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Abstract— Healthcare benefits related to continuous monitoring of human movement and physical activity can potentially reduce the risk of accidents associated with elderly living alone at home. Based on the literature review, it is found that many studies focus on human activity recognition and are still active towards achieving practical solutions to support the elderly care system. The proposed system has introduced a joint approach of machine learning and signal processing technology for the recognition of human's physical movements using signal data generated by accelerometer sensors. The framework adopts the concept of DSP to select very descriptive feature sets and uses ML-based supervised learning techniques for effective classification. The simulation result demonstrates the efficiency of the proposed system regarding the prediction of human movement based on sensor signals.

Keywords-Machine Learning, Security, Support Vector Machine, Neural Network, Signal Processing, Huma movement Detection

I. INTRODUCTION

The care of older people living alone at home is of great concern, as unexpected situations may occur that may affect their safety and happiness [1]. Older people are often more vulnerable to various diseases and are unstable by behavior and slower to respond. It is, therefore, more likely that they may fall and be wounded compared to healthy and younger people. A cost-effective and reliable system is needed to ensure proper care for elderly people living alone [2-3]. An elderly healthcare and supervision application requires an event-driven scheme to monitor the environment and their activities in real-time. Human Motion Analysis (HMA) is one of the active topics in the research studies that deals with human behaviors and movement analysis [4]. Many efforts have been made towards HMA using visual sensors data and camera data based on machine vision, bio-machines, pattern recognition, etc. [5-6]. However, the deployment of vision sensors and cameras is usually limited to residential areas and cannot be installed in private areas (toilets) for privacy reasons. Therefore, it does not provide any relevant data for analysis when the elderly go to the toilet. Incidents that can hurt the elderly (accidental falls, lying down) can occur in areas where visual sensors and cameras cannot predict, and the consequences are fatal. Such emergency situations can be evaded by endlessly monitoring the physical and functional parameters and activities of the elderly [7].

The advent of smart devices with proximity and accelerometer sensors (such as fitness bands, smartphones) surpasses the limits of visual sensors and cameras [8]. The data generated by these sensors can provide a mechanism to monitor and analyze the condition of the elderly in various locations. Also, it serves as a highly decentralized and assistive tool with visual sensors to make effective classification and predictions in HMA, thus improving the quality of care and living style of the residents. However, sensor data is associated with unwanted factors, i.e., sensor data is usually associated with noisy signal and results in deceptive values in most cases, which poses significant challenges towards data analysis and its interpretation in HMA. Therefore, due to changes in viewpoints, and noisy signal data, accurate identification is a very challenging and time consuming task. Several methods and algorithms have been developed in the past few years to address various problems in human behavior analysis and HMA [9-10]. However, most of these existing methods are associated with multiple problems like consuming more time in preprocessing operations, have greater computational complexity in classification, and larger dependencies on samples. The joint approach of machine learning- (ML) and digital signal processing- (DSP) enables a way to better understand data by filtering out noise signals from the dataset or by lowering the impact of noise using DSP techniques. The filtered signal is then used for signal analysis along with the process of feature selection and extraction to improve prediction accuracy using efficient ML-based classification techniques. Therefore, this paper proposes an analytical framework for identifying the distinct physical activities of humans using signal data generated by the accelerometer sensor. The framework adopts the concept of DSP for selecting a very descriptive feature set and uses ML-based supervised learning techniques for performing effective classifications. The remaining portions of this manuscript are ordered as follows: Section-II presents a review of existing literature. Section III presents the proposed system

design and algorithm description. Section IV presents the outcome of the proposed system, and finally, the conclusion of the entire work are illustrated in Section V.

