FALL DETECTION FOR ELDERLY PEOPLE USING MACHINE LEARNING

Sejal Badgujar
Department of Electrical and Electronics Engineering
Amrita School of Engineering, Coimbatore
Amrita VishwaVidyapeetham, India.
bsejalnil@gmail.com

Anju S. Pillai
Department of Electrical and Electronics Engineering
Amrita School of Engineering, Coimbatore
Amrita VishwaVidyapeetham, India.
s_anju@cb.amrita.edu

***Abstract*—Health is the major worrisome point whose impalpability increases with increase in the age. Thus, taking care of elders is very important responsibility. In such scenario, technology is helping people by providing living assistance. One of the major causes of health degradation or death of elders is 'fall'. In this paper, a fall detection system is proposed based on machine learning. The system detects falls by classifying different activities into fall and non-fall actions and alert the relative or care taker of the elderly person in case of emergency. The dataset SisFall with variety of activities of multiple participants is used to calculate features. Machine learning algorithms SVM and decision tree are used to detect the falls on the basis of calculated features. The system acquires accuracy up to 96% by using decision tree algorithm.**

***Index Terms*—Fall detection, Gait analysis, Machine learning, Activities of daily living, Elderly care, Health care systems.**

I. INTRODUCTION

Now-a-days elderly people live alone at home because of poor conditions, different working culture of people and due to many other reasons. According to World Health Organization (WHO) studies, falls causes many accidental deaths. Greatest number of fatal falls is seen in adults older than 65 leading to health problems or injuries [1]. Thus, elderly people require an attention at the times of emergencies at their residence because they cannot call for help due to lack of technology access in rural areas or due to their physical conditions. To improve quality of life of old aged people and to provide living assistance to them, automatic fall detection systems are in place. The risk of falling is high among older people, individuals with Parkinson's disease or patients in rehabilitation units [3]. Main reasons for occurrence of falls are physical factors like of muscle weakness, posture, Gait balance, vision, due to old age, or psychological factors or environmental factors etc. Falls are the major cause of injuries and hip fractures [4]. If immediate aid is not provided, it may lead to death. To ensure proper treatment and care of the elderly people, fall detection system plays important role.

Various researches have been done on the fall detection system. There are no fixed criteria on basis of sensors used or on calculated features or on algorithms used to classify. Image processing techniques are used after capturing images from camera to detect falls. Wearable sensors like accelerometer, gyroscope at knee, wrist, neck, and waist are used to get the data input. Features are calculated by using sensor readings to get some meaningful data out of the raw data. Falls also can be detected by using ambient sensors like IR sensors or movement based sensors.

Major hurdle to develop precise fall detection system is false alarms i.e. alerting fall when there is a fall like activity but not exactly a fall. Most of the researches are focused on reducing false alarms and improving accuracy of the fall detection system. The main aim of studies is to detect fall in the daily life activity situations with high accuracy.To classify the activity into fall or not fall criteria, threshold based algorithms also can be used. But if sensor detects an unusual activity, then the probability of false alarm increase unlike machine learning based approach.

In this work, a fall detection system is proposed which monitors elderly people in real-time. The system uses open source available dataset SisFall which has recorded Gait data by using Tri-axial accelerometer [15]. By using machine learning algorithms, falls are detected after calculating various features. Two different machine learning algorithms, SVM and decision tree are implemented and compared for better accuracy and performance.

The rest of the paper is organized as follows: section 2 discusses about the literature survey in the area of fall detection followed by methodology of implementation in section 3. The results are presented in section 4 and the paper is concluded in section 5.

II. LITERATURESURVEY

There are no standard sets for fall detection, to get perfect fall detection system, in terms of sensors used, features extracted, and machine learning algorithm with better performance. Fall detection system can be implemented by using cameras, wearable sensors or ambient sensors. When cameras are used in the system, image processing algorithms are used but it has been seen that 24% of the falls are not getting detected [3]. Ambient based sensors like motion detector or passive infrared (PIR) sensors also can be used in fall detection system detection [7]. But these are limited to particular area in which sensors are implemented.

Wearable sensor based fall detection systems are more suitable for elderly people because it can detect the fall any time and any place unlike vision based and ambient based fall detection which are restricted to the house or particular indoor environment. Also wearable sensor is lesser in cost than that of camera or PIR sensors. In literature, sensors are used in necklace [8], subjects' head band, chest band, waist band, right wrist band, right thigh band, and right ankle band [9], waist band [10], etc. The pendant connected to mobile phone via Bluetooth and phone communicates with concerned person. The problem with this system is, phone should be in 100 meters range of pendant; and activities like front bending or front falls are not considered due to false interpretation of fall [8]. Too many sensors also lead to miss prediction of the accurate activity. Wearable sensor accelerometer is better than camera based and ambient based techniques.

