ISSN No. 0976-5697
Volume 4, No. 3, March 2013 (Special Issue)
International Journal of Advanced Research in Computer Science
RESEARCH PAPER
Available Online at www.ijarcs.info

Wireless Sensors Network Based Safe Home to Care Elderly People: A Realistic Approach

Harish Dadhich
Marwar Engineering College & Research Centre, CSE Dept., Jodhpur (RAJ)
dadhich_harish@rediffmail.com

Aarti Choudhary
Marwar Engineering College & Research Centre, CSE Dept., Jodhpur (RAJ)
it.aarti@gmail.com

Abstract: In this paper, we present the design intricacies and implementation details of a wireless sensors network based safe home monitoring system targeted for the elderly people to provide a safe, sound and secured living environment in the society. Programmed system will minimize the number of false messages to be sent to care provider and supports inhabitant through suitable prompts and action to be performed when there is irregular behaviour in the daily activity. Developed system was tested at various elderly homes instead of test bed and the results are encouraging.

Keywords: : Wireless Sensor Networks, Home monitoring, Elder care, Activity recognition, Xbee.

I. INTRODUCTION

Tendency of old, aged people is to stay independently rather than communal, and their livelihood activities are cyclic. In the recent past, there were numerous ideas proposed for the development of monitoring daily activities of elderly people. The intention of the monitoring system for the elderly activity is to provide appropriate assistance in a timely manner and avoid catastrophic situation that may be cause of irregular behavioral activity.

This paper discusses about providing ambient intelligence to home monitoring unit for elderly care. Integrated wireless sensors unit are fabricated to function properly with the house-hold appliances in turn are used for identifying and recognizing the habitual nature of the elderly person.

The system is designed to support people who wish to live alone but, because of old age, ill health or disability, there is some risk in this, which worries their family or friends. The system works on the principle of using wireless sensor units (SU) to monitor the appliance throughout a house and detect when certain desired electrical as well as non-electrical appliances such as bed, toilet, water-use etc. are turned on or used. Rules are defined for appliances to turn on in certain time intervals. The rules are flexible and can be user-defined based on the daily activities of a person. Several levels of alarm conditions have been created based on the combination of rules that are violated. Any number of sensor units may be installed in a house, one each to monitor an electrical appliance or other non-electrical appliances used for daily activities. A central controller unit (CCU) queries the sensor units and logs the data into a Personal Computer (PC) at a pre-defined rate.

Communication between the SU and the controller is using radio-frequency wireless media. The rules inference engine runs on the PC and whenever the situation requires, sends a text message to the care -givers or relatives. The system is completely customizable, allowing the user to select which appliances to monitor and define exactly what is classified as unusual behavior.

During the current decade, multiple methods are proposed for observing and efficient estimation of elderly behaviour in smart home. Monitoring activities of the person based on camera based sensors or Charge Coupled Devices (CCD) cameras are reported [1, 2] for surveillance and security in which the images of the person are taken and analyzed. However, in real circumstances systems of camera based for home monitoring activities require acceptability of the elderly which may not be possible.

Significance of the developed system is that no vision sensors (camera or infra -red) are used, the system is noninvasive, respects the privacy and has found wide acceptance. Feedback from the users of the system indicates a huge acceptability among the elderly community.

In addition to camera based systems, infrared based Small Motion Detectors (SMDs), passing sensors, operation detectors and IR motion sensors have been incorporated in the house for monitoring the human activity behaviour [3] and the interpretation of human activity is limited to only to a few human activities.

There are projects involving wearable health devices [4, 5] integrated with sensors providing continuous monitoring of person's health related issues and daily activities. Using Radio Frequency Identification (RFID) communication technology in elderly center with the necessary hardware gadgets was introduced [6, 8]. However, these projects are for precise purposes and have severe concerns related to security, privacy and legal aspects [7].

