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Contents

Rice and Wheat Yield Prediction in India Using Decision Tree and Random Forest

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ABSTRACT

One of the main sources of revenue and growth in Indian economy is from agriculture. It is often a gamble for the farmers to obtain a decent yield, considering the unpredictable environmental conditions. This paper deals with the prediction of the yield of rice and wheat using machine learning algorithms using the annual crop yield production and the annual rainfall in the different districts of India. In this paper, a popular prediction model is developed using algorithms such as decision tree and random forest to predict the yield of most widely grown crops in India like rice and wheat. The features used were the area of production, rainfall, season and state. The season and the state were one hot encoded features. Mean square error was used to measure the loss. The dataset was prepared by combining the crop production in the various states and the rainfall dataset in the respective states.

Keywords- Machine Learning, XGBoost, Decision Tree, Random Forest, Data Preprocessing, Data Visualization, Prediction.

I. INTRODUCTION

In agriculture the yield is the amount of crops grown or products from the crops such as milk, wool or meat produced per unit area of land. As an alternative technique, the agricultural productivity can also be calculated using the seed ratio.

Rice is a type of seed originating from the grass species. It is considered as the staple food for most of the countries especially in Asia. It is a cereal crop and it is one of the most important commodities from agriculture point of view.

Wheat is also a grass species grown for its seed. It is a cereal grain which is widely consumed as staple food. Wheat requires different conditions to grow as compared to rice and is also an important commodity for agricultural trade.

In earlier days the farmer's experience was considered for the effective production but was of false hope. Due to the daily change in the various conditions, farmers feel the compelling need to produce more crops. Due to this present situation, manyof the farmers are not having enough information and knowledge regarding the new crops and their farming. Also, they are not completely educated regarding the benefits they get while farming the new crops. In this regard, understanding the use oftechnology and forecasting crop performance in different environmental conditions, the productivity of various crops can be increased and is of beneficial importance to the farmers.

In the proposed system, Machine learning techniques are used and prediction algorithms like decision trees and random forest to predict rather accurately which crop cultivated yield better production at the present environmental conditions.

Rice and wheat is a primary staple diet throught out India and the requirement for it's large production is a must. There must be a method to increase the production or to grow it in ways that can maximize the yield over time and meet the demands of the people. This model helps to find out the yield what it can be it can be for the crops rice and wheat and what the effective conditions are in terms of rainfall, to optimize the yield of the crops.

This model implements the use of decision trees and and random forest classifier, machine learning algorithms to predict the yield of various crops. The dataset used consists of the the following crop yield production on a yearly basis in the different districts of Punjab along with the rainfall on a yearly basis in these districts respectively.

The decision tree algorithm uses only the essential features from the set of existing features in giving results for the desired output. However the drawback of this algorithm is that there is a probability for overfitting as it iterates through the dataset. Therefore the results are tightly bound to the dataset and if a network trained on this algorithm is used to predict future crop yield there will most probably be an error in the result. In order to overcome this problem the random forest classifier is used yielding higher accuracy results.

This model helps the farmers to increase their productivity of their respective fields and the wastage is minimized. Being the current day situation where the population is increasing implying the increase in demand this model will be useful for the farmers to maximize the yield and also to maximize their profits

2. Literature survey

In paper[1], the process of prediction of crop yield involves two stages. First stage is to analyse and then second is to categorize them using data mining algorithms. The authors have implemented the classification methods of Naive Bayes and K-Nearest Neighbour for crop yield prediction using the soil dataset. The results of the experiment classifies the soil into categories of low, medium and high. The soil with high confidence value can be used for larger crop yields, medium is for average crop yield and low value infers that the crop yield may be less than average. The dataset size is limited and as a future work, authors claim to use a larger dataset for higher accuracy.

The authors in [2] describe the crop prediction process with respect to the dataset of rainfall, crop type and soil type for a given land. The main algorithm used here is K-means and fuzzy logic. The dataset is used to generate the rule based fuzzy inference system. Both the algorithms are applied to predict the type of crop suitable for the anticipated rainfall and soil type to generate high production in crop yield. About 20 fuzzy rules are formulated and the type of crop is given as input for thesystem that predicts the production of the crop.

The system implemented is a useful tool for farmers to predict the productivity of the upcoming season and increase their productivity and thus provides by minimizing the losses. The authors do not consider the current weather conditions to predict the crop yield but instead use the data from previous few years. Also, there is no standard quantifiable metric used in the system for rainfall or crop yield.

As per the discussions in the paper [3], the authors have employed different data mining techniques in the field of agriculture. Various techniques include K-means, support vector machine and artificial neural networks to predict the crop yield with different climatic parameters like temperature, rainfall, evapotranspiration, wet day, etc. The authors have implemented C4.5 algorithm to develop decision tree and rules for prediction and an accuracy score of about 90% was achieved for selected crops and over 75% for all the crops. The dataset used in this system was for more than 20 years of data.

The paper [4] gives an analysis of yield prediction by using the environmental parameters such as area used for cultivation, rainfall recorded annually and the food price index. The algorithms used are Regression Analysis and Linear Regression with above parameters for crop yield prediction. The dataset used for analysis is for a period of 10 years. The algorithms use the environmental parameters as exploratory and response variables that helps to make the decision. The results depicts that the parameters influence an average of 70% for the crop yield. The paper lacks usage of weather conditions, minimum support price and soil parameters for yield prediction.

