A Conceptual Framework for An Elder-Supported Smart Home

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***Abstract*—This paper describes a conceptual framework for smart home that supports elderly people. We describe and compare the principles and general techniques used in automatic human fall detection via a surveillance indoor camera, which are implemented in smart home applications. The comparisons illustrate the benefits and the weak points of each technique. In addition, the challenges and trends are discussed for improving the effective fall detection applications, which is a part in elderly smart care systems in near future.**

***Keywords*—fall detection; elderly care system; smart home; acidenent alarmimg system; human falling warning**

I. INTRODUCTION

Fall detection in the smart elderly caring system is a very useful application of the Internet of Things (IoT) [1-2]. We are now leading to the "Elderly Society", and most of elders stay home alone. The risk of unexpected accidents can happen in anywhere and anytime. Hence, if there is a system being able to alarm and calling somebody to ask for help when the elderly have some accidents, it will decrease the severity of injury in time.

This paper presents the general principles and recent approaches embedded in the falling detection system. The strong and weak points of each technique in many involved researches are also reviewed. Finally, trends and challenges in the near future are discussed as a guideline for developing the further applications.

II. PRINCIPLES OF INDOOR FALL DETECTION SYSTEM

To detect the human fall, a system has to recognize and classify any personal actions into two main postures such as lie-down (falling) and others (standing, siting, bending, and so on). The principles and approaches that fashionably utilized in this decade [3-4] are summarized in a workflow as shown in Fig. 1. As shown in the workflow, most systems is divided into three main parts as the following: Sense, Analysis, and Communication which of those details is explained in the following subsections:

A. Sense Part

Sense is the first part of the workflow that a user signal will be collected from the sensors in systems. These sensors can be divided to two types as explained in the following:

1) Attached or Wearable Sensors Devices: Users have to wear or take these sensors to everywhere for all time. These divices are buit-in the *motion sensors* inside, for example, accelometer, gyroscope, and magnetometer/ digital compass, etc [5-6]. These sensors track the positions and directions in 3-D while a user is moving. Then, the balance of a human body will be calculated for detecting the fall. In addition, there are these sensors buit-in to recent *smart phones*. Therefore, many developers applied the smart phones as a device to detect the fall also [7-8].

2) Camera Sensors: With these devices, there is no attached device on a user. The sensors capture signals as a image from light. Different light souces give the different data images. There are many kinds of light sources, for instance, infrared, visible light, thermography, pressure, etc [9-10]. Image and video processing techniques are applied to this system for analysis the fall of human.

B. Analysis Part

The goal of this part is to classify and recognize the falling postures from others. Therefore, the researchers always define the *falling* as the posture of *lying* down. Generally, the systems are on the alert when detecting lying postures. However, the effective falling analysis is necessary to has more details and more analysis. The differentiation between *real falling*, *normal lying down* and *sleeping* will be described in next section.

Using the techniques in the analysis part, after sensors have collected the personal signal, data will be analyzed with the techniques of *features extraction* and *postures classification*. Many researches applied in varying techniques [3-18].

For the camera sensors, we can divide into two approaches for analysis the input data in various, as follow;

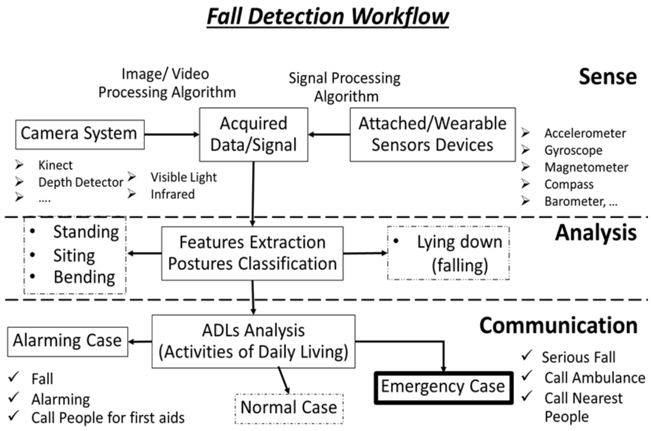

Fig. 1. Principle fashionably utilized in fall detection sysytems in this decade.

1) Base on Input Data in 3-D Axis: The specific instuments as *Kinect* and 3-D tracking programs are neccesary for this system for detecting and tracking particular points in three dimentsions. In the beginning, the system has to register and identify the data of user bodies in each part in three dimentions, such as a head, wrists, elbows, a torso, hips, ankles, etc [11]. After that, when a user is moving, the camera will capture and the program will track each point. Then, the system will analyze all of data and recognize as what he/she is doing. However, the accuracy of this system is very high because the system can detect the depth as well.