Fall can be detected using two techniques after collection of data from sensors and feature calculation. One is threshold based, if reading of the sensor is above particular threshold, it can be categorized as fall. In this technique, threshold for each calculated feature is different and many false alarms may be generated. If machine learning classification is used, the calculated features can be tested on a pre-trained model with high accuracy and guarantee lesser false alarms.

In the current work, accelerometer data from a wearable sensor is used, which is already measured for different activities in SisFall dataset [15]. Most relevant features are calculated. Machine learning models of SVM and decision tree are trained and tested.

In literature, these features are used for threshold based fall detection, and the proposed work implements machine learning approach on same features and provides improved accuracy. Also, none other paper have used decision tree algorithm for training and testing this dataset. The current work implements SVM and decision tree algorithm and compares its performance

III. METHODOLOGY

Fall detection system consists of the following steps as in Fig. 1 and is explained below:

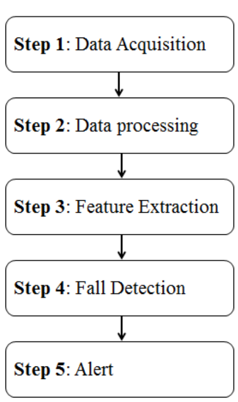

Figure 1 System flow

A. Data Acquisition

The SisFall [15] dataset is considered which consists of data collected with the help of ADXL345 accelerometer from the waist band. Tri- axial accelerometer ADXL345 is used to get the acceleration values along three axes x, y and z. It is energy efficient as it can work with low power mode.

Figure 2 Waist belt with sensor position

In this work, six young adults and two elder's acceleration data is considered. Adult participants have performed 19 daily life activities and 15 fall activities, only one elder performed all the activities. 1 lakh data is considered for training as partial dataset and 40,000 acceleration data samples are used for testing purpose. (Young participant's code- SA02, SA05, SA10, SA15, SA20, SA23, Adult participant's code- SE06,SE10).

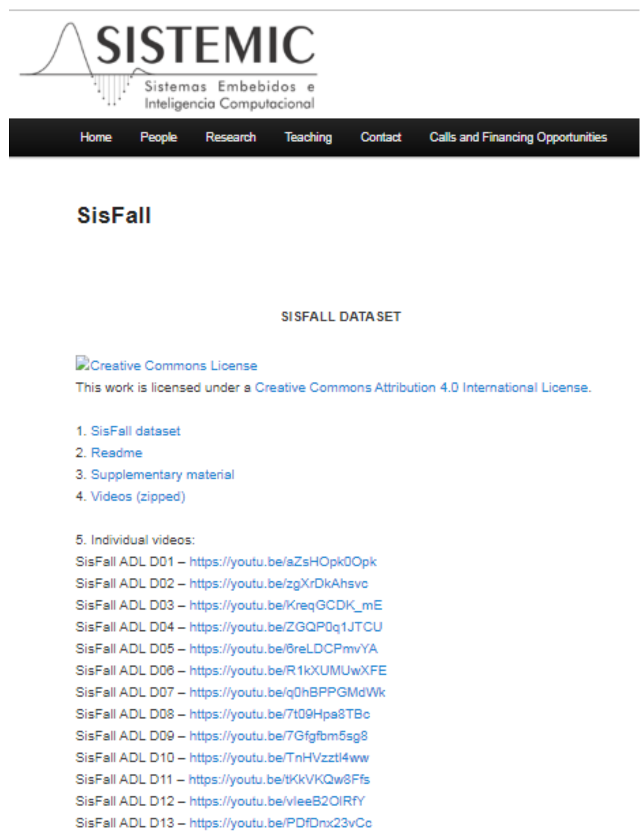

Figure 3 SisFall Dataset

B. Data Processing

Data processing is done by using 4th Order butter-worth filter with cutoff of 5Hz to the sensor data to remove noise and unwanted glitches. This filter is used because it has given similar results as that of more elaborated IIR and FIR filters at different frequencies [15]. Figure 3a) and 3b) shows original and filtered data respectively.