If many sensors are installed for monitoring of all appliances used by the elderly in a newly constructed

CONFERENCE PAPER II International Conference on
"Advance Computing and Creating Entrepreneurs (ACCE2013)"
On 19-20 Feb 2013
Organized by
2nd SIG-WNs, Div IV & Udaipur Chapter , CSI , IEEE Computer Society Chapter India Council ,
IEEE Student Chapter Geetanjali Institute of Technical Studies, Udaipur, Rajasthan, India

house, it provides necessary data for elderly monitoring [9]. This situation may not be possible in most practical scenario. For long term usage maintenance issues are more critical. This paper highlights the installation issues and maintenance concerns for effectively running the system in a real environment.

Systems like remote human monitoring using wireless sensor networks [10, 11] were introduced. Also, monitoring and modeling of inhabitant activities of daily living were incorporated [12]. Adding to the hardware setup mentioned earlier, diversity of machine learning methods are proposed for human activity recognition in smart environments e.g. Hidden Markov models and fuzzy logic [14]. However, in real circumstances, using supervised machine learning methods is not practical, as it requires complex processing of data such as labeling of data at run-time. Moreover, offline analysis has been studied for predicting activity recognition and abnormal situation [15]. Offline analysis mechanisms are not suitable for applying in real-time data processing system of inhabitant activity behavior analysis.

There is a big requirement for a stable system which can continuously run without any interruption and can execute several tasks in parallel for maximum behavioral analysis with intelligent mechanism, less cost, flexible, and robust.

The smart software along with the integrated sensor system can recognize the daily activity pattern of elderly in real-time. Important functions of the system are to accurately recognize essential daily activities performed by the elderly and classify them as either regular or irregular behavior.

The paper will present the architecture of the sensors networks, sensor design, and communication protocol, priority of sensor, optimum number of sensors and their locations to make a safe home.

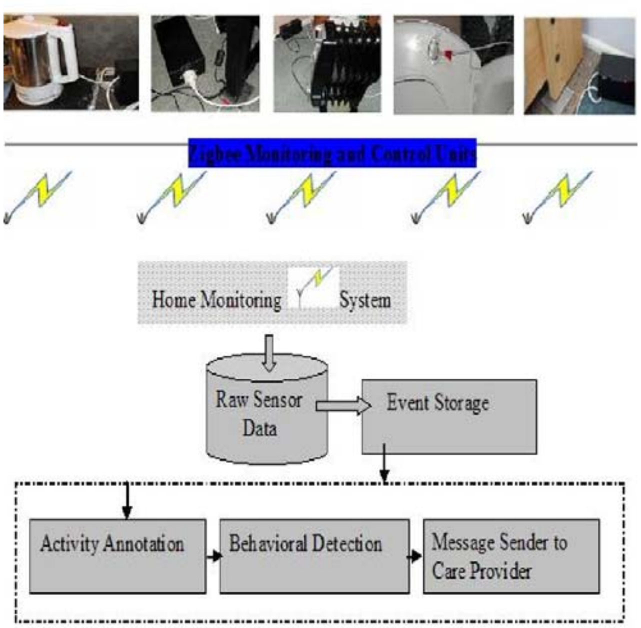


Figure 1. Architecture of the developed system with few sensors and functional description of activity recognition.

II. SYSTEM DESCRIPTION

A. *Architecture of the sensor network:*

Intelligent home monitoring system based on ZigBee wireless sensors has been designed and developed to assist and monitor the elderly people. Fig: 1 depicts the structural design of the developed system. Wireless Sensor Network is designed and developed by following IEEE standard 802.15.4 of ZigBee. Communication is established and managed by the functional set of the modem configuration with appropriate values for Network, security, serial and I/O interfacing.

B. *Data Collection Unit:*

Fig: 2 show the user interface and the front end of our developed system. In real-time processing, the corresponding sensor icon will be highlighted to display if the connected house-hold appliance is active. At any point, of execution elderly activity can be known by viewing to the front end of the system.