Weather forecasting and crop prediction both are integral part of farming [5]. The application built here uses collaborative filtering technique with weather factors such as temperature, wind speed, humidity, etc., for predicting the crop yield. The application also predicts the air quality index that predicts the pollution in the air. Multiple open source APIs are used toextract the data and analysis is carried out on it for prediction. The application suggests the best crop for the conditions that prevails for a better yield. The paper does not discuss on the results and accuracy of the prediction technique used.

3. The Proposed Model

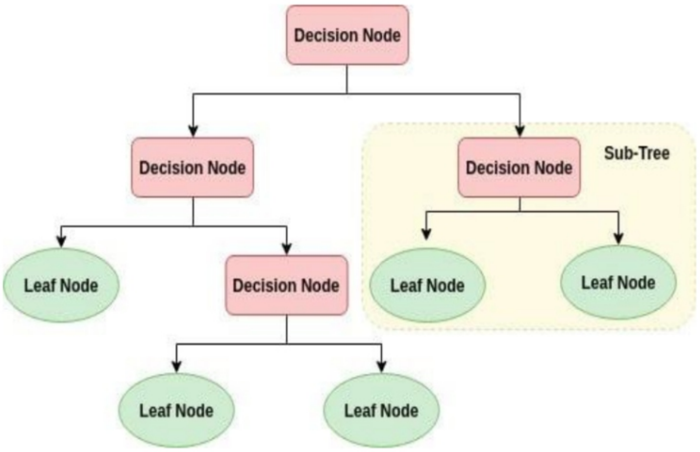
A. METHODOLOGY

The proposed model makes use of three well-known machine learning algorithms applied to the customized input datasets for rice and wheat separately. They are:

1. Decision Tree Algorithm

It is a supervised learning algorithm, based on condition based decision making, which is applicable for both classification and regression. In Decision Trees, in order to predict a class label of an input record, the decision making starts from the root of the tree and classifies the input records by passing them down from the root to some terminal node of the tree, with the terminal node giving the classification of the input.

Each node in the tree is responsible for testing one feature, and every edge going down the node corresponds to plausible answers to the tested feature. This method is recursive and is repeated for every non leaf node.



The following table shows the root mean square error (RMS) values using this algorithm:

Crop	RMS Value
Rice	0.02538
Wheat	0.02198

2. Random Forest Classifier

Random Forest is an ensemble learning technique, which uses a combination of a number of machine learning algorithms to obtain better performance in prediction.

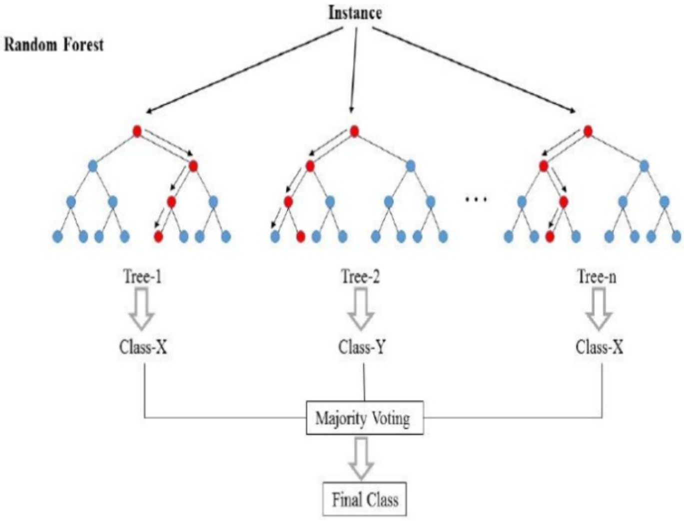
Two key concepts of the classifier:

a) Training data is randomly sampled while building the trees.

b) Subsets of features are chosen randomly while splitting the nodes.

Bagging technique is used to create an ensemble of trees where many subsets of training data are produced with replacement.

In this technique, a dataset is divided into a number of subsets using randomization. Based on a single learning technique, a classifying model is built based on the samples of subsets. A classification with most votes, as a contribution of many trees in the forest is considered as the result for the corresponding input.

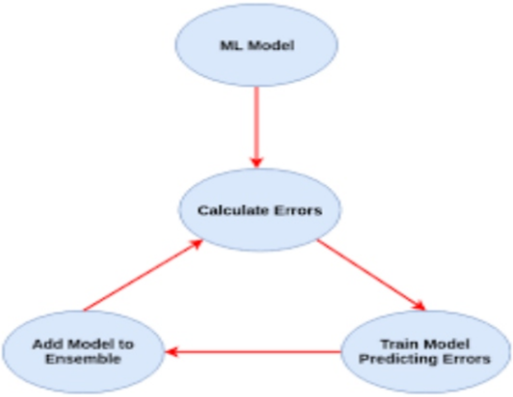


The following table shows the root mean square error (RMS) values using this algorithm:

Crop	RMS Value
Rice	0.01942
Wheat	0.01680

3. XGBoost Classifier (Extreme Gradient Boost Classifier)

XGBoost is an ensemble Machine Learning algorithm and uses a gradient boosting framework based on decision trees. It makes use of system optimization techniques such as parallelization, tree-pruning, to avoid overfitting of the model, and hardware resource optimization. It also uses algorithmic enhancements to yield results in the shortest possible time.



B. IMPLEMENTATION

1. Data Preprocessing

The crop yield dataset used in the proposed model is take from the website 'data.gov.in', titled 'District-wise Season-wise Crop Production Statistics from 1997-2015' and the rainfall dataset used is taken from Kaggle, titled 'rainfall in India 1901-2015'.

