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SAFE GUARDING ELDER PEOPLE USING ADVANCED FALL DETECTION METHODS

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Abstract : **The main source of concern is health, which becomes more serious as one gets older. Thus, caring for the elderly is an extremely vital job. In such cases, technology assists individuals in their daily lives. 'Fall' is one of the leading causes of health decline or death among the elderly. This paper proposes a fall detection system based on machine learning. The system detects falls by categorising distinct activities as fall or non-fall actions, and it alerts the elderly person's relative or carer in the event of an 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.

***Index Terms* - Fall detection, Machine learning, Daily living Activities, Senior Citizens Care, Health Monitoring Systems.**

I. INTRODUCTION

Nowadays, elderly individuals live alone at home due to poor living conditions, differences in working cultures, and a variety of other factors. According to World Health Organization (WHO) studies, falls cause many accidental deaths. Adults over the age of 65 have the highest rate of fatal falls, which result in health problems or injuries [1]. As a result, older individuals require assistance during emergencies at their homes since they are unable to call for aid due to a lack of technological availability in rural areas or their physical ailments. Automatic fall detection systems have been installed to improve the quality of life of the elderly and to offer them with living help. Falls are common among the elderly, people with Parkinson's disease, and patients in rehabilitation facilities. [3]. The main causes of falls are physical issues such as muscle weakness, posture, gait balance, vision, old age, psychological factors, and environmental variables, among others. Falls are the leading cause of injury and hip fractures [4]. If prompt assistance is not offered, it may result in death. Fall detection systems are essential for ensuring proper treatment and care for the elderly.

Several studies have been conducted on the fall detection system. There are no fixed criteria based on the sensors used, the derived features, or the classification methods. To detect falls, image processing techniques are applied after the camera images have been captured.

Wearable sensors like accelerometer, gyroscope at knee, wrist, neck and waist are used to get the data input. Features are calculated by taking sensor readings and extracting useful info from the raw data. Falls can also be detected using environmental sensors such as infrared sensors or movement-based sensors.

False alarms, or alerting when there is fall-like behavior but not a fall, are a significant barrier to developing a precise fall detection system. Most of the research focuses on lowering false alarms and enhancing the accuracy of the fall detection system. The primary goal of investigations is to detect falls in regular life activity settings with high accuracy. To classify the action into fall or not fall criteria, threshold-based algorithms also can be utilized. However, unlike machine learning-based approaches, if the sensor detects unusual activity, the likelihood of a false alarm increases.

This paper proposes a fall detection system that watches elderly persons in real time. The method makes use of the open-source dataset SisFall, which recorded gait data using a triaxial accelerometer [15]. Falls are recognized using machine learning algorithms that calculate numerous features.
Two alternative machine learning techniques, SVM and decision tree, are used and compared to improve accuracy and performance.
The rest of the paper is organized as follows: section2 discusses about the literature survey in 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. LITERATURE SURVEY

There are no standard setups for fall detection to achieve a great fall detection system in terms of sensors used, features retrieved, and machine learning algorithms with superior performance. A fall detection system can be constructed utilizing cameras, wearable sensors, or ambient sensors. When cameras are used in the system, image processing methods are employed, yet it has been discovered that 24% of falls are not recognized [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 sensors are less expensive than cameras or PIR sensors. Sensors are utilised in necklaces [8], subjects' head bands, chest bands, waist bands, right wrist bands, right thigh bands, and right ankle bands [9], waistbands [10], and so on. The necklace connects to a mobile phone via Bluetooth, and the phone communicates with the worried person. The issue with this technique is that the phone should be within 100 metres of the pendant, and behaviours such as front bending or front falls are not taken into account due to incorrect fall interpretations [8]. Too many sensors also result in incorrect estimate of accurate activity. Wearable sensor accelerometer outperforms camera and ambient-based approaches. After collecting sensor data and calculating features, two strategies can be used to identify falls. One is threshold-based; if the sensor's reading exceeds a specific threshold, it is classified as a fall. This approach generates many false alarms because the threshold for each calculated feature varies.
If machine learning categorization is used, the generated features can be evaluated against a pre-trained model to ensure high accuracy and fewer false alarms. In the current study, accelerometer data from a wearable sensor is employed, which has already been collected for various activities in the SisFall dataset [15]. The most relevant features are calculated. Machine learning models such as SVM and decision trees are trained and tested In the literature, these features are used for threshold-based fall detection, and the suggested work improves accuracy by using a machine learning approach to the same features. Furthermore, no previous publication has used the decision tree approach to train and test this dataset. The present study examines the performance of SVM and decision tree algorithms.

