can automatically monitor whether the user is currently in a safe state [15] [16] [17]. When necessary, portable device may access the Assisted Global Positioning System Server via 3G to obtain the user's location. Meanwhile, the analysis results of related data are delivered, as an Extensible Markup Language, to the Hospital Server to notify medical staffs. The remainder of this paper is organized as follows. Section 2 introduces related background, and proposes key points and limitations of care system. Section 3 describes the scenario and system analysis. Section 4 details the system implementation method. Section 5 presents the system performance evaluation. Finally, Section 6 gives the conclusion, and suggestions for directions of future studies.

II. Related work

According to the definition of Emergency Care Research Institute (ECRI), a health care system should have following properties:

1. Substantial cost
2. Efficiency
3. Safe
4. Appropriate equipment meeting patient demand

To provide users with larger activity space, a wireless network must be considered. In addition, since the system needs to operate on a portable device, portable device limitations must be considered:

1. Accuracy
2. Limited power

3. Limited operational ability
4. Real-time operation
5. Base station coverage

In addition, a sensor should be light, safe, have low power consumption, and be easily available to ensure that location sensors on the user can be positioned immediately in case of an accident, and related staffs can be notified in real-time, the system should guarantee network and communication signal quality, and an emergency contact list should be prepared in order that related staffs can be informed immediately.

III. System and scenario analysis

The main purpose of this system is to realize real-time user care through real-time information monitoring, while addressing the handheld device operational ability, power consumption, and accuracy. As shown in Figure 1, behaviors of remote users will affect accelerator values; which are delivered via Zigbee to a portable device and be entered the Accident Analysis Algorithm analysis system. When the system determines that an accident has occurred, the portable device can obtain user location in real time through the Assisted Global Positioning System Server, and notify the hospital network, user's family, and medical staff. The system framework primarily includes three aspects: (1) user end; (2) handheld device end; and (3) hospital network. As shown in Figure 2, the scenario is constructed in a global network in order to provide users with freer activity space, where the user end displays current user behavior. After received by the tri-axial accelerator, the data will be sent in a Zigbee format. The handheld device is the core of the system, thus it should have functions of communication, accident analysis, report system, and network communication. Finally, a hospital should have a smooth network to receive accident incident reports of various users, and medical staffs must be informed immediately of the occurrence of accidents. When necessary, they must ask about the user's condition, have discussions with doctors, and contact user family.