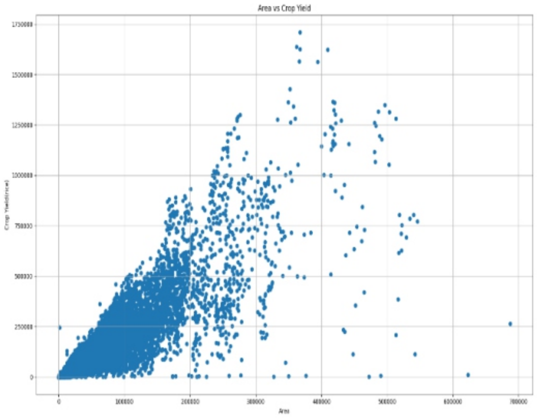
Out of many crops present in the dataset, it is split into two datasets, a rice dataset and a wheat dataset. For each of these datasets, the rainfall statistics is mapped according to the corresponding seasons, district and year. All the null values are filled with mean values. Thus, two processed datasets, containing crop yield and rainfall statistics are obtained.

2. Data Visualization

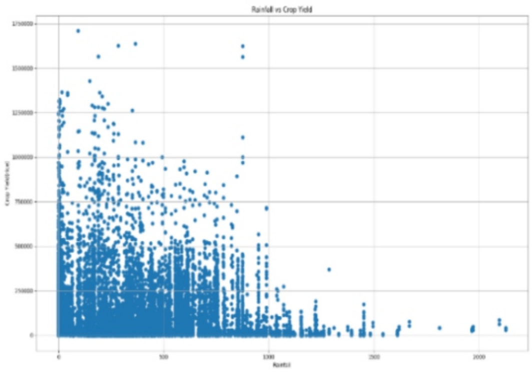
Several plots are plotted to understand the statistical data visually, for both rice and wheat. Units of measure for area of production, rainfall and crop yield are metres, millimetres and kilograms respectively.

Rice

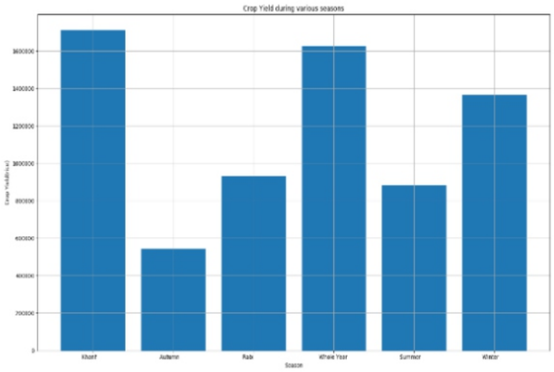
Area of Production v/s Crop Yield



Rainfall v/s Crop Yield

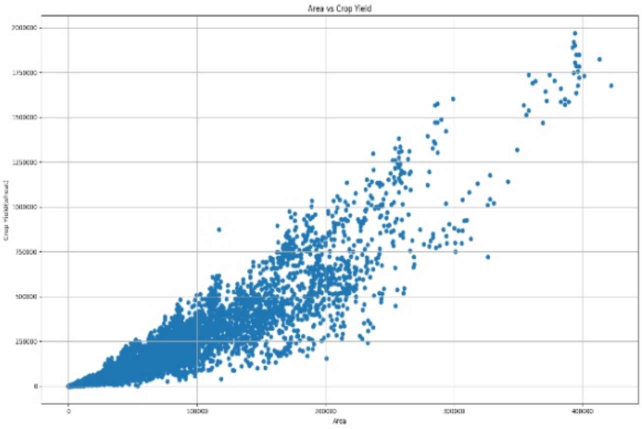


Seasons v/s Crop Yield

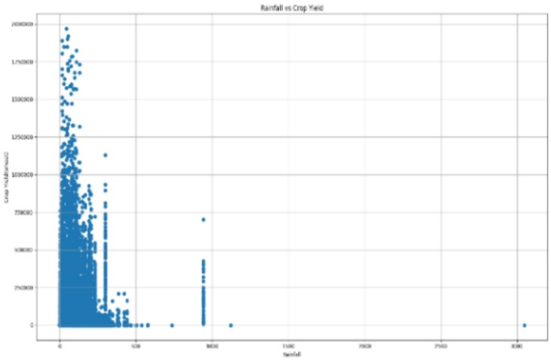


Wheat

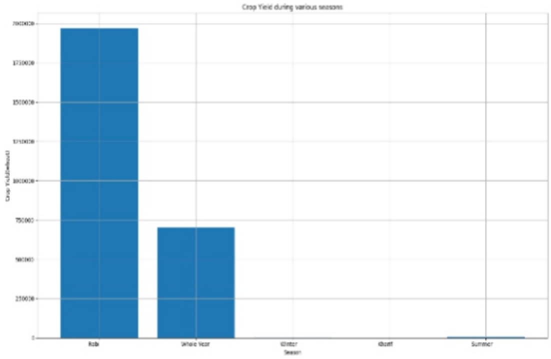
Area of Production v/s Crop Yield



Rainfall v/s Crop Yield



Seasons v/s Crop Yield



From the above plots, it can be interpreted that crop yield is linearly related to area. It is also observed that rice is mainly grown in Kharif season and wheat in Rabi.
Hence all these features are vital in predicting crop yield.

3. Feature Extraction

The features considered are state name, district name, area of production, yield, mapped rainfall data and season.
All the categorical features like state name, district name and season are one-hot encoded.