2) Base on Input Data in 2D Axis: This is a video survillance system that there is no person identification and registeration preocess for this system. The person will identify in each image frame and recognize the postures automatically [12-13]. Most of researches always classify postures into four types, such as *standing, sitting* (on the chair or floor), *bending* (which is the pose before falling), and *lying* (which is the same pose as falling down).

After termination of the analysis part, the system has only been able to separate the *lying* postures, just only a part for the lying down action.

Anyway, falling is composed of some postures, acting continuously. The continued postures in a such period which act as a behaviors in everyday life is called an *activities of daily living (ADLs)*. To decide which event will be the “falling” action, ADLs will be analyzed as the next part.

C. Communication Part

A challenge problem for applying the falling detection system to the real world efficiently is how to detect the *real falling* from the *normal lying down* and *sleeping*.

Activities of daily living (ADLs) will be created for alarming the accidents from falling. ADLs is based on the *events* of fall analysis, that depends on two periods of time, such as *before,* and *after* falling [14]. The principle of ADLs analysis for fall detection shows as Fig. 2.

ADLs can be analyzed as three cases as follows:

1) Case I: Emergency Case (Alarm and Ambulance Call) Users in this case cannot help themselves in anyhow. It refers to that the users have the high risk to be unconscious (including epilepticus), stop breathing, or injured in the important parts. For instance, heads, backs, and legs [15-16]. With these results, the system aims to detect the events when users change the postures from standing to lying immediately (the period of *before-falling* is less than 5 second) and identify this events as *Emergency case.* The system has to be alarm and activate to other systems in the house for co-acting. It can be devided into 3 steps;

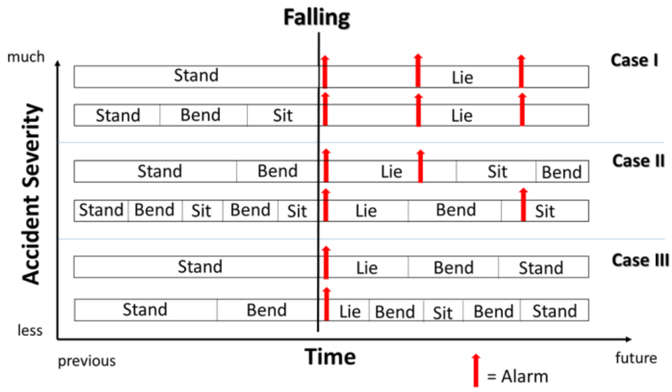

Fig. 2. Principle of ADLs analysis for fall detection

- First alarming *(warning step)*: Alarming system in the house will be woring for calling someone in surrounding help them. Moreover, the message will be sent to the relative's mobiles. Then, the system monitors the *after* period of falling, respectively. If users cannot change the posture to sitting, bending, or standing in time (1-3 minutes), it goes through second alarming.

- Second alarming *(serious warning)*: If users cannot change the posture to anyhow in 1-5 minutes (This case means to users will be unconscious) or users can change the posture to siting or bending but they cannot change to standing in 5-10 minutes. Alarming will be working again and lounder. After that, the third alrming will be continued.

- Third alarming *(critical warning)*: The system calls to ambulance automaticaly and sends alarms to the family or nearest people to help elders in time.

2) Case II: Requiring Help Case (Alarm and Warning) Users in this case are not severed as case I. They cannot get up from falling by themselves but still be conscious. They have risk to have some injury and need someone to help them to go to hospital or get the first aids in time. The system detects a before-falling period as changing the potures, for example, standing→bending→sitting→lying (5-30 seconds) and after-falling period as taking posture *sitting* or *bending* about 3-10 minutes. Hence, the system will work as the first and second alarming as sending the alarms and calling to the nearest person to help elderly with the first aids and go to the hospital later.

3) Case III: Normal Case There is no fall. It is refer to normal lying down and sleeping. The system define these events as the peiod of before-falling is > 30 sec. In addition, the event is evaluated as *normal fall*, defined by peiod of after-falling is 5-10 mins. It refers that users can help themselves and have gotten just a little pain. The system will refer to the after-falling period as they can change the postures to standing.

Notice that, the falling detection system should be connected and collaborated with surveillance system and telecommunication system in smart home. In order to that when a critical accidence occurs, the system can call for the ambulance and nearest people immediately. Furthermore, it can help to decrease the risk of severe harm from the accident and prevent the accidental death in elderly from falling as well, which is the main aim of fall detection system.