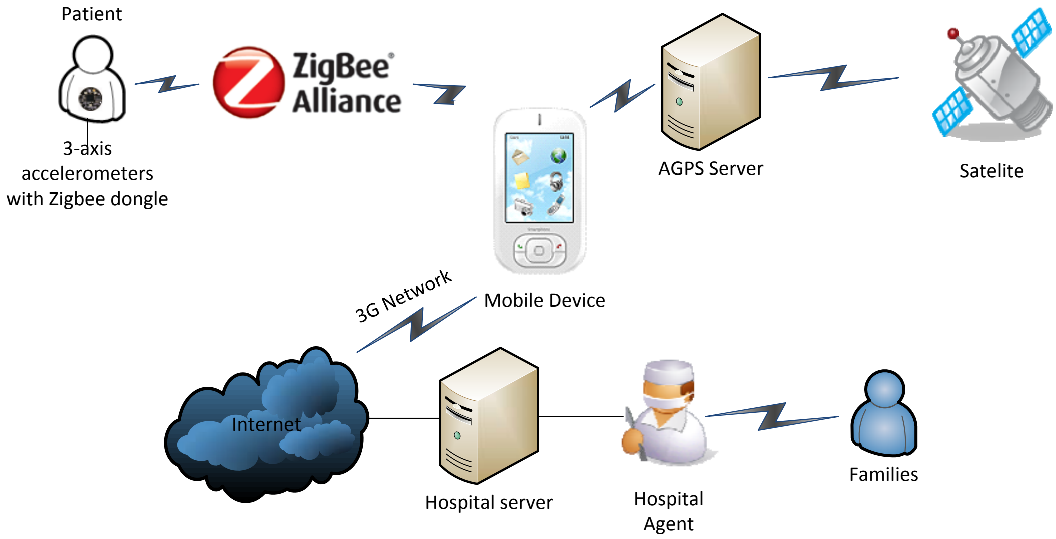

Figure 1. System Scenario

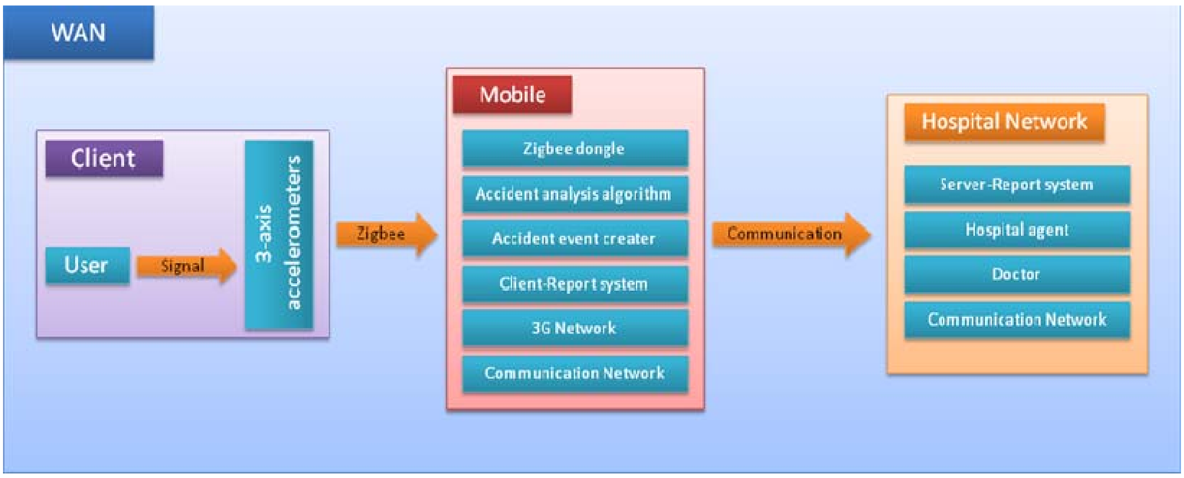

Figure 2. System Architecture

a. Tri-axial Accelerator

To allow the system to have accurate control of sensor values, and improve the judging accuracy of accidents, this study fitted tri-axial accelerator sensors, with Zigbee transmission ability, to user's neck, left/right wrists, waist, and left/right ankles, as shown in Figure 3.

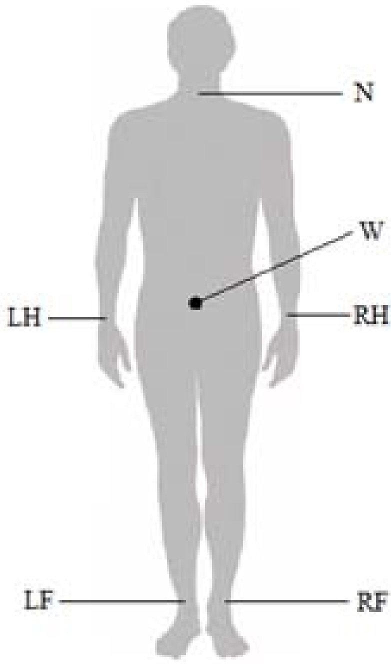

Figure 3. Tri-axial Accelerator Sensors Position

According to the tri-axial component force data of a sensor, the system can obtain force through equation, and analyze whether the user is impacted. The equation is as follows:

$$G = \sqrt[2]{G_{ax}^{2} + G_{ay}^{2} +} \quad (1)$$

Where G_{ax}, G_{ay}, and G_{az} are the components of force on a tri-axial accelerator in various directions, total tri-axial force can be calculated from Eq. (1). As the human body is subject to gravity, total force in a stable state is approximately 1G. Based on gravity distribution, this study used an inverse trigonometric function to obtain relevant angles. As shown in Figure 4, when coordinating an object in X, Y, and Z, it is only subjected to 1G, when in a stable state, regardless of how it rotates. However, component of force at each axis differ, and forms three included angles, with three axes in space, i.e., θ, φ and ρ. By means of an inverse trigonometric function, variation of component force can be converted into rotating angles, as shown in Eqs. (2), (3), and (4):