Area of production and yield are normalized, and the ‘NaN’ values if any are filled with mean values, for each of the features. Mean value method has been used because all the features considered are numeric and statistical.

All features except yield are considered to predict the yield. The dataset including these features is split into training data (75%) and testing data (25%) and fed into the above-mentioned Machine Learning models.

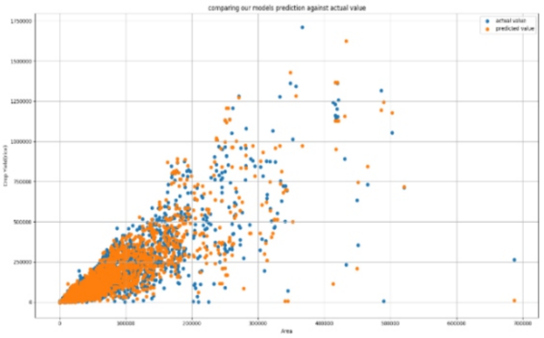
4. Training and observations

The training data is fit into models from ‘sklearn library’. All parameters for the regressor are set to default. The results obtained are visualised in the graphs shown below:

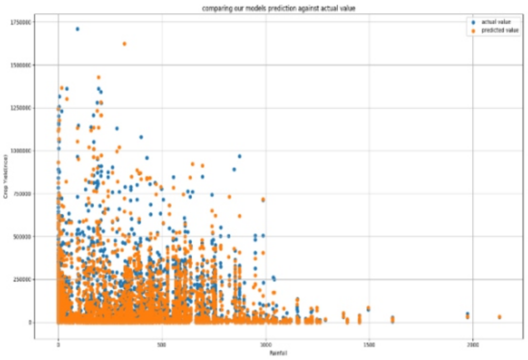
a) Decision Tree Regressor:

Rice

Area v/s crop yield

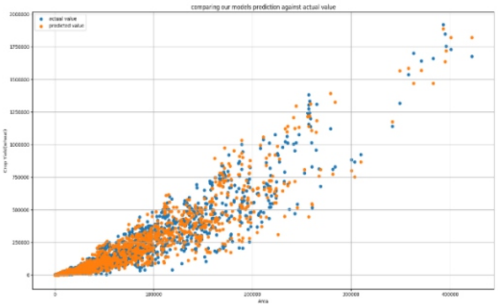


Rainfall v/s crop yield

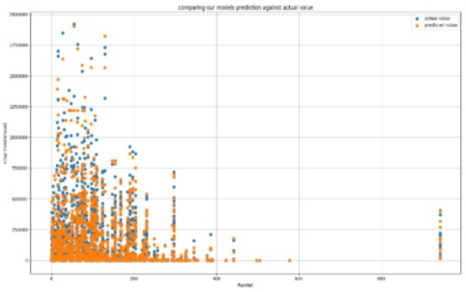


Whea

Area v/s crop yield



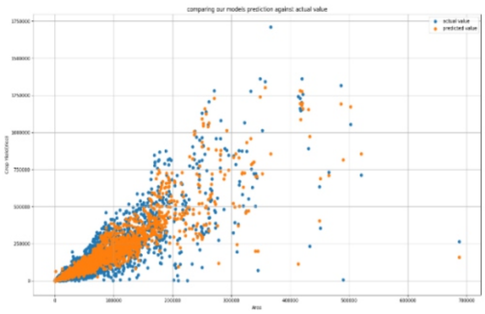
Rainfall v/s crop yield



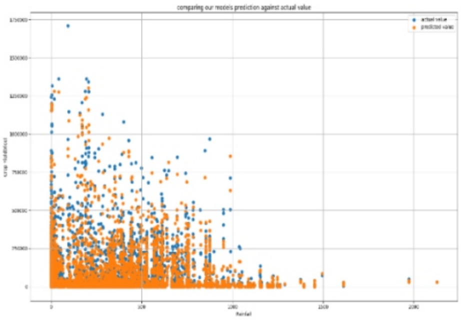
b) Random Forest Classifier

RICE

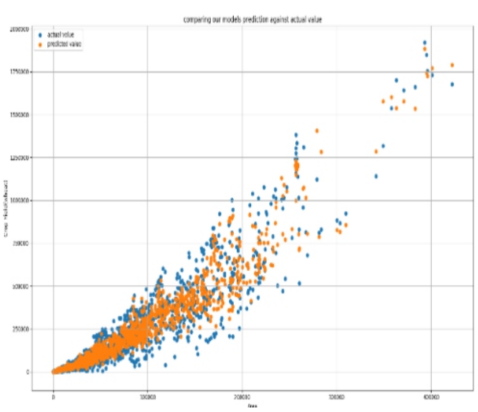
Area v/s Crop Yield

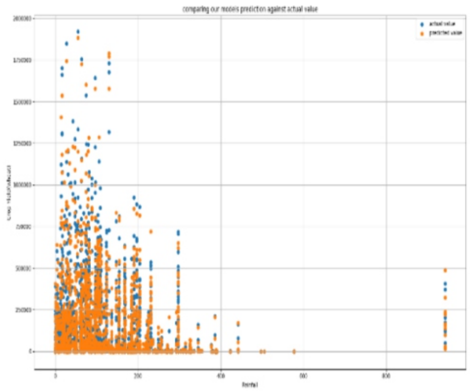


Rainfall v/s crop yield



Wheat


Area v/s crop yield


Rainfall v/s crop yield

4. Results

In this paper, the algorithms such as decision tree and random forest are used to predict rice and wheat yield. The Mean square error has been used to measure the loss incurred by the model.