III. Benefits and Defects of Each Technique

The strong and weak points of each approach that were used in the fall detection in this decade are compared as Table I.

TABLE I. THE BEFITS AND DEFECTS COMPARING EACH APPROACHES THAT WERE USED IN RECENT FALL DETECTION SYSTEM

Topics	Approaches and Techniques			
	Wearable Sensors	Smart Phone	Camera system	Kinect
Attach with Users all time	X	X	O	O
Users feel comfortable	X	X	O	O
Very high accuracy	O	X	O	O
Cheap price/ Low cost	X	O	O	X
Independent from surrounding/ environment	O	O	X	O
Limit resources	O	X	O	O
No pesonal setting before beginning use	X	O	O	X

O = Benefits, x = Defects,

The commercial fall-detection instrument in nowadays, most are in a type of wearable devices. As the results, these devices are decided and used in specify work, there are no problem about the resources to support them. Moreover, the sensors can receive the signal form human directly. So, the system can make the high accuracy in detection. However, because of specific instruments, it makes the high cost and have the complicate set up. In addition, the users have to carry devices all time that makes the users feel uncomfortable when using.

Developers have attempted to apply the Smart-phone to use as the wearable devices to detect the fall-detection because it is a device that most of everyone use. There are some specific instruments for measuring the direction, such as, gyroscope, digital compass, etc., were built in also. Hence, everyone can access to them that makes it more popular. Anyway, the limitation of resources, which have to share on the phone, makes the accuracy, is not satisfy. So, the developers have to continue to develop the applications and the resources for more efficiently.

The idea to develop the camera system to detect the falling has a main purpose to apply to the surveillance system in the house in order to make people more convenient and comfortable. This system, people cannot attach or carry any devices. So, it can save cost also. Furthermore, this system can get high accuracy because the efficient techniques of image and video processing and it is a part of smart home, so, there is no problem with the limitation of resources. Nevertheless, an only disadvantage of this system is it depend on surrounding because the input signal is the images. It is not receive directly from the human. Hence, if we change the scene for capturing, the system have to renew register the background.

The process of applying Kinect to fall detection is close to camera system. The system can capture the image of users automatically. The users do not carry or attach any devices. Thus, users feel comfortable and very convenient, that they can living as usual. Kinect capture the image same as the camera system but it can know the depth and cutout the background automatically. These advantages make this system get higher accuracy. However, Kinect system have a pre-process for register each person before using. Therefore, every time when there is a new person in the family, users have to register the body of the new person. It cannot detect the new person correctly without registration.

Anyway, these systems are still in process of development. There are a lot of challenged target and problem to reach and solve in near future, in order to make the system get high accuracy, flexible, more efficient, and most of users are able and easy to access it. These topics will discuss in the next part.

IV. Challenges and Trends for Near Futer

Trends in near future for development of fall detection in smart home system and the challenged problem that the developers will face, we discuss as each topic, as follow;

A. *Acceptability and Practicality*

Recently, the researches for acceptability and practicality of this technology is still too less. A problem is the elderly always adjust themselves and accept to the new technology difficultly. Hence, the system, utilizing with them, should be designed based on the principles of easy, comfortable, and flexible [17]. In order to the elderly will rely on the system.

B. *Standardization*

Recently, there is no general database in this field. Most of researches built and tested their system with their own dataset. We do not know and cannot compare the accuracy and efficiency to each other as the same standard. Thus, if there is a general dataset, the improvement will be faster and in the same right way.

C. Accuracy, Robustness and Efficiency

As the results, the recent system is still during of development, the developers have to concern that the percentages of accuracy and effectiveness are all in the laboratory. For example, users were setup to carry the smart-phones in the standardized position all time in laboratory. Thus, they could get very high accuracy [18-19]. But in practice, gentlemen always collect them in their pockets and ladies keep them in their handbags [20]. As this mentioned situation, the smart-phones have to be applied in unusual, which the developers have to concern more. Hence, the percentage of recognition in practical will be decreased [21] because of the unexpected environment and various behaviors of users. The researchers that test with the simulation of real events are still more required.

Moreover, most experiments in the previous research were setup the ADLs and asked volunteers perform such a time. It is not enough for testing the robustness in real situations, which do not have the certain patterns of ADLs and monitoring all-day and all-night continuously more than several months. Hence, a way to test the robustness of systems as research that proposed the experiment for testing the significant number of false activations [22]. This is a starting point of the research that proposed a good measurement. It is a way to guarantee the efficiency of systems for working in the real situations.