II. REVIEW OF LITERATURE

Human activity and motion analysis are key factors in various applications such as elderly care, robotics, human-machine communication, and many more. It has the potential to provide effective and fast decision-making mechanisms. Therefore due to this fact, it has become a matter of significant concern in the active research community. Various researchers have proposed different methods and prediction models for identifying people's movements and activities. This section briefly introduces existing motion and activity prediction techniques primarily based on advanced learning algorithms and analytical models. The work conducted by Leightley, (2016)-[11] developed a model considering feature representation and ML techniques that uses a depth camera to identify and evaluate human mobility patterns automatically. Lin et al. (2015)-[12] constructed a model for classifying and evaluating various segmentation algorithms. This model is applied to motion segmentation by forming a set of clustering. Gong et al. (2013)-[13] focused on issues related to the accurate recognition of human actions using monocular signals. The author first represents the monocular signal here as a time series and uses kernelized time shear to deal with nonparametric and high-dimensional problems of human motion. The outcome exhibits that the proposed method effectively performs real-time segmentation and classifies actions with high accuracy. Mandery et al. (2016)-[14] suggested a large human motion database, which includes various techniques and tools that can uniformly represent captured human motion, and perform effective search and transmission in the database. Nava and Melendez-(2016) [15] reviewed various existing literature on motion analysis, in which the authors focused on research to explore the effectiveness of various techniques used in human motion analysis (HMA). The authors also attempt to analyze the different sensor configurations used in this analysis and evaluate the performance of each prior art approaches. The study of Sun et al. (2018)-[16], have introduced a hybrid depth model oriented on convolution operations, loop units, and ELM classifiers. The framework does not depend on any form of expert knowledge, the temporal dynamics of features, and it reduces the runtime. Kwon and Choi- (2016) [17] introduced a detection system that uses data from smartwatches signal and adopts artificial neural networks-(ANN) to classify and enhance location information. Experimental results show that this approach has achieved a good accuracy rate to recognize various activities. In the study of Fong et al. (2015) [18], the authors have considered that that traditional data mining-based methods cannot accurately analyze activity patterns using sensor data due to their methodological design. In particular, the authors propose a different form of the scheme for feature selection using swarm search. This technique enables fast pre-processing to introduce an improved mechanism in classification operation. Zhang et al. (2017)-[19] conducted a survey work to highlight the effectiveness of existing work, focusing mainly on classification methods and data sets for activity representation. The work carried out by Ding et al. (2018)-[20] has described an approach for identifying human activities using temporal action recognition. For this work, the authors have used multilayer CNN to extract features. Subasi et al. (2018)-[21] carried an in-depth analysis of ML-based HMA and discussed its critical role in the area of elderly healthcare. The author has also highlighted some significant challenges towards meeting HRA in the context of its accuracy in pattern classification and highlighted some significant factors that should be considered in the future research direction. The work of Paniagua et al. (2012)-[22] presented an approach of HMA based on mobile sensor data. In this, they have applied the concept of parallel computing and cloud technique with the MapReduce tool for conducting effective training operations for achieving effective and accurate action pattern classification. The study by Shanthamallu et al. (2019) [23] described various activities to introduced the effectiveness of a combined approach of ML and DSP to use appropriate signal analysis for feature extraction and classification. Delic et al. (2019)-[24] presented an investigational analysis of speech signal analysis using the ML approach. In this study, the authors have discussed various existing techniques with their advantages and challenges and suggested some essential points for the future research direction. Peric et al. (2019)-[25] and Prasad et al. (2011)-[26] presented a survey work in which the authors have discussed the potential of using adaptive ML and signal processing techniques together in a variety of applications. Similarly, the work of Li et al. (2019)-[27] discussed the role of the Deep learning method for wireless signal analysis for future generation wireless communication systems.

Based on the above review and analysis, it can be analyzed that numerous attempts were made by the researchers in context human motion and activity detection. Also, many surveys and review articles have been published that different cover aspects of the human action recognition system based on different types of data sources and techniques. Most of the existing work does not consider the practical implementation of machine learning techniques for HMA. Also, the various existing techniques are inclined towards specific objectives and do not cover the entire range of applicability in this area. The usage of a machine-learning-based prediction approach is also analyzed, and few studies have also shown the utilization of signal processing techniques to analyses signal generated from the sensors. However, still, there is a requirement for improvements. However, a combined approach based on ML, AI, and the Digital signal process can provide a cutting-edge mechanism in the field of human behavior and action analysis for various applications and automation filed. Therefore, this paper attempts to introduce a joint approach of ML and signal processing techniques for human motion analysis. The next section presents a description of the proposed system and the methodology adopted.