ALGORITHM	CROP	MSE
Decision Tree	Rice	0.0006418
	Wheat	0.0004834
Random Forest	Rice	0.0003772
	Wheat	0.0002825

The results clearly show that random forest algorithm fared much better than decision tree algorithm. This behaviour is expected as random forest algorithm is an ensemble model. Due to this, randomness in induced in the model which leads it to generalize better than stand alone models. This can also be seen in the graphs for decision tree and random forest (the plots for decision tree show that the model is slightly overfitting when compared to random forest model.)

5. Conclusion

From the results, it can be observed that decision tree algorithm overfits as mentioned earlier, and random forest does not These experiments also showed that rice yield was dependent on the amount of rainfall experienced where as wheat yield was not affected much by it.

This paper can be further extended by adding more features such as temperature, soil conditions, etc., and using more advanced models such as XGBoost.

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A Research Perceptive on Deep Learning Framework for Pedestrian Detection in a Crowd

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ABSTRACT

In populated cities, we often find crowded events like political meetings, religious festivals, music concerts, and events in shopping malls, which have more safety issues. Smart surveillance systems are used in big cities to keep crowds safe and make crowd security less complicated and more accurate. However, the surveillance systems proposed for a crowd are monitored by human agents, which are inefficient, error-prone, and overwhelming. Even with deep learning-based feature engineering in crowds, many variants of crowd analysis stilllack attention and are technically unaddressed. Considering this scenario, the smart system requires the most advanced techniques to monitor the security of the crowd. Crowd analysis is commonly divided into crowd statics and behavior analysis. This paper explores more about crowd behaviour analysis, pedestrian and group detection which describes the movements that are noticed in the crowd image. Subsequently, the issues of the current methodology of pedestrian detection, datasets, and evaluation criteria are analyzed.

Keywords: Crowd Analysis, Pedestrian and group detection, deep learning, Crowd IoT analysis, Human Activity Recognition.

I. INTRODUCTION

Mass events occur with a major crowd of human societies, which are highly probable in sports events, public places, and political meetings. The is an increase in population for these events that attract an ever-rising number of people[1]. The high population in the cities leads to multiple crowd situations, which need more ever-rising. Cities are establishing intelligence systems based on video cameras which humans have monitored over the last decades, and smart cities use the technology to amend the wellness of urban people. Computer vision techniques for crowd analysis become more and more popular as a result. To better understand how people and crowds behave, several research has been conducted in crowded settings. The two primary research facets of crowd analysis are crowd information, which provides the gathering count, and community behavior analysis, which examines how people behave in crowds. Fig 1 shows the basic framework of crowd detection.

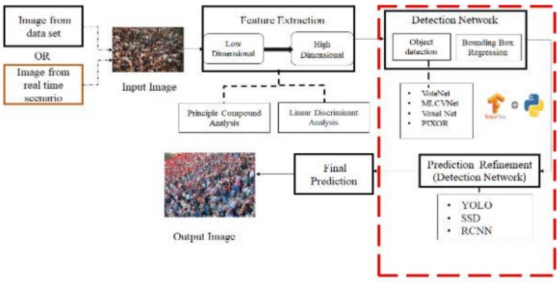

Fig1: Basic Crowd detection framework

Real-time pedestrian identification is a significant field of study within the ideas of deep learning and computer vision, and it has become a significant issue in recent years. There are numerous potential applications for pedestrian detection, particularly in the field of surveillance. Machines incorporating vision-based intelligence systems can see objects according to computer vision. When deep learning algorithms are put under pressure, the deep learning models offer suitable improvements. Detecting, analyzing, and detecting public violations in streams of surveillance camera data are currently used to tackle deep learning approaches. The number of cameras in crowded places grows every year in terms of the aspect of security. The cameras are used to capture after the incident. The development and more systematic use of object detection, especially for pedestrian detection, helps as a pre-processing step for uninterrupted analysis of the video footage. Several algorithms have been developed, which focus on improvements in both accuracy and speed are analyzed and studied. The main properties of designing the detection algorithms are the evaluation speed and the accuracy. The detection accuracy is dependent on the convolution of the images.

Detectors experience several forms of occlusions, and real-time crowd scenes are frequently congested. It is still difficult to create a high-precision pedestrian and group detector that will work on systems with quick response times and reasonable computational resources. The system developed must react fast since individuals usually outpace the camera's field of vision. Therefore, an efficient deep framework with multi-modal image fusion is vital to prevent false alarms.

This study extends to the surveillance systems[2] offered for pedestrian detection in crowds because there is a possibility of a high-risk factor in accidents when pedestrians walk on footpaths and intersections in a crowded area. Therefore, the safety systems should focus on the accuracy and effectiveness of pedestrian tracking, localization, and potential obstacles. The rest of the survey extends with related work, methodology of crowd analysis, human behavior analysis, and pedestrian behavior concluded with the above-related datasets, annotators, and evaluation metrics.

2. Methods of Crowd Analysis

Over the last few decades, a great number of works on crowd analysis and pedestrian detection have been analyzed and discussed. This section follows the literature review for providing an overview of crowd analysis that include (i)Overall crowd analysis, (ii)Anomaly Detection, (iii)pedestrian and group detection, (iv) Human Action Recognition, (v) IoT-based crowd analysis

A. Crowd Analysis

A spatiotemporal feature [3] of crowd motion is used as a set of priors for the individual tracking in the video of densely populated environments. sequences from the film that show pedestrians moving at different speeds and directions both physically inside each frame and chronologically over the entire scenario Reviews of crowd analysis taxonomies are made in the following subsections.