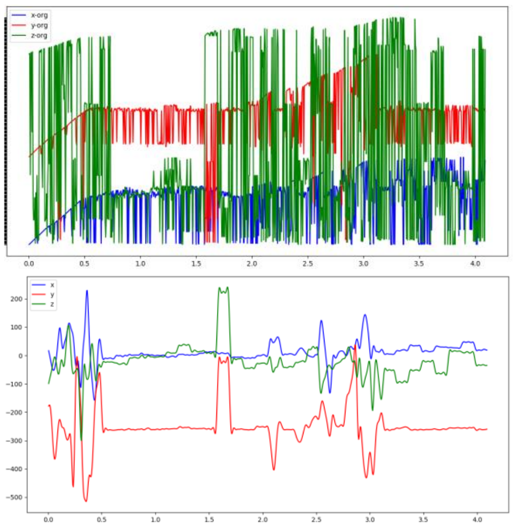

Figure 3 a) Original data of X, Y, Z axes b) Filtered data

C. Feature Calculation

There are many features that can be calculated using accelerometer data, and which are significant. In this work, we have considered the same features SisFall dataset [15]. But they have used threshold technique and this paper uses machine learning technique to cover all non-listed activity classification as well. The features with formula are mentioned in the Table 1. For one acceleration sample i.e. acceleration along all the three axes, all above features are calculated. For 1 lakh data samples, 1 lakh features are calculated.

Table 1: Calculated features

Type	Code	Feature	Equation
Amplitude	C1	Sum vector magnitude	$C_1[k] = RMS(a[k]) = \sqrt{a_x[k] + a_y[k] + a_z[}$
	C2	Sum vector magnitude on horizontal plane	$C_2[k] = \sqrt{a_x[k] + a_z[k]}$
	C3	Maximum peak-to-peak acceleration magnitude	$C_3[k] = RMS(max(a[k]) - min(a[k]))$
Orientation	C4	Angle between z-axis and vertical	$C_4[k] = atan2(\sqrt{a_x[k] + a_z[k]}, -a_y[k])$
	C5	Orientation of person's trunk	$C_5[k] = \sigma(atan(\frac{RMS(a_x[k], a_z[k])}{a_y[k]}))$
	C6	Orientation change in horizontal plane	$C_6[k] = mean(a_x[k-N]) - mean(a_x[k])$
Time	C7	Jerk (Rate of Acceleration Change)	$C_7[k] = \frac{a_x[k] - a_x[k-N]}{t[k] - t[k-N]}$
Statistics	C8	Standard deviation magnitude on horizontal plane	$C_8[k] = \sqrt{\sigma_x^2[k] + \sigma_z^2[k]}; with \sigma_i = std(a_i[k]$
	C9	Standard deviation magnitude	$C_9[k] = \sqrt{\sigma_x^2[k] + \sigma_y^2[k] + \sigma_z^2[k]}$

D. Fall Detection Algorithms

The machine learning algorithms used are Support Vector Machines (SVM) and Decision Tree. SVM is an algorithm that can be used for classification as well as regression. SVM finds the hyper plane such that it has largest distance from nearest training data point of any class to provide good separation. For non-linear dataset, it can be possible to find hyper plane to determine the classification by using kernel function. Data points falling on each side of the plane belongs to different classes.

In decision tree algorithm, data is represented as tree like model with nodes and edges. Trees basically have the root node, internal nodes and leaf nodes, but with real datasets, different features get added. The decision tree is a classification technique with the finite number of classes. Once tree is ready with training data, decision rules are drawn, on basis of that decisions for classification is taken. The reason behind decision tree is classification model popularity is they are easy to interpret, the results obtained can be more easily understood. With decision tree algorithm, complex decision-making process becomes simpler and solution of the problem can be interpreted by decision makers.

These algorithms are compared on basis of fall detection accuracy. The models are tested on 40,000 data samples and accuracy is calculated. The most accurate model is saved for further testing. It has been seen that,sum vector magnitude (C1), sum vector magnitude horizontal plane (C2), standard deviation magnitude horizontal plane (C8) and standard deviation magnitude (C9) features gives higher accuracy than all other features considered together.

E. Alert

In case of fall, concerned person should be informed. When real time data is collected and tested for fall, message or call should be initiated on fall detection.

IV. ALGORITHM IMPLEMENTATION

The flowchart of implementation of algorithm is shown in Fig. 4. Software implementation is done using Python 3.7 and sklearn.

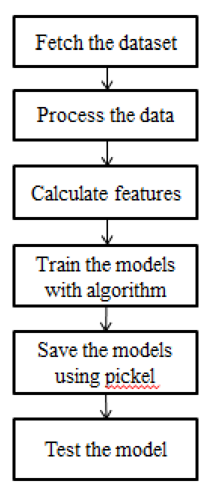

Figure 4 System implementation

IV. OUTCOME ANDDISCUSSION

To evaluate various trained models and to compute the efficiency of various algorithms, different parameters such as: confusion matrix, sensitivity, specificity, accuracy, training time and prediction time are computed.

Sensitivity represents the actual positive cases which got predicted as positive (or true positive), Specificity represents the actual negatives, which got predicted as the negative (or true negative). Accuracy is ratio of predictions our model got right which is calculated by using average of sensitivity and specificity. Also confusion matrix is used to get true positive and true negative values. The accuracy is calculated with selected features and is shown in Table II.