III. PROPOSED SYSTEM

The proposed system presents an analytical design of the human movement detection-(HMD) system as an assistive tool for older-people care living alone at home. The analytical design incorporates two different approaches, i.e., machine learning and digital image processing, for performing analysis of data generated from a sensor signal. An accelerometer-sensor collects the signal data. Therefore, the system considers accelerometer data to measure the acceleration signal of the human movements. The system contains various functional component and module which works in the sequential procedure to process signal data and to perform its classification to predict human motion with respect time. The schematic representation of the proposed HMD system is illustrated in the figure-1. □

The system considers sensor data or time-series data using an open-source dataset [28] that contains acceleration signals components, and different features. The dataset was prepared with the experiments conducted with the various subjects under age between 18 to 50 years. In this, each subject was assigned to perform multiple physical activities, holding a smartphone configured with an accelerometer, proximity, and gyroscope sensors. The sensor data are captured and stored with tri-axial acceleration and angular velocity at a frequency rate of 50Hz. The recorded time-series data were prepared considering different patterns of movement activities and labeled manually in different sets of classes. Also, the data in the dataset are portioned into two different sets with a ratio of 70% for training operation, and 30% data are chosen for performing a testing operation for the validation.

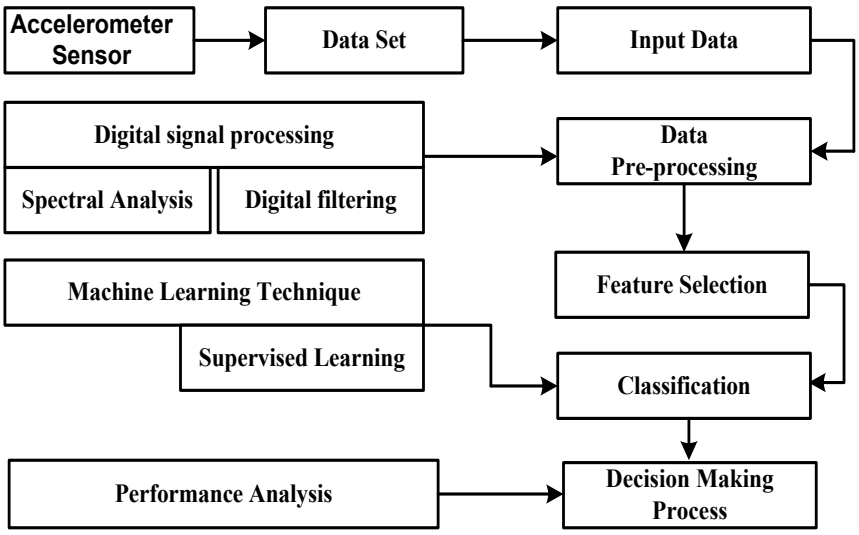

Figure 1 Architecture of the proposed system for sensor signal Analysis

The systems present a joint approach of machine learning and signal processing that can be applied to pre-processed signals and to extracting descriptive features and perform effective pattern recognition and prediction. The proposed system explores the effectiveness of both ML and DSP in the field of sensor signal analysis to ensure better performance in pattern classification from the available features in predictive systems. The motive of the proposed study is to understand what activity the subject is doing purely based on the DSP and ML methods. The first module of the framework is subject to the dataset that acts as an input for the system for performing its later operations pre-processing, signal analysis, feature extraction, and classifications. In this, the accelerometer signal capture using a smartphone is used, which provides time-series data associated with human body position and motion analysis, engaging in different physical activities. The system uses labeled recorded data for the validation. The study takes three components(x, y, z) of the sample acceleration coming from an accelerometer sensor and predicts the pattern of the physical activity of the person between different activity classes (walking, standing, sitting, and laying). Once the data is ready for the input for the system, then it undergoes the next operation of data leaning and normalization to obtain relevant features to the particular activities. Dealing with time series data is a quite challenging task. Therefore, the system performs some statistical measurements on a portion of consecutive samples distributed in time series to analyses the pattern like walking, standing, sitting, and laying. This is precisely what the signal