B. Anomaly Detection in crowd

The existing crowd anomaly detection models have high complexity due to the incompetence of traditional deep learning methods to extract the time-related features and the absence of training of images. Yan Hu [4] created an enhanced spatial-temporal convolution to address this problem. This improved convolution uses an aggregation channel feature model to perform picture monitoring and selects aberrant behaviors in the image with low-level features. Sonkar [5] compared the ViBe and CNN algorithms to identify anomalous behaviors in the photos. Due to their computing flexibility, statistical approaches are extensively utilized in video frame computation designs, and real-time abnormal event detection typically makes use of fast algorithms with minimum computational costs. [6]. However, these assumptions cause some anomalous event detection to degrade, making it impossible for them to deliver real-time outputs. In addition, some strategies for reducing computing complexity result in a more minor video sequence, which can negatively affect predictive modeling and even the overall appearance of people in the crowd, leading to poor monitoring or higher recognition error [7,8].

C. Pedestrian and Group Detection

Recognizing pedestrians is a challenging problem in real-world situations that video surveillance software frequently observes. Detectors must deal with a range of occlusions in the usually crowded scenes. Deep Learning models frequently deliver fantastic results, whereas conventional techniques frequently fail to recognize pedestrians in challenging environments. The major goal of the research is to develop a robust, fast, and highly accurate pedestrian detector which is an efficient system to be improved with stringent processing power constraints.

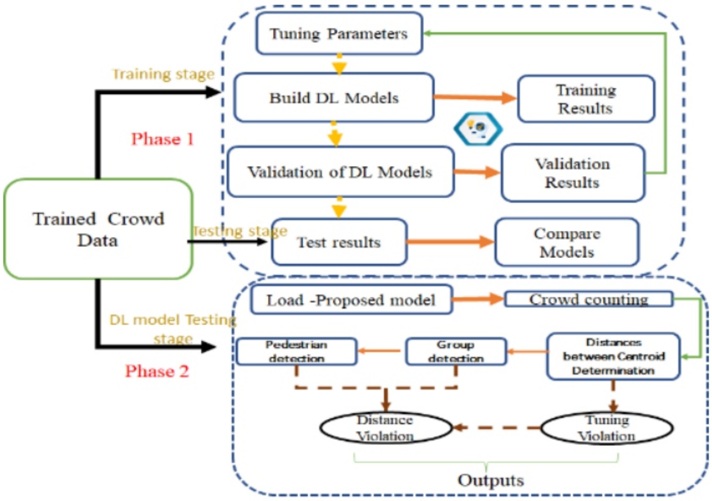

Fig 2: General Deep learning framework for pedestrian and group detection

Several studies employed conventional techniques to extract features and nourish those data into machine-learning algorithms. This is done to identify pedestrians and groups before the emergence of deep learning-based approaches for crowd analysis. The study in this field includes two different detection frameworks and uses hand-crafted approaches for identifying pedestrians and groups. Despite being less recent, it is nonetheless highly regarded. A framework with a two-stage detection framework is divided into different parts: on the image, a series of region suggestion boxes are given before object identification methods are used. One approach is RFCN [9], which provides information of location to the pooling layer, enhances location sensitivity, and enhances processing results for location-sensitive pedestrian identification problems. Adding FCN leads to more network parameters and feature sharing compared to Faster RCNN, as well as a smaller overall network size. As a result, the network's performance is improved while the amount of repetition is decreased. How quickly you're moving. When performing mask prediction tasks, the Mask RCNN follows the pooling layer with a convolutional layer. This structure can perform tasks like segmenting and recognizing pedestrians and separating them from the background. The output may also be used to identify bodily motions in people. The SAF RCNN [10] enhances general object detection, but general object detection improvement is constrained because object size changes are more frequent in pedestrian identification. Area proposal and classification are the two components of the two-stage pedestrian detection framework [11]. By offering innovative preselection box generation and feature extraction approaches, improving the prediction component, or both, researchers might boost the detection effect. The overall structure is highly complex than a single stage frameworkbut it offers more accuracy.

Ge[12] demonstrated that cluster analysis can find small groups of people moving together and that video may be used to construct paths from automated pedestrian detection and tracking. As far as we know, the first study demonstrates that the outcomes of agglomerative clustering are statistically consistent with judgments of one-to-one human in a crowd. As a discipline like a computer vision develops, its influence on other fields is one way to assess the significance of research in that area. The results suggest that automated monitoring may quantitatively characterize actual crowds more quickly and accurately than human observation, offering up a new avenue for empirical research on social behavior.

D. Human Activity Recognition

Human activity recognition is extremely important in various sectors, including human-computer interface, robotics, everyday monitoring, ecological observation, and video surveillance systems. This activity recognition task may be effectively completed by using several datasets such as Sports-1M, UCF-101, and HMDB-51 and training them. Convolutional Neural Network [13] model implementation for image identification using OpenCV aids in the model's effective operation. The use of several datasets in the action recognition model has made it simple to classify activity according to whether it is normal or abnormal and suspicious. The server delivers an alert to the authorities on the occurrence of abnormal behavior occurring in real-time by the specified nature. Many hazardous actions can be prevented with their negative effects reduced due to the adoption of this concept.

