Falling Angel – A Wrist Worn Fall Detection System Using K-NN Algorithm

Hamidur Rahman[1(✉)], Johan Sandberg[1], Lennart Eriksson[1], Mohammad Heidari[1], Jan Arwald[2], Peter Eriksson[2], Shahina Begum[1], Maria Lindén[1], and Mobyen Uddin Ahmed[1]

[1] School of Innovation, Design and Engineering, Mälardalen University, Västerås, Sweden
{hamidur.rahman, johan.sandberg, lennart.eriksson, mohammad.heidari, shahina.begum, maria.linden, mobyen.ahmed}@mdh.se

[2] Exformation AB, Lidingö, Sweden
{jan.arwald, peter.eriksson}@exformation.com

Abstract. A wrist worn fall detection system has been developed where the accelerometer data from an angel sensor is analyzed by a two-layered algorithm in an android phone. Here, the first layer uses a threshold to find potential falls and if the thresholds are met, then in the second layer a machine learning i.e., k-Nearest Neighbor (k-NN) algorithm analyses the data to differentiate it from Activities of Daily Living (ADL) in order to filter out false positives. The final result of this project using the k-NN algorithm provides a classification sensitivity of 96.4%. Here, the acquired sensitivity is 88.1% for the fall detection and the specificity for ADL is 98.1%.

Keywords: Fall detection · Angel device · k-Nearest Neighbor

1 Introduction

Today fall-related injuries are increasing due to the increasing life expectancy. So, falls amongst elderly is a major global problem which has an expensive effect in the society. In a Swedish report from 2013 it has been shown that more than 270,000 fall accidents happened where patients had to visit the emergency room [1]. Since the risk of fatality increases by 12% if a person is not found within the first hour after a fall has occurred, fall detection system that both are accurate and comfortable to wear are urgently needed [2]. There are several approaches for detecting falls such as Vision based, wearable devices and other ambient devices [3–5]. In this paper we present a wrist worn fall detection system using a built-in accelerometer in an Angel (M1)[1] sensor device. This system consist of a bracelet that has several sensors and communicates with a smart phone with the help of the Bluetooth Low Energy protocol (BLE). We also present an algorithm using thresholds to detect all potential falls and if a fall is detected on the

[1] www.angelsensor.com.

M.U. Ahmed et al. (Eds.): HealthyIoT 2016, LNICST 187, pp. 148–151, 2016.
DOI: 10.1007/978-3-319-51234-1_25

wrist worn device the buffered data is analyzed using the k-Nearest Neighbor (k-NN) [6] algorithm on the connected phone to confirm a fall.

2 Data Collection, Data Analysis and Method

The data collection was taken place by 3 male subjects of different age, height and weight using Angel sensor. A mattress was placed on the floor and a bench of equal height was placed besides the mattress, the test subjects were told to fall 10 times for each defined event. All the data from the Angel sensor is saved in a Comma Separated Variable (CSV) file and the application at the same time gather accelerometer data from the phone. Initially the raw data is visualized using a MATLAB[2] function which shows that the data from both the phone and Angel sensor follows 3 main phases as shown in Fig. 1(a). The first phase is rather stable state and falling toward the ground (the G-force drops before the person hits the ground), in the second phase the person hits the ground (the G-force gets very high for a short time and then bounces up and down a few times) and in the third and final phase the person lays still on the ground (the G-force smooths out and gets close to the gravity on earth 9.807 m/s^2). Comparing falls against walking for instance, which is one of the more common ADL that will happen during a regular day and it is seen that the pattern is repetitive and the distances between the lowest point and the highest is further apart from each other.

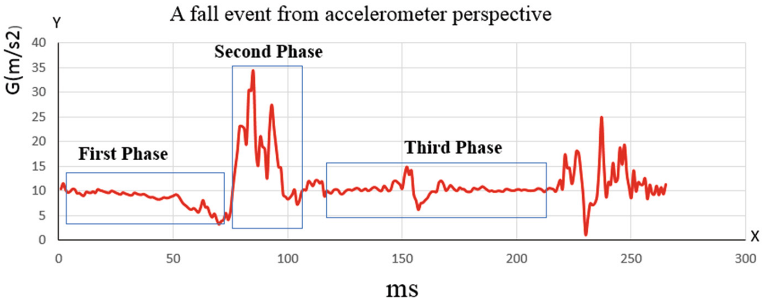

Fig. 1. Accelerometer perspective of a fall event

This knowledge helps when selecting and tuning the algorithms used later on. For the pattern recognition part of the fall detection system, the machine learning algorithm k-Nearest Neighbor (k-NN) was chosen due to its somewhat low computational power in comparison to other techniques such as neural networks etc. The strength of this is that the system can look at the similarities from other activities that it has been trained with and then make a classification based on the training data.