Figure 2. Front end of the Data Collection Unit.

Captured raw sensor data are collected, and stored in the processing unit in the form of event based activity (i.e) when status (active or inactive) of the sensor is changed. This is most efficient technique, as it reduces the size of storage to a large extent and more flexible for processing of data in real-time. Figs 3 show the storage file size with respect to continuous and event monitoring at subject 1 elderly house.

Issues like: Storage requirements for continuous flow of data streams and processing of data to generate activity patterns or unusual activity events in real-time were effectively dealt in the current system with the help of event based storage rule.

CONFERENCE PAPER
II International Conference on
"Advance Computing and Creating Entrepreneurs (ACCE2013)"
On 19-20 Feb 2013
Organized by
2nd SIG-WNs, Div IV & Udaipur Chapter , CSI , IEEE Computer Society Chapter India Council ,
IEEE Student Chapter Geetanjali Institute of Technical Studies, Udaipur, Rajasthan, India

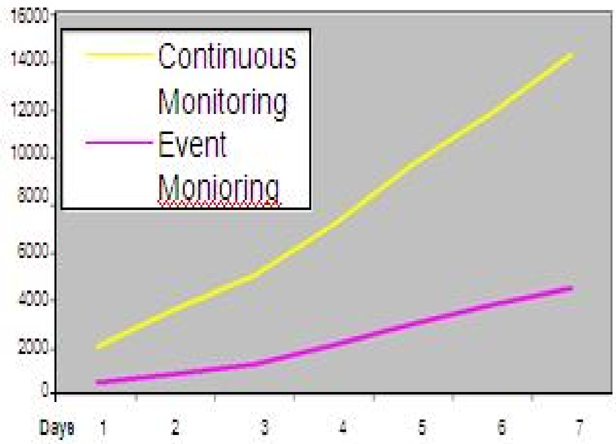


Figure 3. Continuous monitoring vs Event Monitoring based storage.

C. Intelligent Process for recognizing real-time activity behavioral changes

The important functional unit of the system is of the elderly activity behavior. Elderly activity behavior model is systematically learned for long duration by the system based on the daily activities performed in the real-time situation. Activity recognition model for the developed system consists of various tests in real-time execution in order to reduce unnecessary alarms (warning messages) while the system is in use.

Test #1: is done during the event based storage data stage. If the event data match with the predefined unusual event conditions of the system, then the event is flagged with “IR” status otherwise event is flagged with “R” status and updated accordingly in the knowledge base.

Predefined unusual event conditions can be customizable depending on the elderly behavior. In our testing case, based on the questionnaire filled by the elderly, prior to the system installation, unusual event conditions are identified and were inserted at appropriate timing sequence of real-time execution.

Test #2: is performed after the events are triggered with R or IR flag status and while sensor-id is ON, and a particular activity is in begin state. The function of this level test is to discover event activity occurring such as: If the active sensor duration of the present event is greater than existing event duration in the knowledge base then alarm message is generated.

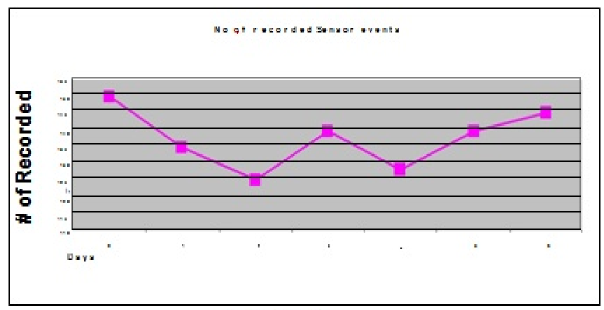
Test #3: is done after the above mentioned two tests are performed. Basically, alarm is generated during this test with the combination of temporal variables: the month, day of week, Hour of Day. Normally, these tests are executed by the system after a certain time period of self learning. In our testing case, we have activated these tests after one week of the day-to-day activity self learning by the system. The alarms generated from this test will help the care giver about the status of elderly activity.