Fig 3: Human Activity Recognition Framework

E. IoT-based crowd analysis

The use of overhead view video sequences to conduct people detection and counting is shown using an IoT-based crowd monitoring system [14]. The SSD-Mobilenetv2 detection model is examined for detecting purposes. Because people's appearances from the above perspective differ significantly in visibility, shapes, sizes, body articulations, and postures, the detection model was trained using the standard frontal view data set. Eventually, during the phase of transfer learning, theadditional training is done using an overhead data set. The recently learned features are combination of existing trained model in which two virtual lines are utilized to count the number of people after detection. The experimental findings describe the efficiency and determined the learning-based crowd surveillance system.

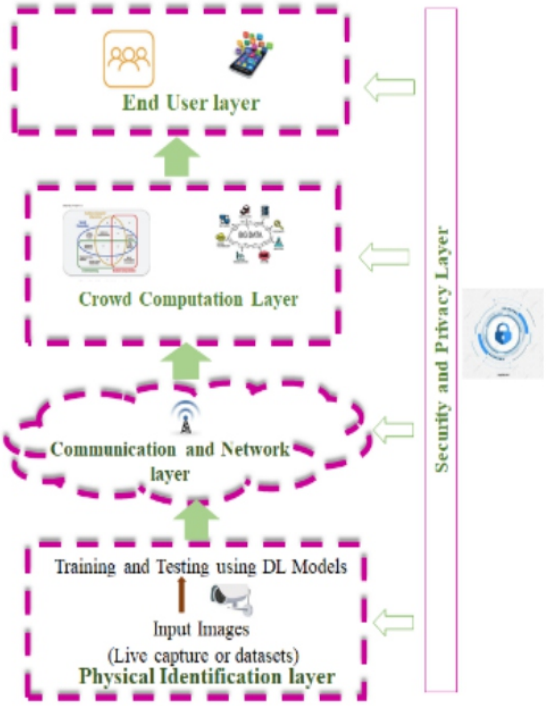

Fig 4 IoT Architecture for Crowd Analysis

3. Data Sources

Crowd Human dataset: CrowdHuman[15] is a dataset that may be used to compare detectors in crowd settings. The CrowdHuman dataset is extensive, well-annotated, and diverse. For training, validation, and testing, CrowdHuman has 15000, 4370, and 5000 photos, respectively. The dataset contains 470K human examples from the train and validation subsets, with 23 people per image and various types of occlusions.

KITTI dataset: Kitti[16] is a dataset created with help of autonomous driving platform.The tasks, such as stereo, optical flow, visual odometry, are listed in the comprehensive benchmark. In addition, to the object detection dataset the monocular pictures and bounding boxes, are included. This dataset tagged 7481 training photos with 3D bounding boxes.

UCF crowd datasets[17]: The goal of the Static Floor Field is to capture the scene's beautiful and consistent features. Favorite places, such as prominent paths typically chosen by the audience as it flows around the scene, and preferred departure spots are among these qualities. For human action detection UCF101,UCF50 and UCF11 are used .

Pedestrian and Group Detection datasets

COCO datasets: The Microsoft Common Objects in Context dataset [18] is large-scale object detection, segmentation, key-point detection, and captioning dataset with 328K images. Bounding boxes and per-instance segmentation masks with 80 item types are included in the dataset as annotations for object detection. More than 200,000 photos and 250,000 human instances have been classified with key points. Per-pixel segmentation masks containing 91 categories, such as grass, wall, and sky, are used in the stuff-based image segmentation.

Behave Dataset[19]: The dataset consists of eight individuals interacting with twenty items in five different naturalistic environments. With four Kinect RGB-D cameras, a total of 321 video sequences were captured. Human and object masks, as well as segmented point clouds, are included in each frame.

Each picture is coupled with 3D SMPL and object mesh registration in-camera coordinates. For each sequence, the camera takes a different stance. Reconstructions of the 20 objects using textured scanning.

4. Challenges and Future Direction

The multiscale challenges and occlusion issues listed above are the primary problems impacting pedestrian detection. The multiscale issue among them calls for it to be possible to measure the size of pedestrians correctly; simultaneous detection places more demands on the system. on the network for feature extraction. The occlusion issue demands specific pedestrian detection parts and suggests additional restrictions and improvements in the recognition algorithm. These concerns directly enhance pedestrian effects and sophisticated scene detection, a crucial strategy to enhance pedestrian detectors. The hardware requirements are frequently considerable, even though the large distribution network has significantly improved.

5. Conclusion

Smart city development is mainly concerned with intelligent surveillance systems. The deployment of these devices necessitates the creation of a framework that can accurately scan video surveillance settings. In addition, crowd analysis-related approaches are in high demand since video surveillance is frequently used in public places. This overview is captured in a review paper by considering both parent fields and recent trends within the area. In this review study on crowd analysis, we discussed current developments in the industry. We looked at earlier reviews of crowd analysis throughout this work. We observed recent works just on branches and many sub-branches of crowd analysis, pedestrian and group detection, and human activity recognition

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A Review of Deep Learning Techniques for Encrypted Traffic Classification

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ABSTRACT

Network traffic classification is significant for task such as Quality of Services (QoS) provisioning, resource usage planning, pricing as well as in the context of security such as in Intrusion detection systems. The field has received considerable attention in the industry as well as research communities where approaches such as Port based, Deep packet Inspection (DPI), and Classical machine learning techniques were thoroughly studied. However, the emergence of new applications and encryption protocols as a result of continuous transformation of Internet has led to the rise of new challenges. Recently, researchers have employed deep learning techniques in the domain of network traffic classification in order to leverage the inherent advantages offered by deep learning models such as the ability to capture complex pattern as well as automatic feature learning. This paper reviews deep learning based encrypted traffic classification techniques, as well as highlights the current research gap in the literature.