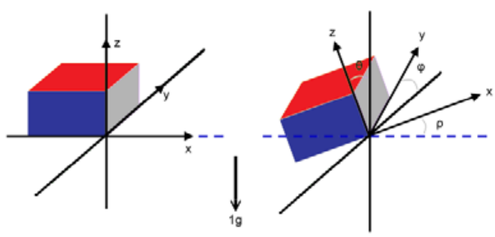

Figure 4. Tri-axial angle

$$\rho = \arctan\left(\frac{A_x}{\sqrt{A_y^2 + A_z^2}}\right) \quad (2)$$

$$\phi = \arctan\left(\frac{A_y}{\sqrt{A_x^2 + A_z^2}}\right) \quad (3)$$

$$\theta = \arctan\left(\frac{\sqrt{A_x^2 + A_y^2}}{A_z}\right) \quad (4)$$

The angle should be calculated when the object acceleration approximates to zero. However, in fact, it fails to ensure that all sensors approximate to equal velocity or still state; therefore, estimation of rotation angle should consider all acceleration parameters, as in Eqs. (3), (4), and (5). The calculated value is the Absolute Angle, and even if all accelerations are considered, the system should still limit the total acceleration to a certain value in order to calculate an accurate angle.

b. Accident Analysis Algorithm

Accident analysis determines accident occurrence primarily through total force and angle. To determine exactly whether there is accident, this study divided accident state into two types: impact falls, and faint and drop. Impact indicates that the force on any sensor on the body exceeds safe levels; falling is divided into two patterns, falling forward, and falling backward. Fainting is an imbalance when a user suddenly feels weak all over. Table 1 shows the accident incident classification.

Table 1. Accident event table

Accident	Sensor	Condition
bump	Neck(N)	$N_G > N_{Gstable}$
	Left Hand(LH)	$LH_G > LH_{Gstable}$
	Right Hand(RH)	$RH_G > RH_{Gstable}$
	Left Feet(LF)	$LF_G > LF_{Gstable}$
	Right Feet(RF)	$RF_G > RF_{Gstable}$
fall down	Waist(W)Neck(N)	$W_{ANG} > W_{ANGstable}$ && $N_{ANG} > N_{ANGstable}$
Swoon	Waist(W)	$W_G > W_{Gstable}$
falling	Waist(W)	$W_G \sim 0$
coma	All	Static over T Secs

Based on theoretical inference, when an object is impacted, there is an acceleration surge due to force. In normal cases, most actions within human expectation are of smooth acceleration. For example, to sit down on a chair, the body moves downward slowly, not instantly. Sitting instantly is risky, and by determining impact not out of human awareness, accidents can be identified. Body angle is a very important indicator; when falling, the body may tilt forward or backward. Thus, when body inclination angle changes acutely, it is falling. When there is acute impact after falling, the fall can be verified, and the injury of the fall position is added to an emergency incident report, alerting medical staff of the situation for decisions.

The experimental results showed that, as indicated in the impact graphs in Figure 5, at approximately 5 sec, there is a peak near 4, which lasts a very short time, and indicates an occurrence of non-spontaneous behavior, the system detects peak occurrences and monitors maintenances. When these two conditions are satisfied, the above inference holds.

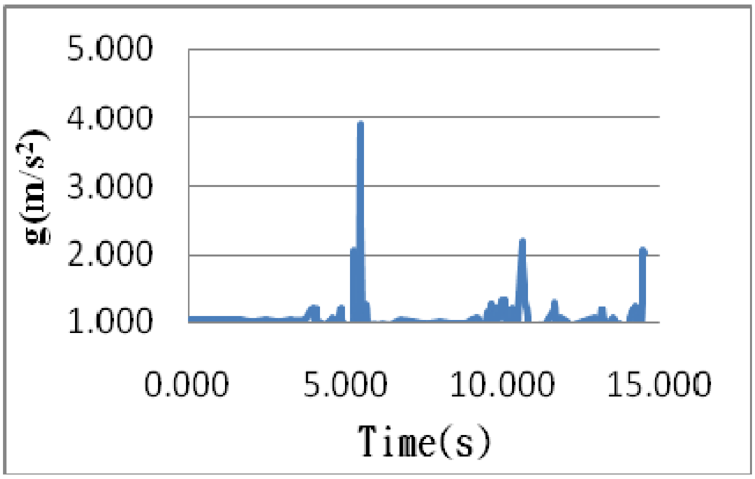

Figure 5. Bump

Therefore, the impact algorithm should include monitoring of number and time of occurrence, where C is at critical value marked Stable in Table 1, e.g., $N_{Gstable}$ denotes acceleration when neck is stable, and T denotes system preset time. Hence, the algorithm can be defined as follows:

- Total acceleration g > critical value C
- Maintaining time not over T

Angle is measured in a similar method, as shown in Figure 6, when a user falls, the angle between axis Z and gravity g is near 90 degrees; taking Figure 6 for example, angles of the user are all above 70 degrees.

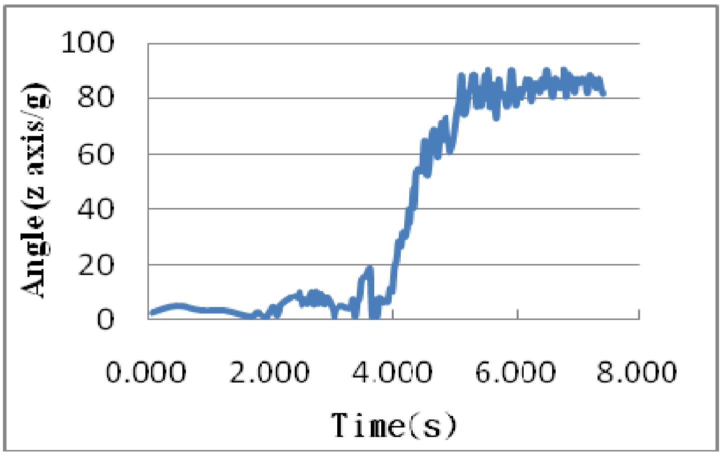

Figure 6. Lying

In this system, the upper body angle can be calculated based on waist and neck acceleration data. When it is observed that body angle increases suddenly, and is under impact, it can be inferred that the user encountered an accident. Later data will record the impacted position of the fall, and accident incident will be documented. System algorithm is expressed as follows, where C is critical angle of lying, or $W_{ANGstable}$ and $N_{ANGstable}$, as shown in Table 1:

- θ>critical angle C
- Impact occurs

As to dropping falls, with the exception of the accidents of users, sensors are ensured not to fall off. Actual test results are shown in Figure 7, when the sensor falls freely, the sensor has no any acceleration.

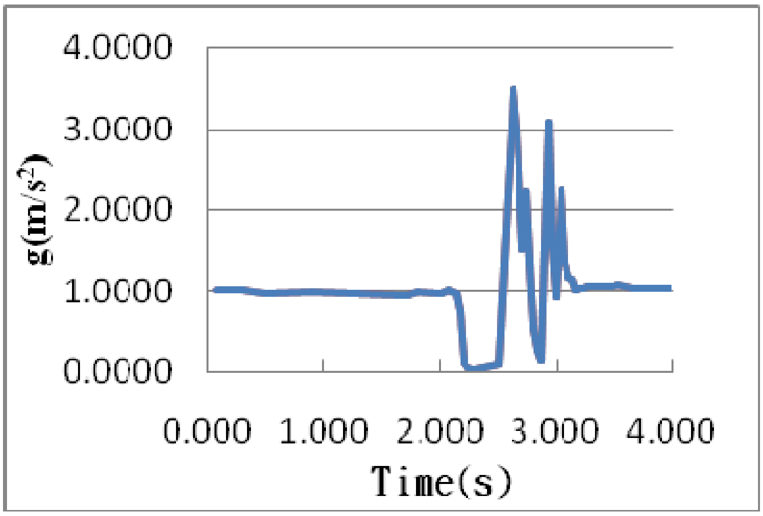

Figure 7. Free Falling

As shown in the figure, at about 2.5 sec, a small interval of zero gravity state lasts for a while. Afterwards, there is an acceleration surge, indicating impact after free fall. Therefore, the algorithm is defined as below, where time T depends on danger altitude:

- Total acceleration g near 0
- Maintaining time over T

In some cases, users may faint without any accident, the tri-axial accelerator fails to judge the fallen detection displacement, however, the human body cannot maintain a motionless state over 5 minutes, thus, when the data are fixed for 5 min and belowΔg, this indicates that the user may have danger. The algorithm is expressed as follows, where g1 and g2 are results at time T_1 and T_2 respectively:

- Total acceleration of each sensor is stable
- $g2-g1<\Delta g$ for maintaining time T

Since the system cannot predict user habits, judgment value of each accident incident, as shown in Table 1, and above algorithms should be preset. Every user has their own parameters, and the system determines the occurrence of accidental incidents. Table 2 lists all parameters to preset, and their definitions:

Table 2. Default Parameter

Parameter	Description
$N_{Gstable}$	Max force for stable neck
$W_{Gstable}$	Max force for stable waist
$LH_{Gstable}$	Max force for stable left hand
$RH_{Gstable}$	Max force for stable right hand
$LF_{Gstable}$	Max force for stable left feet
$RF_{Gstable}$	Max force for stable right feet
$N_{ANGstable}$	The angle between z axis and g of sensor N
$W_{ANGstable}$	The angle between z axis and g of sensor W
Δg	Min difference for identifying coma
T_{swoon}	The min time for identifying coma

In case of accident, the incident report must be sent out through an Extensible Markup Language, thus, accident incident markers are defined in the table below:

Table 3. Accident Label

Accident	Label
Neck bump	NECK-BUMP
Left hand bump	LH-BUMP
Right hand bump	RH-BUMP
Left feet bump	LF-BUMP
Right feet bump	RF-BUMP
fall down	FALL-DOWN

swoon	SWOON
falling	FALLING
coma	COMA

c. Emergency Report System

According to accident subsystem analysis, when a user is in danger, the system will generate an Extensible Markup Language file, which it sends to the hospital server. This file is a user accident report, including user name, call number, time, location, and accidental incident analysis result. An example is as shown as Figure 8:

```
<?xml version="1.0" encoding="big5" ?>
<accident>
  <name>Peter</name>
  <ID>A123456789</ID>
  <tel>0987654321</tel>
  <family>0987654320</family>
  <time>15:21</time>
  <location>
    <longitude>E120:13:18.6</longitude>
    <latitude>N22:59:46.0</latitude>
  </location>
  <event>NECK-BUMP</event>
<accident>
```

Figure 8. User Accident Report

The above figure displays user related data. Through the Assisted Global Positioning System Server, which is built into the handheld device, and shows the current longitude/altitude coordinates of the users. As shown in the above example, the user is located at East Longitude 120°13’18.6”, North Altitude 22°59’46.0”, and user’s neck has suffered impact. After the Hospital Server receives an accident report, medical staffs must confirm with the user by phone; only when a user does not respond or needs assistance is it necessary for further treatment. When such circumstances occur, medical staffs may contact the user’s family through an emergency number, ensuring that the family learns about the user’s status. The whole procedure is as shown in Figure 9.