Table II: Performance comparison of ML algorithms

Algorithms	Accuracy	Training time	Prediction time
SVM	84.17%	294.95 sec	84.71 sec
Decision tree	95.87%	2.741 sec	0.02 sec

The performance of decision tree algorithm is found to be better than SVM algorithm for the considered data. Several factors were considered for comparison and one among them is the ability to define and classify each attribute to each class. The computing time of decision tree is found to be less than SVM. SVM works better out of the box, but decision trees gives more insight into how the model works. Decision trees are great for their simplicity and interpretation, but it has limitations in learning complicated rules and to scale to large data sets.

V. CONCLUSION

This paper presents wearable sensor based fall detection system, which are suitable for elderly people. The proposed method uses machine learning algorithms to detect falls from a set of daily living activities. Machine learning technique are found better than the threshold method, as it gives less false alarms due to pre-trained Gait patterns. The decision tree gives higher accuracy than SVM as decision tree has the ability to define and classify each attribute to each class precisely. Also prediction time of SVM is greater than decision tree which leads to a slower system. The models are evaluated by using parameters such as: sensitivity, specificity, accuracy and confusion matrix. Falls are appropriately detected using decision tree algorithm with an accuracy of 96%. Further improvement in accuracy can be obtained by training the models with large dataset and by identifying optimal features.

REFERENCES

[1]World Health Organization, World Report on Ageing and Health, World Health Organization, Geneva, 2015.

[2]WHO Global Report on Falls Prevention in Older Age, World Health Organization, Geneva, 2008.

[3] De Backere, F., Ongenae, F., Van den Abeele, F., Nelis, J., Bonte, P., Clement, E., Philpott, M., Hoebeke, J.Verstichel, S., et al."Towards a social and context-aware multi-sensor fall detection and risk assessment platform", Computers in biology and medicine 64,307/320, 2015.

[4] Khan, M.S, Yu, M, Feng, P, Wang, L, Chambers,"An unsupervised acoustic fall detection system using source separation for sound interference suppression",Signal processing 110, 199/210, 2015.

[5] Glen Debard, Greet Baldewijns, ToonGoedem, TinneTuytelaars and Bart Vanrumste, "Camera-based fall detection using a particle filter Glen",IEEE, 978/4244/9270, 2015.

[6] Rita Cucchiara,AndreaPrati,RobertoVezzani, "A multi-camera vision system for fall detection and alarm generation", Expert Systems, 24, 5, 2007.

[7] AhmetYazar, FatihErden, A. Enis Cetin," Multi-sensor ambient assisted living system for fall detection", ResearchGate Conference Paper ,May 2014

[8] Joseph Santiago, Eric Cotto, Luis G. Jaimesy, IdalidesVergara-Laurens, "Fall Detection System for the Elderly", IEEE, 978-1-5090-4228-9/17, 2017.

[9] AhmetTuranÖzdemirandBillurBarshan," Detecting Falls with Wearable Sensors Using Machine Learning Techniques" , Sensors, 14, 10.3390/s140610691, 2014.

[10] FalinWu, Hengyang Zhao, Yan Zhao, HaiboZhong," Development of a Wearable-Sensor-Based Fall Detection System", International Journal of Telemedicine and Applications, Volume 2015, Article ID 576364, 2014.

[11]Diana Yacchirema, JaraSuárez de Puga, Carlos Palaua, Manuel Esteve,"Fall detection system for elderly people using IoT and Big Data ", The 9th International Conference on Ambient Systems, Networks and Technologies , 2018.

[12]Tuan Nguyen Gia, Victor KathanSarkera, Igor Tcarenkoa, et.al., "Energy efficient wearable sensor node for IoT-based fall detection systems", Microprocessors and Microsystems 56,34–46, 2018.

[13]HristijanGjoreski, MitjaLuštrek, Matjaž Gams, " Accelerometer Placement for Posture Recognition and Fall Detection", Seventh International Conference on Intelligent Environments, 2011.

[14]Yueng Santiago Delahoz , Miguel Angel Labrador," Survey on Fall Detection and Fall Prevention Using Wearable and External Sensors", Sensors, 14, 19806-19842, 2014.

[15]Angela Sucerquia, José David López ,Jesús Francisco Vargas-Bonilla, "SisFall: A Fall and Movement Dataset", Sensors, 17, 3390/s17010198, 2017.

[16] S. Vadivelu, Ganesan, S., Murthy, O. V. R., and Dhall, A., "Thermal imaging based elderly fall detection", Lecture Notes in Computer Science, vol. 10118, 541-553, 2017

[17] A. Purushothaman, "Fall detection system using Artificial Neural Network", in 2nd International Conference on Inventive Communication and Computational Technologies(ICICCT 2018), Hotel Arcadia, Coimbatore, 2018.