D. Sensitivity, and Specificity

In the real situations, the system has to work all 24 hours and will be mainly applied to elderly. Hence, we have to concern to these two issues also such as high sensitivity and specificity, beside from the accuracy and robustness.

Most datasets are performed by the youth but the real target is elder [23]. Therefore, the ADLs analysis will be different. Some researches built the falling dataset from the elderly [24]. However, it is too risk and dangerous for asking the elder perform "falling" as the database. Consequently, the developers have to plan for saving also.

E. Applicability and Limitation

The interest trends of development is the application on *smart phone* because it has the motion sensors, and it is an important device that everyone have in recent every life [25]. A research [26] surveyed the application that the elderly searched as the most word, and they found that the word of "health-wellness-homecare" and "safety-security-mobility" were the most searched word. It replied that it is still a good idea for developing the fall detection application on smart-phones because it can be access to the most users.

Nevertheless, we have concerned that the smart phone has not been built for main purpose of the home care system. So, it is one of the challenging problems that the developers have to improve the system within the limited resource.

F. Security and Privacy

Security of using devices is important because they will be use with elderly. The sensors of devices should be properly protected for the damage from using. Meanwhile, the electric devices have to be safety for the elserly also, espectcialy the wearable or attached device. These are from the wise design and good creation.

Another important point is the scurity and privacy of the access to data. The behaviour of users who live in the house is the important personal data. The piracy of personal data can be happen because the system will be connected to the internet all time. This is the next problem when the system will be practical used widely. The developer have to mainly concern to this silent risk also.

V. Conclusion

Automatic fall detection for elderly care system was developed continuously in this decade. This paper describes the principle of system, reviews the involved techniques, and discusses to the challenges and trends for development in further. The target for the near future is the attempt for applying to the approximate real situation. With all of hope, when this system is applied in widely practical, it will improve our quality of life.

References

[1] Prajapati, T., Bhatt N. and Mistry, D. "Review Article: A Survey Paper on Wearable Sensors based Fall Detection". *International Journal of Computer Applications,* 115(13): 15-18, April 2015.

[2] Igual, R., Medrano, C. and Plaza, I. "Challenges, Issues and Trends in Fall Detection Syst-ems". *BioMedical Engineering OnLine2013*, 12: 66, 2013.

[3] L. Zhu, P. Zhou, A. Pan, J. Guo, W. Sun, L. Wang, X. Chen, and Z. Liu, "A Survey of Fall Detection Algorithm for Elderly Health Monitoring", in *IEEE 5th Int. Conf. on Big Data and Cloud Comp. (BDCloud),* Dalian, 2015, pp: 270-274.

[4] M. Mubashir, L. Shao, and L. Seed, "A Survey on Fall Detection: Principles and Approaches". *Neurocomput,* 100, pp. 144-152, 2013.

[5] S. Mann, "Wearable Computing". *Interaction Design Foundation. https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/wearable-computing.*(6/6/2017).

[6] J.T. Perry, S. Kellog, S.M. Vaidya, J.-H.Youn, H. Ali, and H. Sharif, "Survey and Evaluation of Real-time Fall Detection Approaches," in *6th Int. Sym. on High-Cap. Optic. Net. and Enable. Tech. (HONET),* vol., no., pp. 158-164, 28-30 Dec. 2009.

[7] N.D. Lane, E. , Miluzzo, H. Lu, D. Peebles, T. Choudhury, and A.T. Campbell, "A Survey of Mobile Phone Sensing," in *IEEEC omm. Mag.*, vol. 48, no. 9, pp. 140-150, Sep. 2010.

[8] M. A. Habib, M. S. Mohktar, S. B. Kamaruzzaman, K. S. Lim, T. M. Pin, and F. Ibrahim, "Smart phone-Based Solutions for Fall Detection and Prevention: Challenges and Open Issues". *Sensors (Basel, Switzerland)*, 14(4), pp. 7181-7208, 2014.

[9] Z. Zhang, C. Conly, and V. Athitsos, "A Survey on Vision-based Fall Detection" *In Proc. of the 8th ACM Int. Conf. on Pervasive Tech. Related to Assist. Environ.* (PETRA '15). ACM, New York, NY, USA., Article 46, 7 pages, 2015.

[10] H.W. Tzeng, M.Y. Chen, and J.Y. Chen. "Design of Fall Detection System with Floor Pressure and Infrared Image," in *Sys. Sci. & Eng. (ICSSE), 2010 Int. Conf. on*, vol., no., pp. 131-135, 1-3, July 2010.