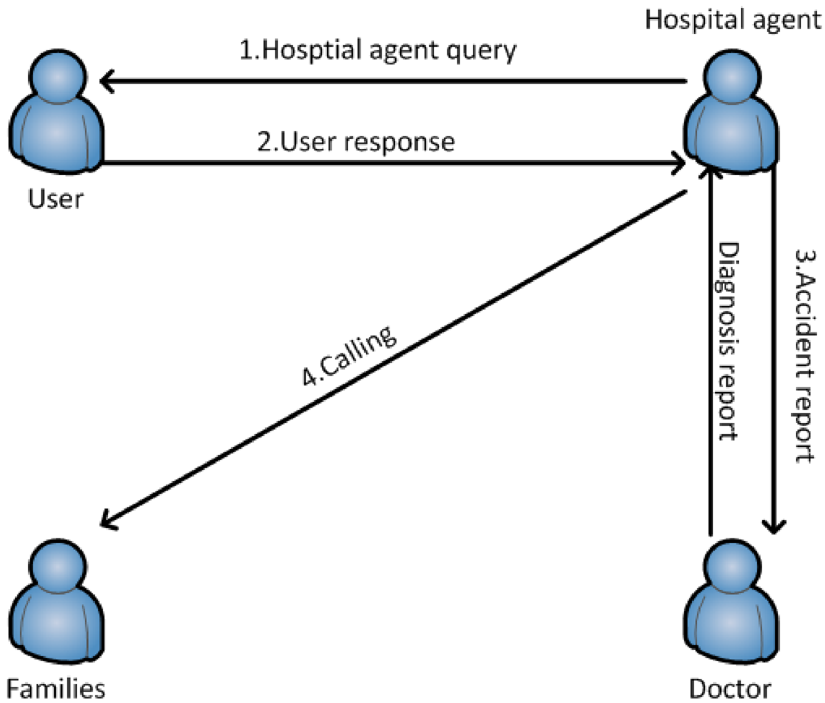

Figure 9. Accident Detection Procedure

Human behaviors are complicated, take the example of opening a door; when opening a heavy door, people tend to push with extra force, and thus, the resulting reaction force is greater in return. In addition, adjusting parameters to avoid wrong judgments, medical staffs will ask the user when the accident occurred in order to filter system errors. When an accident occurs, medical staffs must confirm directly with the user whether there is an accident, and enquiry into user status. If a user does not respond, the status is unknown, thus, medical staffs must rely on accident analysis reports, direct doctor diagnosis, and assistance in treatment. During diagnosis, doctors can contact the user's family from the emergency contact number listed in the accident incident report.

IV. System implementation

V. The sensors on the user end were made from RRD3172MMA7456 (ZSTAR3) by the Free Scale company, and attached to the user's body, as shown in Figures 10 and 11. System implementation was by Hava 2 Micro Edition (J2ME); Java cross-platform ability was used in operations. Hospital Server ran on Java 2 Platform, Standard Edition (J2SE).

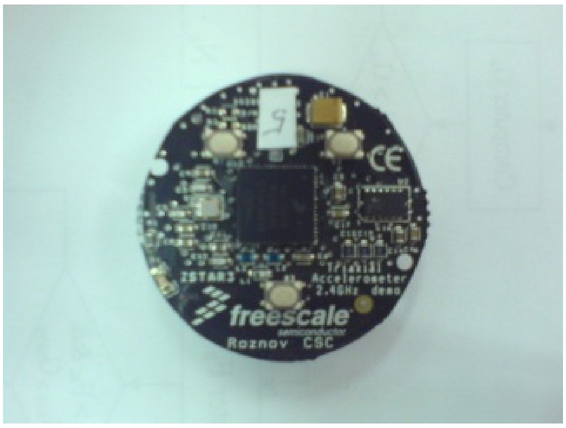

Figure 10. RRD3172MMA7456(ZSTAR3)

Figure 11. Fixed with User

In an accident, a mobile phone issue immediate warning, as shown in Figure 12. The hospital then receives the accident incident information sent by handheld device on the screen, as shown in Figure 13. Later, medical staffs will contact the user directly through contact number listed in the accident incident report, as shown in Figure 14.