III. EXPERIMENTAL RESULTS

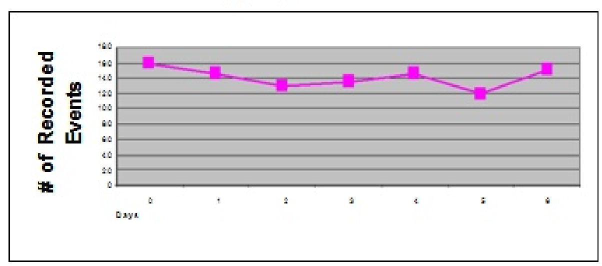
The performance of the developed system was evaluated by running the system at four different elderly houses and recording the data and simultaneously performing the activity recognition in real-time. The houses are equipped with the wireless sensor network with the fabricated sensor units attached to various house-hold appliances. Six electrical sensors are connected to appliances Microwave, Toaster, Water Kettle, Room Heater, TV and Audio. Four force sensors are connected to Bed, Couch, Dining chair and Toilet. One contact sensor is connected to grooming table and one temperature and humidity sensor to monitor the ambient environment readings.

Along with the wireless sensor network a laptop installed with the developed intelligent software connected with Zigbee module acting as coordinator is associated with WSN to collect and monitor the elder behaviour. Programs for Data collection behavioral detection are written using Microsoft Visual Studio. Data was collected for one week of trial run followed by one week of testing. This section concludes with the issues encounter during the installation of the system at various elderly houses.

From Fig.4, it can be inferred that number of recorded sensor events at different subject houses varies and are helpful in the calculation of the activity recognition for day to day activities.



(a) Subject #1



(b) Subject #2

Figure 4. Total number of recorded sensor event over time (time unit=days).

A. Optimal number of sensors to be considered for recognizing the elderly activity behavior:

Based on frequency of the usage of the house -hold appliances at various locations of the elderly house, we were able to determine the importance of the sensor required to be positioned at various points of the house. Frequency (η) of a particular sensor type in a location is determined by eq.1.

CONFERENCE PAPER II International Conference on
“Advance Computing and Creating Entrepreneurs (ACCE2013)”
On 19-20 Feb 2013
Organized by
2nd SIG-WNs, Div IV & Udaipur Chapter , CSI , IEEE Computer Society Chapter India Council ,
IEEE Student Chapter Geetanjali Institute of Technical Studies, Udaipur, Rajasthan, India

$$\eta_T(loc) = \frac{1}{|S_c^l|} \sum_{s \in S_c^l} fT(s) \qquad \text{(eq.1)}$$

Where loc=specific location, c=sensor type, S_c=Set of Sensors of a particular type c, f_T (S) = frequency of sensors over a time period T.

Table 1. Frequency of sensor unit usage for determining an optimal number of sensors required for activity recognition.

Room Type	Sensor Type	Connected to Device	η Trial	η Test
Living	Force, Electrical	Couch, Chair, TV, Heater	0.03, 0.05, 0.05,0.1	0.03, 0.04, 0.03,0.1
Kitchen	Electrical	Microwave, Toaster, Kettle	0.05, 0.05, 0.02	0.04, 0.06, 0.00
Bed	Force	Bed	0.29	0.37
Bath	Force	Toilet	0.35	0.33
Storage	Contact	Cupboard	0.01	0.00

From table I It can be determined that the usage of contact sensor for the storage room is inadequate and can be ignored for determining the elderly activity recognition.

B. Activity Behaviour in terms of Appliance usage duration in real-time:

Fig. 5 show the sensor event information recorded in the computer system at subject 1 elderly house based on the activity of the house -hold appliance. The information consists of sensor_id, status, date, time and Active/Inactive duration followed by usual (R) or unusual event (IR). R or IR flags are generated in real time based on the Test #1 condition incorporated into the system. These conditional checks can be customizable depending on the different elderly activity behaviour.