[11] E. E. Stone, and M. Skubic, "Fall Detection in Homes of Older Adults Using the Microsoft Kinect," in *IEEE Jour. of Biomed. and Health Inform.,* vol. 19, no. 1, pp. 290-301, Jan. 2015.

[12] C.F. Juang, and C.M. Chang, "Human Body Posture Classification by a Neural Fuzzy Network and Home Care System Application," in *IEEE Trans. on Sys., Man. Cyber., Part A: Sys. and Hum*, vol. 37, no. 6, pp. 984-994, Nov. 2007.

[13] P. Silapasuphakornwong, S. Phimoltares, C. Lursinsap, and A. Hansuebsai, "Posture Recognition Invariant to Background, Cloth Textures, Body Size, and Camera Distance Using Morphological Geometry," *in Inter. Conf. on Mach. Learn. and Cyber. (ICMLC),* vol. 3, pp. 1130-1135, 11-14 July 2010.

[14] K.Wongpatikaseree, A.O. Lim, Y. Tan, and H. Kanai, "Range-based Algorithm for Posture Classification and Fall-down Detection in Smart Homecare System," in *Consumer Electronics (GCCE), 2012 IEEE 1st Global Conf. on.*, pp. 243-247, 2-5 Oct. 2012.

[15] WHO Library. "WHo Global report on falls Prevention in older Age : Chapter 1, Magnitude of fall", *France,* 2007, pp. 1-7. www.who.int/ageing/publications/Falls_prevention7March.pdf (aviable 9/8/2017)

[16] A. Cherian, S. V. Thomas, "Status epilepticus", *Annals of Indian Academy of Neurology*, vol.12, no.3, pp. 140–153, 2009. http://doi.org/10.4103/0972-2327.56312

[17] S. Kurniawan, "Older people and mobile phones: A Multi-method Investigation". *Inter. Jour of Hum-Comp. Studies*, 66(12), pp. 889-901, 2008.

[18] J. Dai, X. Bai, Z. Yang, Z. Shen, and D. Xuan. "PerFallD: A Pervasive Fall Detection System Using Mobile Phones," in *Pervasive Comp. and Comm. Workshops (PERCOM Workshops), 8th IEEE Inter.Conf. on*, pp. 292-297, 2010.

[19] B. Aguiar, T. Rocha, J. Silva, and I. Sousa, "Accelerometer-based Fall Detection for Smart phones," in *Med. Measur. and App. (MeMeA), 2014 IEEE Inter. Symp. on*, pp. 1-6, 11-12 June 2014.

[20] M. V. Albert, K. Kording, M. Herrmann, and A. Jayaraman,"Fall Classification by Machine Learning Using Mobile Phones". *PLoSONE*, 7(5), 2012.

[21] N.Noury, A. Fleury, P. Rumeau, A.K. Bourke, G.O. Laighin,V. Rialle, J.E. Lundy, "Fall Detection - Principles and Methods," *in Engineering in Medicine and Biology Society, 2007. EMBS 2007. 29th Annual Inter. Conf. of the IEEE*, vol., no., pp. 1663-1666, 22-26 Aug. 2007.

[22] S. Brownsell, and M. S. Hawley, "Automatic Fall Detectors and the Fear of Falling".*J Telemed Telecare.* 10(5), pp. 262-266, 2004.

[23] F. Bagalà, C. Becker, A. Cappello, L. Chiari, K. Aminian, J. M. Hausdorff, and J. Klenk, J. "Evaluation of Accelerometer-Based Fall Detection Algorithms on Real-World Falls". *PLoS ONE*, *7*(5), e37062, 2012.

[24] M. Kangas, I. Vikman, J. Wiklander, P. Lindgren, L. Nyberg, and T. Jämsä, "Sensitivity and Specificity of Fall Detection in People Aged 40 Years and Over" *Gait Posture.* 29(4), pp. 571-574, 2009.

[25] https://itunes.apple.com/us/app/fall-safety-app-for-pros/id870864283?mt=8 (accessed 18/08/2017)

[26] I. Plaza, L. Martín, S. Martin, and C. Medrano, "Mobile Applications in an Aging Society: Status and Trends", *Journal of Systems and Software*, 84(11), pp. 1977-1988, 2011.

[27] P .Silapasuphakornwong, C .Lursinsap" :Automatic Fall Surveillance and Detection System for Elders Inside Smart Home "in *A Memorial Book on The Occasion of Her Royal Highness Princess Maha Chakri Sirindhorn's 60th Birthday Anniversary*, Bangkok, pp 231-244, 2016.