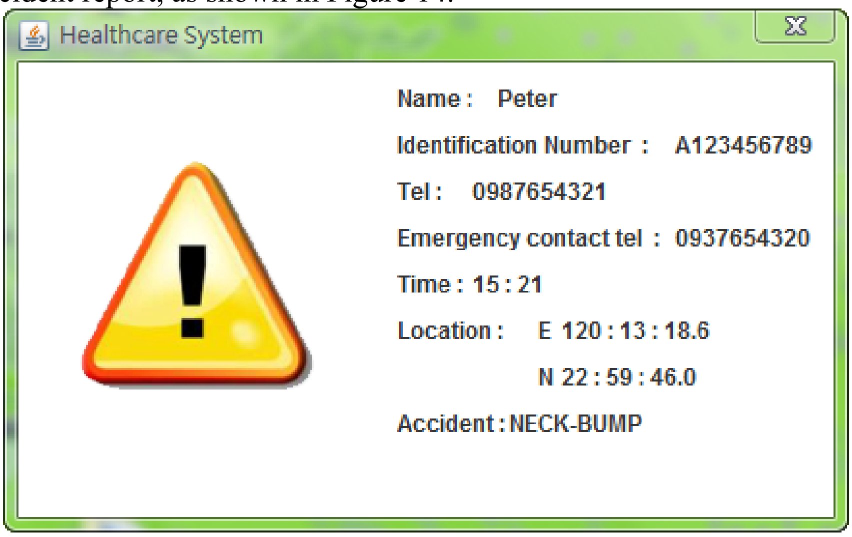

Figure 12. Hospital Server Report

Figure 13. Accident Report

Figure 14 Hospital Agent Query

VI. Performance evaluation

In the proposed system, adjustable individual parameters were set, and accidents were confirmed twice to reduce error probability. Sensors on a user's body must continuously monitor user movement signals, thus, the mobile phone must maintain operations. Therefore, the system performance was studied in two aspects: (1) accuracy, and (2) power consumption.

a. Accuracy

Since accident analysis systems determine the accident only from signal data and user parameters, the user's parameter settings are important. The experiment results are shown in Table 4.

Table 4. Accuracy Test

Event	All	Correctly	Wrong	Rate
Bump	11	11	0	100%
Fall down	16	15	1	93.75%
Swoon	11	9	2	81.82%
Falling	11	11	0	100%
Coma	11	11	0	100%

As seen in some cases, a user's faint and fall could not be distinctly detected. However, when a user is impacted for any cause, the impact accident is recognized. The advantage of this approach is that, if a user suffers an impact accident, and the system misjudges, accident occurrence can still be detected.

b. Power Consumption

Power consumption measurement may vary according to hardware design. However, algorithm operations are not large, and network transmission is needed only in case of accident. Hence, the system can secure maximal power. Table 5 shows the standby time of the test platform, and the state of related functions. Figure 15 shows the power consumption test results.

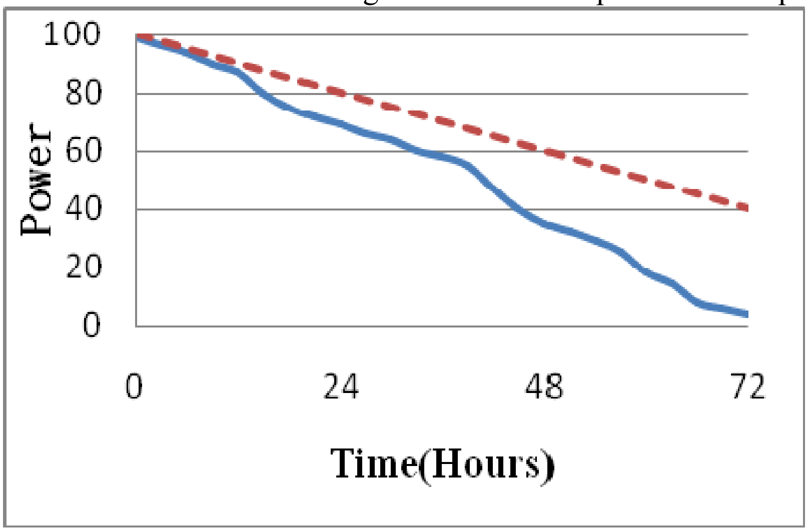

Figure 15. Power Consumption

According to the experimental results, system power consumption is almost linear. Time of use is about 72 hours. As seen, at times of sleep or rest, there is less movement, thus, handheld devices can reduce power consumption. In addition, when not activated, the system can remain in stand by mode for approximately 118 hours; thus, the reduction of operational quantity demands helps reduce power consumption.

VII. Conclusions and future studies

The proposed system was built based on users' convenience, followed by considerations of hardware limitations, and cost. Such design guarantees the satisfaction of users. In the second stage, hardware limitations and costs are key points; which improves practical usability. Portable devices are continuously improved in technology, and are increasingly stronger in functions, thus, if handheld device operational abilities are well utilized, it would be very convenient to develop multi-operation systems on such platforms. Along with network technology progress, more and more applications can be realized in mobile phones, and handheld devices can have learning abilities, which observes and records user's daily life on a weekly basis, and alerts user of relevant notices in a user-friendly manner. These are possible research directions.

References

[1] N. Thome, S. Miguet, and S. Ambellous, "A Real-Time, Multiview Fall Detection System: A LHMM-Based Approach," IEEE Trans. Circuits and Systems for Video Technology, vol. 18, no. 11, 2008, pp. 1522-1532.