016,0,4,6,2011,20,36,5,6,S6InADur,0,4,38,R 0021,
57.18,4,6,2011,20,36,10,6
018,1,4,6,2011,20,36,10,6,S8ActDur,0,2,7,IR
016,1,4,6,2011,20,36,11,6,S6ActDur,0,0,5,R
018,0,4,6,2011,20,36,11,6,S8InADur,0,0,1,IR

Figure 5. Figure Sensor events stored in the file during the real time processing.

Table II shows the maximum active duration of the appliances at subject 1 elderly house. The values are recorded simultaneously into appropriate files while the system is running.

Table 2. Subject1 maximum active duration of the appliances during one week trial run.

Date/Appliance	Maximum Active Duration(hh: mm: ss) Bed	Toilet	Chair	TV	Couch
05/06/2011(Sun)	9:35:40	0:12:20	0:17:45	1:10:50	0:57:45
06/06/2011(Mon)7:50:10		0:10:35	0:15:35	0:45:20	1:45:50
07/06/2011(Tue)	9:20:10	0:14:45	0:25:28	2:15:10	2:30:10
08/06/2011(Wed)8:45:50		0:13:55	0:10:20	1:45:50	0:55:20
09/06/2011(Thu)	8:35:25	0:12:20	0:19:45	1:55:30	2:20:10
10/06/2011(Fri)	8:50:25	0:15:45	0:20:35	1:30:20	1:30:45
11/06/2011(Sat)	9:25:15	0:10:55	0:28:30	1:40:10	2:10:35
Maximum		9:35:400:15:450:28:302:15:10			2:20:10

Table 3. Subject1 maximum active duration of the appliances during one week testing phase.

Date/Appliance	Maximum Active Duration(hh: mm: ss) Bed,	Toilet,	Chair,	Couch,
12/06/2011(Sun)	9:25:20,	0:11:10,	0:18:55,	1:27:45,
3/06/2011(Mon)	7:20:45,	0:12:15,	0:16:25,	**3:15:50,**
14/06/2011(Tue)	8:50:37,	0:10:45,	0:20:18,	2:45:20,
15/06/2011(Wed)	9:15:15,	0:12:55,	**0:34:30,**	1:15:20,
16/06/2011(Thu)	9:35:35,	0:15:20,	0:13:15,	2:50:40,
17/06/2011(Fri)	8:30:55,	0:13:45,	0:25:25,	1:45:50,
18/06/2011(Sat)	**10:25:15** ,	0:12:15,	0:18:40,	1:55:35,

C. Activity behavior in terms of sequence of sensor activity:

Sensor activity behavior is recorded simultaneously into appropriate files of the personal computer in order to derive the activity recognition of the elderly. Table IV shows the file contents of elderly activity pattern.

Table 4: Sensor Activity Pattern For Twenty Four Duration At Subject 1 Elderly House.

Day	Sensor Activity Pattern*
0	(0-23:B) 011, 0, 4, 1,6,S1 InADur, 0,16,11,011,0,26,14,6, S1 InADur,0,16,2,011,0,48,32,6,S1 InADur, 0,16,5,…011,23, 41, 39,6,S1InADu r,0,16,8,(0-23:E) (0-23:B)011,0,4,19,0,S1 In ADur,0,16,14,011,0,26,58,0,S1InADur ,0,16,20, …011,23, 18, 4,0,S1InADur,0,15,38,011,23,39,50,0,S1InADur,0,15,29,(0-23:E)
1	(0-23:B) 011,0,1,54,1,S1InADur, 0,15,38,011,0,23,55,1, S1 In ADur,0,15,41 ,… 011,23,56,39,1,S1InADur,0,12,54,(0-23:E) (0-23:B) 011,0,16,13,2,S1InADur, 0,12,50,011,0,36,3,2,S1 In ADur,0,12,50,011,0,55,37,2,S1InADur,0,12,42,…011,14,6,55, 2,S1InADur,0,14,50,(0-23:E)

0-23B, 0-23E: Delimiters,*: sensor-id, start: hour, min, secs, day, inactive duration: hour, min, secs

D. Alarm Generations for unusual behavior:

Alarms (warning sounds) are produced by the system based on the above mentioned two procedures: i) unusual activity behavior in terms of appliance usage duration in real-time and ii) unusual activity behavior when there is a different sequence of sensor activity on a particular day of the week.