III. METHODOLOGY

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

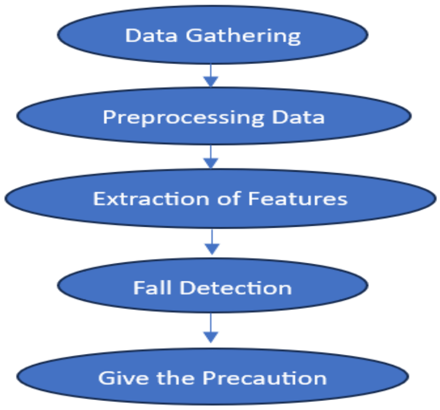


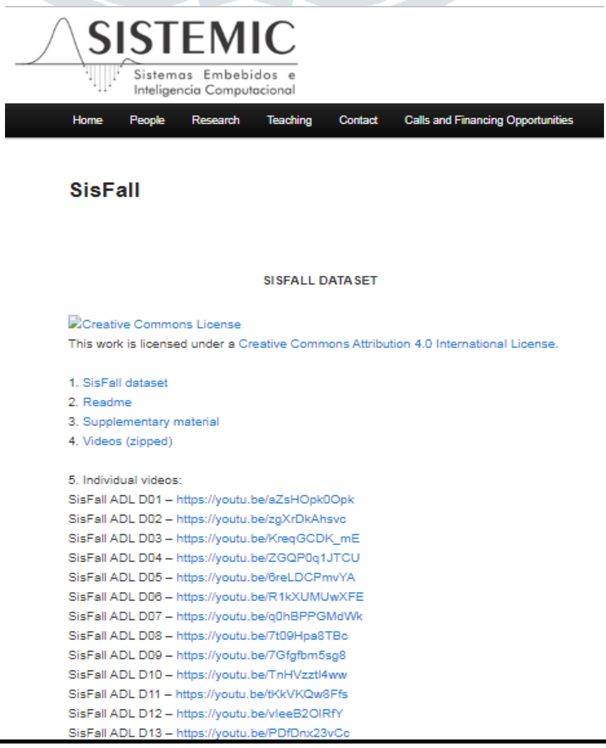
Figure 1 System Flow

A. Data Gathering

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

This study considers acceleration data from six young individuals and two elders. Adult participants completed 19 daily living tasks and 15 autumn activities, with only one elder performing all of them. 1 lakh data points are selected for training as a partial dataset, and 40,000 acceleration data samples are used for testing. (Young participant's code- SA02, SA05, SA10, SA15, SA20, SA23, Adult participant's code- SE06,SE10).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SisFall

SISFALL DATASET

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1. SisFall dataset
2. Readme
3. Supplementary material
4. Videos (zipped)

5. Individual videos:
SisFall ADL D01 – https://youtu.be/aZsHOpk0Opk
SisFall ADL D02 – https://youtu.be/zgXrDkAhsvc
SisFall ADL D03 – https://youtu.be/KreqGCDK_mE
SisFall ADL D04 – https://youtu.be/ZGQP0q1JTCU
SisFall ADL D05 – https://youtu.be/6reLDCPmvYA
SisFall ADL D06 – https://youtu.be/R1kXUMUwXFE
SisFall ADL D07 – https://youtu.be/q0hBPPGMdWk
SisFall ADL D08 – https://youtu.be/7t09Hpa8TBc
SisFall ADL D09 – https://youtu.be/7Gfgfbm5sg8
SisFall ADL D10 – https://youtu.be/TnHVzztl4ww
SisFall ADL D11 – https://youtu.be/tKkVKQw8Ffs
SisFall ADL D12 – https://youtu.be/vleeB2OIRfY
SisFall ADL D13 – https://youtu.be/PDfDnx23vCc

Figure 3 SisFall Dataset

B. Pre-Processing Data

Data To reduce noise and undesirable glitches, data is processed using a 4th Order Butterworth filter with a cutoff frequency of 5Hz on sensor data. This filter is employed because it produces similar results to more complex IIR and FIR filters at various frequencies [15]. Figures 3a and 3b show the original and filtered data, respectively.

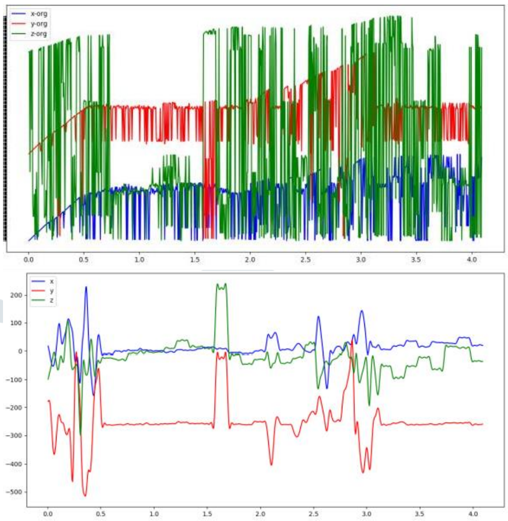

Figure 3 a) Original data of X, Y, Z axes b) Filtered data

C. Extraction of Features

There Accelerometer data can be used to calculate a variety of important attributes. In this study, we analysed the same features as the SisFall dataset [15]. However, they used the threshold technique, but this article uses the machine learning technique to classify all non-listed activities as well. Table 1 lists the features associated with the formula recomputed. 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