[2] L. C. D. Silva, "Audiovisual Sensing Of Human Movements For Home-Care And Security In A Smart Environment," International Journal on Smart Sensing and Intelligent Systems, vol. 1, no 1, 2008, pp. 220-245.

[3] H. Foroughi, A. Naseri, A. Saberi, and H. S. Yazdi, "An eigenspace-based approach for elderly fall detection using Integrated Time Motion Image and Neural Network," Proc. 9th Int'l Conf. Signal Processing (ICSP 2008), IEEE Press, 2008, pp. 1499-1503.

[4] W. Chia-Chi, C. Chin-Yen, L. Po-Yen, C. Yi-Chieh, I. T. Kuo, H. Chih-Ning, and C. Chia-Tai, "Development of a Fall Detecting System for the Elderly Residents," Proc. 2nd Int'l Conf. Bioinformatics and Biomedical Engineering (ICBBE 2008), 2008. IEEE Press, 2008, pp. 1359-1362.

[5] C. Sminchisescu and B. Triggs, "Estimating articulated human motion with covariance scaled sampling," IJRR, vol. 22, no. 6, pp. 371-391, Jun. 2003.

[6] G. Mori, "Recovering 3D human body configurations using shape contexts," IEEE Trans. Pattern Anal. Mach. Intell., vol. 28, no. 7, pp. 1052-1062, Jul. 2006.

[7] P. F. Felzenszwalb and D. P. Huttenlocher, "Pictorial structures for object recognition," Int. J. Comput. Vis., vol. 61, no. 1, pp. 55-79, 2005.

[8] I. Haritaoglu, D. Harwood, and L. Davis, "W4: Real-time surveillance of people and their activities," IEEE Trans. Pattern Anal. Mach. Intell., vol. 18, no. 8, pp. 809-830, Aug. 2000.

[9] H. Zhong, J. Shi, and M. Visontai, "Detecting unusual activities in video," Comput. Vis. Pattern Recognit., 2004. [6] J. W. Davis and A. F. Bobick, "The representation and recognition of action using temporal templates," Comput. Vis. Pattern Recognit., 1997.

[10] L. R. Rabiner, "A tutorial on hidden Markov models and selected applications in speech recognition," Proc. IEEE, vol. 77, pp. 257-286, 1989.

[11] N. M. Oliver, B. Rosario, and A. Pentland, "A bayesian computer vision system for modeling human interactions," Pattern Anal. Mach. Intell., pp. 831-843, 2000.

[12] R. Cucchiara, H. Rita, A. Prati, O. Andrea, R. Vezzani, and C. Roberto, "A multi-camera vision system for fall detection and alarm generation," Expert Syst., vol. 24, no. 5, pp. 334-345, Nov. 2007.

[14] C. Stauffer and W. Grimson, "Learning patterns of activity using realime tracking," Pattern Anal. Mach. Intell., 2000.

[13] N. Thome and S. Miguet, "A robust appearance model for tracking human motions," AVSS, pp. 528-533, 2005.

[14] M. Kangas, A. Konttila, I. Winblad, and T. Jamsa, "Determination of simple thresholds for accelerometry-based parameters for fall detection," Proc. 29th Annual Int'l Conf. Engineering in Medicine and Biology Society (EMBS 2007), IEEE CS Press, 2007, pp. 1367-1370.

[15] D. M. Karantonis, M. R. Narayanan, M. Mathie, N. H. Lovell, and B. G. Celler, "Implementation of a real-time elderly movement classifier using a triaxial accelerometer for ambulatory monitoring," IEEE Trans. Information Technology in Biomedicine, vol. 10, no. 1, 2006, pp. 156-167.

[16] J. Y. Lee and K. Ya, “Multi-Target, Multi-Sensor Tracking Based On Quality-Of-Information And Formal Bayesian Frameworks,” International Journal on Smart Sensing and Intelligent Systems, vol. 1, no 4, 2008, pp. 842-857.

[17] Peter Wide, “Human-Based Sensing – Sensor Systems to Complement Human Perception,” International Journal on Smart Sensing and Intelligent Systems, vol. 1, no 1, 2008, pp. 57-69.