processing method to be part of the proposed system. It's reasonable to assume that the body movements produce faster variations while the gravity contribution is often almost constant, therefore the system applies digital filtering for the pre-processing operation. In the filtering operation, the system involves 1D- digital filtering operation with another discrete-time filter object at the sampling rate of 50Hz. Once the filter is designed, then the filter is further applied to a vertical acceleration signal that creates a new version, i.e., filtered signal highly relevant to the body movements. This filtering operation reduces the impact of the gravitational force and further offers a normalized version of the input signal, i.e., in the form

of the acceleration signal. The next module of the proposed system is associated with signal analysis and feature selection operation, which is the most crucial operation of the proposed system for performing the pattern recognition of the different classes of the subject activity. For each signal segment, the feature is extracted from the pre-processed data with a finite set of measurements of the similarities and differences between signals in the considered classes. Here the feature selection process selects various relevant features and extracts significant features considering tri-axial acceleration data(x, y, z), which is computed based on the analysis of peaks function and obtains peak values with respect to time graph. These obtained values are then processed using discrete functions to obtain descriptive features mean acceleration, RMS acceleration, interactive values, spectral position, and power band. After the successful execution of feature selection operation, the system stores the feature value in the vector. It applies the ML technique where two different supervised learning algorithms-(support vector machine-SVM and Neural network-NN) is applied to perform classification and pattern recognition for each particular class of action. The system considers NN as an alternative option where 2-layer using 18 nodes entirely linked with neural network in the hidden layer are considered for processing the hidden layer is considered for the classification analysis. Also, the system utilizes some statistical methods to achieve the desired result of the activity analysis. The system also proposes algorithmic steps for demonstrating the implementation of the methodology of motion detection framework. The significant steps of algorithms are as follows:

Algorithm-1 Human motion detection system using sensor data analysis

The algorithm takes input value as acceleration values captured obtained from the accelerometer-sensor signal, which undergoes several processing operations and functional modules. After successful execution, it provides classified values as output for the subject activity predictions.

Input: Ac_{Data}
Output: F_{CD}
Start
Step1- init $\rightarrow S_N, T_{w,}$ g
Step2-Load $\leftarrow Ac_{Data}$
Step2-for i=1:N(Ac_{Data})
Step3- $Ac_{Data}^{P} \rightarrow f_{hp}(Ac_{Data})$
Step4 end
Step4-$F_{Select}[\,]_{m \times n} \rightarrow f_1(Ac_{Data}^{P})$
Step5-$F_{vec} \rightarrow f_2(F_{Select})$
Step6- Apply $\rightarrow$SLA
Step7- if SlA = 1
Step8- call $\leftarrow$ SVM
Step9-end
Step10- if SlA = 2
Step11- call $\leftarrow$ NN
Step12- end
Step13. $[D_{train,}\, D_{test}] \leftarrow (F_{Vec,}\, n\,\%, m\%)$
Step14. Execute $\rightarrow$ training and testing operation
Step15- return: performance score $\rightarrow f_{val}(F_{CD})$
End