Test 2 Rules:

Duration_Appliance (A) > Max_Duration_Trail_Appliance (A) And Duration_Appliance_DayofWeek (A) > Duration_Trail_DayofWeek (A) or NumberofTimes_Active_DayofWeek_Appliance (A) > NumberofTimes_Active_DayofWeek_Trail_Appliance (A)

Based on the above test2 condition alarm messages were generated at three different instances(bold values in Table III) in subject1 house during the testing phase, accordingly

'panic_ope("S018"),		'panic_ope("S017")	
and	'panic_ope("S019")	functions	were
executed to raise alarm		sounds.	

Elderly person pressed sensor_id "000" to deactivate the alarm and consider the excess duration of the appliances as normal duration.

If the alarm is not deactivated, by the elderly person then a message is sent to the care provider.

Similar rules are framed and added into the software system to minimize frequent false alarm messages.

Sensor activity recognition is tested during the second week of system execution and sequence match with the existing pattern is checked with the stored file contents as shown in Table III.

E. Practical Issues in installing the Elderly activity monitoring system at different subject houses:

-Attachment of electrical sensor to the TV electrical plug point.

-Placement of the force sensor beneath the bed.

-Frequent ON and OFF status from the electrical (TV) and force sensors (Bed, Couch).

Bed to heavy to lift for placing force sensor correctly in order to read status.

-No status change from Bed, Couch because of heavy weight. -Unable to plug Toilet force sensor to electrical point.

- Some electrical sensor like TV and microwave were always ON due to the make feature of the respective electrical device.

IV. CONCLUSIONS AND FUTURE WORK

In this paper, we presented sensor activity pattern and predicting the unusual behavior of an elderly person based on the usage of house-hold appliances. The developed system continuously monitor the activity of the elderly person staying alone and generate the sensor activity pattern to analyze and foresee the changes in daily activities of the elderly person. In the near future, the generated activity pattern related to weekdays and weekends will be used to predict the unusual behavior of the elderly person based on the classification model of regular and irregular sensor activity. The investigation on the real-time sensor status monitoring at four different elderly houses with the tests mechanism indicates the reduction of false alarms and optimally predicting the irregular behavior. As the wireless sensor network is scalable, we would like to include sensors related to remaining house-hold appliances at elderly house in order to study highly structured behavioral pattern for more precise abnormal detection.

V. REFERENCES

[1]. Nasution A.H., Emmanuel S., "Intelligent Video Surveillance for Monitoring Elderly in Home Environments", Proceedings of IEEE 9th Workshop on Multimedia Signal Processing, 2007, MMSP 2007, Page(s): 203 – 206.

[2]. Zhongna Z., Wenqing D., Eggert J., Giger J.T., Keller J., Rantz M., Zhihai He., "A real-time system for in-home activity monitoring of elders", Proceedings of the Annual International Conference of IEEE Engineering in Medicine and Biology Society, EMBC 2009, 3-6 Sept. 2009, Page(s):6115-6118.

[3]. Jae Hyuk S., Boreom L., Kwang S P., "Detection of Abnormal Living Patterns for Elderly Living Alone Using Support Vector Data Description", IEEE Transactions on Information Technology in Biomedicine, Vol. 15, No. 3, May 2011, Page (s):438-448.