[2] "MATLAB Computer Vision Toolbox," R2013a ed: The MathWorks Inc., pp. Natick, Massachusetts, United States.

3 Result and Evaluation

The evaluation is performed by looking at the True Positives (TP) (a fall occurs and registered), True Negatives (TN) (an ADL is performed and a fall is not registered), False Positive (FP) (an ADL is performed but the phone registered it as a fall), and False Negative (FN) (a fall occurred but the phone did not register it as a fall). To evaluate the sensitivity, the total number of tests were 210, 10 falls per subject for every case and FN can be divided into two different types; one is Missed Falls (MF) which is when the threshold algorithm is not finding a fall and the other one is the real FN when the k-NN classified the fall incorrectly. To evaluate the specificity of the system, 8 test subjects were told to perform the different scenarios (ADL) as used in the data collection part. Each subject had to do the same activity five times which lead to a total of 160 cases. The result of the evaluation is shown in Table 1.

Table 1. The evaluation result

Features	Evaluation		
	Sensitivity with MF	Sensitivity k-NN	Specificity
No. of cases	160	141	160
TP/TN	141	136	157
FP/FN	19	5	3
Result (%)	88.1%	96.4%	98.1%

It is seen from Table 1 that k-NN algorithm is rather effective in differentiating falls from ADLs. This evaluation shows that the algorithms provide good result without creating false positives. The accelerometer based techniques shows that the system can work in a real environment. Devices worn on the waist are likely to add less interference by sudden movement when they are close to body's center of gravity. Since the angel sensor can be used like any ordinary watch it feels less intrusive and more comfortable to the user. However, it produces more sudden readings which need to be filtered out using machine learning i.e., K-NN algorithm.

4 Conclusion

Falling angel project aims at detecting fall in elderlies using Angel device with the help of machine learning on an android mobile phone. It pairs with a nearby Angel sensor via low energy Bluetooth and the results show a promising 96.4% correct classification during a fall event in the machine learning part and overall about 88.1% of sensitivity in fall detection. To our knowledge the application of a threshold algorithm together with a machine learning i.e., K-NN algorithm using a wrist worn accelerometer that work independently from the phone data is limited. However, the there are possible ways to improve the algorithm using experience based learning methods e.g., case-based reasoning.

Acknowledgement. We would like to express our gratitude to all the participants, who give their time and data.

References

1. Fallolyckor. Myndigheter för sammh ällskydd och beredskap, statistic och analys, MSB752. https://www.msb.se/RibData/Filer/pdf/27442.pdf
2. W. H. Organization: Who global report on falls prevention in older age. http://www.who.int/ageing/publications/Falls_prevention7March.pdf
3. Fahmi, P.N.A., Viet, V., Deok-Jai, C.: Semi-supervised fall detection algorithm using fall indicators in smartphone. In: 6th International Conference on Ubiquitous Information Management and Communication, ICUIMC 2012, pp. 122:1–122:9 (2012)
4. Fudickar, S., Karth, C., Mahr, P., Schnor, B.: Fall-detection simulator for accelerometers with in-hardware preprocessing. In: 5th International Conference on PErvasive Technologies Related to Assistive Environments, PETRA 2012, New York, NY, USA, pp. 41:1–41:7 (2012)
5. Vilarinho, T., Farshchian, B., Bajer, D.G., Dahl, O.H., Egge, I., Hegdal, S.S., et al.: A combined smartphone and smartwatch fall detection system. In: IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing (CIT/IUCC/DASC/PICOM), pp. 1443–1448, October 2015
6. Altman, N.S.: An introduction to kernel and nearest-neighbor nonparametric regression. Am. Stat. **46**, 175–185 (1992)