The computing mentioned above steps in from of algorithm is responsible for carrying out the movement and physical activity detection based on the analysis of accelerometer-sensor generated signal, which is in the form of time-series data. The entire operation of the proposed algorithm is carried out on the signal segment of different activities performed by the human movement and multiple actions. The first step of the proposed algorithm is to initialize the variables to assign values for each variable such as S_N- (number of samples), T_{w-} (length of time window), and g refers to earth gravitational force, which is kept equal to its default or standard value. The next step of the algorithm is subjected to the process of taking input values in the form of acceleration data-(Ac_{Data}) to carry out further essential operations for the different activities of the subjects. The algorithm executes the process of data normalization and noise filtering so that the input can be prepared for the feature selection. Here, the system applies digital filtering operation for the pre-processing operation using function $f_{hp\ over}\ Ac_{Data.}$ This function mainly refers to the execution of high pass Chebyshev-2 filter, considering stopband and passband gain at the sampling rate of 50Hz. Once the filter is applied to the original signal, then it generates a new version Ac_{Data}^{P} i.e., filtered signal, which highly relevant to the body movements. The obtained pre-processed filter Ac_{Data}^{P} is quire free form the impact of the gravitational force. The next step of the proposed algorithm is responsible for the appropriate selection of the features with a finite set of measurements of the similarities and differences based on the tri-axial acceleration data(x, y, z) using another discrete functions-f_2 to obtain descriptive features. After extracting significant features, the system performs vectorization operation to store the computed features in vector to make ease of computation and to achieve higher accuracy in the classification process. The algorithm uses two forms of a supervised learning algorithm for classification i.e., SVM and NN. Classification operation describes a popular class of ML algorithms in which the key concepts is to predict the class of a new sample, in this case, a signal segment on the basis of prior knowledge of

similar data where the training operation is carried out with a large set of labeled cases and optimizing its free parameters to identify labeled cases as accurately as possible. However, before executing supervised learning algorithm-(SLA), the feature data are divided into two distinct sets where 70% of data is subjected to training-(T_{rain}) process, and 30% of featured data is subjected testing-(T_{test}). After which the trained data-(D_{tr}) and data for testing-(D_{tst}) The next step, the algorithm applies SLA and obtains detection outcome final outcome-(F_{CD}) for the predictive analysis. Also, the system utilizes some statistical method and DSP tool to achieve the desired result of the activity analysis in the visual form with performance validation using function f_{val} with the outcome in terms of multiple performance metric scores. The next section presents the outcome and results in an analysis of the proposed system. □

IV. RESULT & DISCUSSION

The proposed system presents a human movement prediction system using time series data obtained from the sensor signal. The proposed system uses the concept of machine learning technique and signal processing technologies to perform prediction of human movement activity. The entire design of the proposed methodology is carried on the MATAB computing tool installed on windows 10-64 bit system. The simulation outcome demonstrates that the proposed system has achieved better performance with a good accuracy rate in predicted observation, which means the predicted observation and actual observation are found to be nearly similar to each other. □