The machine learning algorithms employed include Support Vector Machines (SVM) and Decision Trees. SVM is a method that can be used for both classification and regression. To offer good separation, SVM selects the hyperplane with the greatest distance from the nearest training data point of any class. Using the kernel function, it is feasible to find a hyper plane for a non-linear dataset in order to decide classification.
Support Vector Machines (SVM) and Decision Trees are the two machine learning techniques used. SVM is a method that can be used for both classification and regression. To offer good separation, SVM selects the hyperplane with the greatest distance from the nearest training data point of any class. Using the kernel function, it is feasible to find a hyper plane for a non-linear dataset in order to decide classification. Data points that lie on each side of the plane belong to separate classes.
The decision tree algorithm represents data as a tree-like form with nodes and edges. Trees consist of a root node, internal nodes, and leaf nodes, however real datasets include more properties. The decision tree is a classification strategy that uses a finite number of classes.
Once the tree has been trained, decision rules are developed, and categorization judgements are made based on them. The popularity of decision trees and classification models stems from their ease of interpretation, which allows for a better understanding of the results. Decision tree algorithms simplify complex decision-making processes and allow decision makers to interpret problem solutions.
These algorithms are compared in terms of fall detection accuracy. The models are evaluated using 40,000 data samples, and their accuracy is calculated. The most accurate model is stored for further testing. It has been shown that the sum vector magnitude (C1), sum vector magnitude horizontal plane (C2), standard deviation magnitude horizontal plane (C8), and standard deviation magnitude (C9) characteristics provide greater accuracy than all other features combined.

E. Give the precaution

In the event of a fall, the appropriate person should be informed. When real-time data is collected and checked for falls, a message or call should be initiated upon 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.

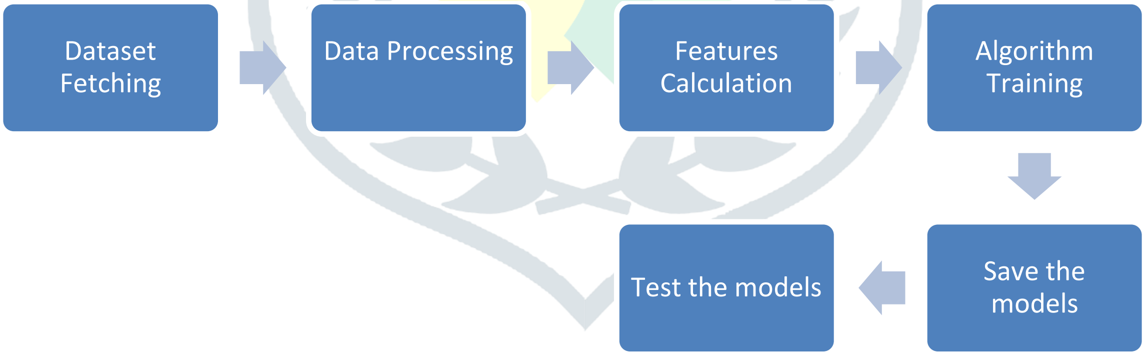

Figure 4 System Implementation

V. EXPERIMENTAL RESULTS

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 reflects the real positive cases that were projected as positive (or true positive), whereas specificity represents the actual negatives that were predicted as negative (or true negative). Accuracy is the ratio of correct predictions made by our model, defined as the average of sensitivity and specificity. Also, a confusion matrix is utilised to determine real 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 decision tree approach outperforms the SVM algorithm for the data under consideration. Several aspects were evaluated for comparison, one of which is the capacity to define and categorise each attribute inside each class. Decision trees require less computing time than SVMs. SVM performs better out of the box, but decision trees provide more information about how the model works.

Decision trees are fantastic for their simplicity and interpretation, but they have limits when it comes to learning complex rules and scaling to enormous datasets.

VI. CONCLUSION

This research provides a wearable sensor-based fall detection system that is appropriate for older individuals. The suggested system detects falls using machine learning algorithms based on a set of daily life activities. Machine learning techniques are used over threshold methods because they produce less false alarms due to pre-trained gait patterns. Decision trees outperform SVMs in terms of accuracy because they can properly define and categorise each attribute for each class. Also, SVM has a longer prediction time than decision trees, resulting in a slower system. The models are evaluated based on metrics such as sensitivity, specificity, accuracy, and confusion matrix. The decision tree system detects falls with 96% accuracy. Training the models with a big dataset and discovering optimal features can lead to even greater accuracy improvements.

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