[4]. Wood A., Stankovic J., Virone G., Selavo L., Zhimin He., Qiuhua Cao., Thao Doan., Yafeng Wu., Lei F., Stoleru R., "Context-aware wireless sensor networks for assisted living and residential monitoring", IEEE Network-2008, Vol:22, No:4, Page(s): 26 – 33.

[5]. Jian Kang Wu, Liang Dong, Wendong Xiao,

CONFERENCE PAPER
II International Conference on
"Advance Computing and Creating Entrepreneurs (ACCE2013)"
On 19-20 Feb 2013
Organized by
2nd SIG-WNs, Div IV & Udaipur Chapter , CSI , IEEE Computer Society Chapter India Council , IEEE Student Chapter Geetanjali Institute of Technical Studies, Udaipur, Rajasthan, India

"Real-time Physical Activity classification and tracking using wearable sensors", Proceedings of the 6th International Conference on Information, Communications & Signal Processing, Dec. 2007, Page(s): 1 – 6.

[6]. Hung K P., Tao G., Wenwei X., Palmes P.P., Jian Z., Wen Long Ng, Chee W.T., Nguyen H. C., "Context-aware middleware for pervasive elderly homecare", IEEE Journal on Selected Areas in Communications, May 2009, Vol: 27, No:4, Page(s):510-524.

[7]. Moshaddique A.A, Kyung-sup K., "Social Issues in Wireless Sensor Networks with Healthcare Perspective", The International Arab Journal of Information Technology, Vol. 8, No. 1, January 2011, Page(s): 34-39.

[8]. Yu-Jin H., Ig-Jae K., Sang C. A., Hyoung-Gon K., "Activity Recognition using Wearable Sensors for Elder Care", Proceedings of the 2nd International Conference on Future Generation Communication and Networking, 2008. FGCN '08, Issue Date: 13-15 Dec. 2008, Vol: 2, Page(s): 302-305.

[9]. Hara K., Omori T., Ueno R., "Detection of unusual human behavior in intelligent house", Proceedings of the 12th IEEE Workshop on Neural Networks for Signal Processing, 2002, Page(s): 697-706.

[10]. Seon-W.L., Yong-Joong K. Gi-Sup L. Byung-Ok C. Nam-Ha L., "A Remote Behavioral Monitoring System for Elders Living Alone", Proceedings of the International Conference on Control, Automation and Systems, ICCAS'07, 2007, Page(s):2725-2730.

[11]. Lymberopoulos D., Bamis A., Eixeira T., Savvides A., "BehaviorScope: Real-Time Remote Human Monitoring Using Sensor Networks", Proceedings of the International Conference on Information Processing in Sensor Networks, IPSN '08, April 2008, Page(s): 533-534.

[12]. George P., George X., George P., "Monitoring and Modeling Simple Everyday Activities of the Elderly at Home", Proceedings of the 7th IEEE Consumer Communications and Networking Conference, CCNC 2010 Vol. 007, No. 01, January 2010, Page(s):1-5.

[13]. Witten H.I., Frank E., "Data Mining:Practical machine Learning tools and techniques",Morgan Kaufmann Pub,2005.

[14]. Medjahed H., Istrate D., Boudy J., Dorizzi B., "Human activities of daily living recognition using fuzzy logic for elderly home monitoring", Proceedings of the IEEE International conference on Fuzzy Systems-2009, Page(s): 2001 – 2006.

[15]. Nazerfard E., Rashidi P.,Cook, D.J., "Discovering Temporal Features and Relations of Activity Patterns", IEEE International Conference on Data Mining Workshops (ICDMW)-2010,Page(s): 1069 - 1075

CONFERENCE PAPER
II International Conference on
"Advance Computing and Creating Entrepreneurs (ACCE2013)"
On 19-20 Feb 2013
Organized by
2nd SIG-WNs, Div IV & Udaipur Chapter , CSI , IEEE Computer Society Chapter India Council ,
IEEE Student Chapter Geetanjali Institute of Technical Studies, Udaipur, Rajasthan, India