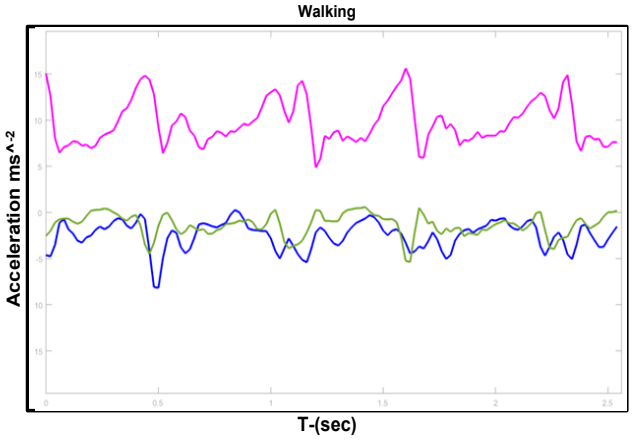

Figure 2Final outcome of signal analysis for walking

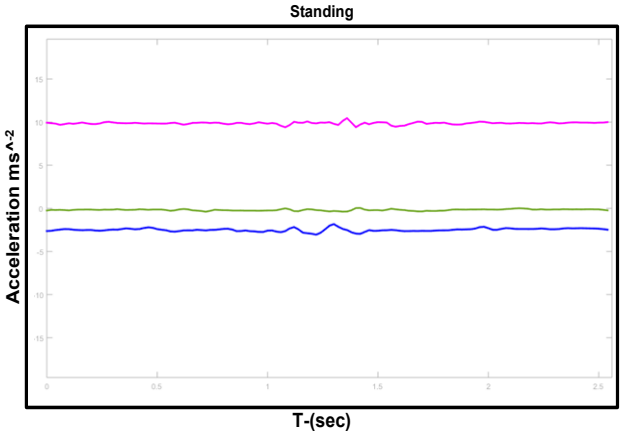

Figure 3 outcome of signal analysis for standing□

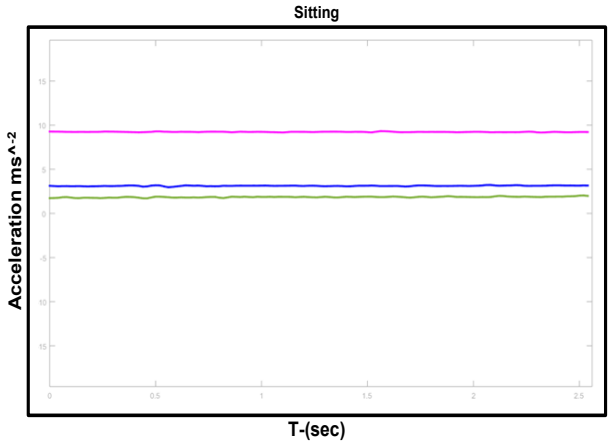

Figure 4 outcome of signal analysis for sitting

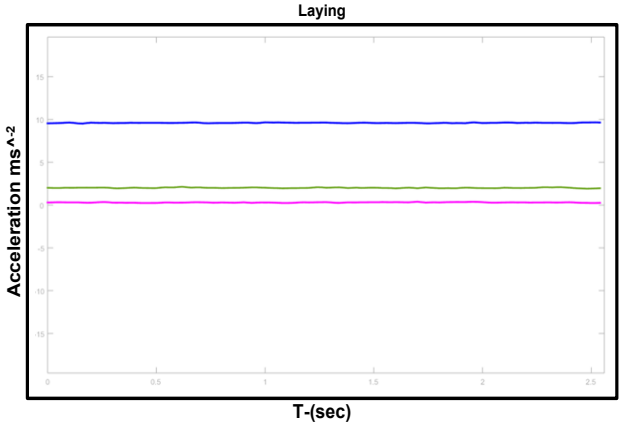

Figure 5Final outcome of signal analysis for lying

The outcome for the prediction of movement and physical activities can be seen in figure 2, figure 3, figure 4, and figure 5. The system utilizes a joint effort of ML techniques and DSP techniques and tools to estimate movement activities of the subject based on accelerometer sensor data. In the simulation performances, it has been analyzed that the predicted output is very close to the expected result. The values predicted are nearly the same from the actual values, and estimated values are the same. The proposed system offers a mechanism to effectively differentiate the different classes of human movements and physical activities-(sitting and laying) based on the sensor data coming from their smartphone. However, there was very little or considerable error due to instant variation over time because of the dynamic movement of the subject body. Yet, the outcomes are found to be accurate most of the time. Hence the proposed system predicts accurate body movements with higher accuracy.

V. CONCLUSION

The proposed system attempts to offer a human movement detection system based on sensor signals using a combined approach of signal processing and machine learning tool. The system considers numerical computing tools to design the entire modeling of the proposed framework to perform effective pre-processing, feature selection, and supervised learning based classifications. The utilization of additional functions/tools of digital processing helps to get proper visualizes the outcome. Through the simulation outcome, the proposed methodology found to be effective where the predicted results are found to quite justifiable in the detection of a different class of movements. The scope of the proposed system can be applicable to large scale deployment in a real-time scenario where the safety of older persons is of prime concern who are living alone. It also acts as a supportive tool in the application of human motion analysis-(HMA) based on the visual sensors, which are often limited to capture only living areas and are not able to analyses the movement in private areas due to privacy reasons. Therefore, the proposed model overcomes the limitation of visual sensor based HMA and provides better security to elderly or older peoples.

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