Keywords-Traffic classification, Encrypted traffic, Deep learning, Machine learning

I. INTRODUCTION

A factor paramount to the management of a network and its security is Network traffic classification. It makes possible for network operators to apply quality of service (QOS), resource usage planning, pricing and security policies (malware detection, and intrusion detection) in accordance with the need of an application. Recently, the field is attracting more researchers due to rapid changes in technologies associated with the internet and mobile communication. One of the transformations is the use of encryption and obfuscation techniques, which are now prevalent in network applications. Encrypted traffic is known to constitute more than 50% of Internet traffic as a result of increase in demand of privacy from users in order to bypass censorship and enable access to services prohibited geographically [1]. This makes the field of traffic classification to remain active as more challenges arise from use of encrypted network applications.

Traditional approaches to traffic classification are:1) the port-based approach, 2) payload-based approach and 3) statistical/machine learning approaches

Port-based Approach: This classification method uses the official Internet Assigned Numbers Authority (IANA) list for classifying applications thereby making it easier for implementation in real time. However, the use of dynamically assigned ports numbers and use of other known port numbers by application to disguise their traffic render this approach ineffective [2].

Payload based approach: This classification method relies on the patterns or keywords in data packet a technique popularly referred to as deep packet inspection (DPI) methods in some literatures. The approach provides very accurate results in classifying applications [3] . Hence, it is mostly employed in commercial tools, however[4], DPI performs poorly against encrypted traffics, and incurs high computational overhead [5].

Statistical/Machine learning-based approaches: To address the limitation of the aforementioned approaches, methods base on flow statistics were introduced. The main intuition behind such methods is that the statistical attributes of network traffic are unique for different applications and can therefore be used to differentiate applications from each other [6]. Machine learning (ML) methods on the other hand are highly efficient in dealing with statistical data[4]. Therefore, several machine learning algorithms such as K-Nearest Neighbor[7], Random Forest [3] , Support Vector[8] Machines are employed. These methods can effectively classify encrypted traffic, since, they rely on statistical attribute of the network traffic data.

Recently, Deep learning (DL) which is a subset of ML have been widely applied for encrypted traffic classification. These approaches do not require feature engineering, and can automatically learn features from the input data without the need fora domain expert to perform feature selection[9],[10]. Thus, DL techniques perform effectively in large and complex data which characterizes the modern-day network traffic [11]

This work reviews research works that apply Deep learning models to classify encrypted traffic. The paper is organized as follows: Section 2 describes Deep Learning architectures. Section 3 presents our taxonomy of Deep learning-based techniques for encrypted traffic classification. In Section 4, Open challenges are discussed, and finally, section 5 concludes the paper.

2. DL Architectures

DL composed of multiple layers of artificial neurons capable of learning representation/pattern using multiple levels of abstraction. DL has seen considerable adoption in many fields such as computer vision, Natural Language processing etc. This subsection explains some state-of-the-art Deep Learning architectures commonly employed for encrypted traffic classification.

A. Multi-layer Perceptron (MLP)

The Multi-layer Perceptron MLP, also known as feed-forward networks are neural networks architectures with at least one hidden layer beside the conventional input and output layers. Layers in MLP are made up of nodes referred to as neurons, each neuron is fully connected to all neurons in the previous layer. Neurons present in each given layer functions independently without sharing any connection. These layers are connected to provide only unidirectional flow of information. Hence the name feed-forward networks. The primary task of MLP is to approximate any given function by making a neuron takes a sum of dot product of its weights with its inputs, and then pass it through a non-linear activation function to produces an output. The output serves as input to another neuron in the subsequent layer. The last fully connected layer is referred to as the output layer and represents the classes score in the classification context [12].

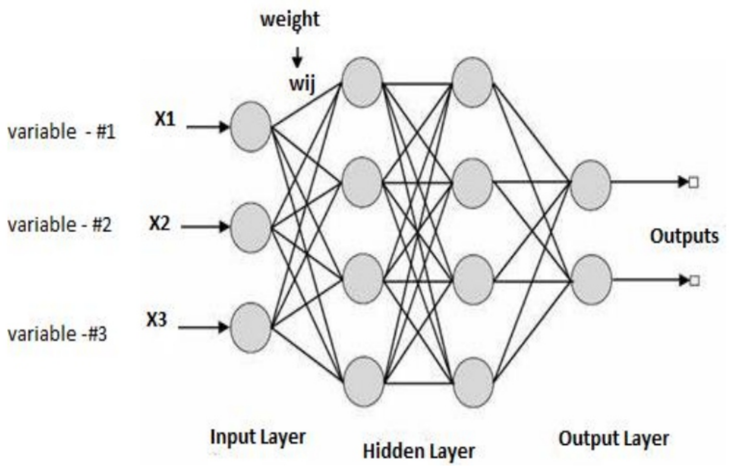


Fig.1. Feed-forward Network Architecture

B. Convolutional Neural Network (CNN)

Convolutional Neural Networks are designed to overcome the drawbacks of overfitting and scaling with high dimensional data associated with regular neural network like MLP, whereby, each neuron in one layer is connected to all other neurons in the next layer. CNN architecture models connectivity pattern of Neurons in mammalian visual cortex, in which individual neurons respond to stimuli only in a limited region of a receptive field. It is made up of a sequence of layers called convolutions. A collection of these fields overlaps to cover the visual area. Each neuron in a convolution layer is connected to a small region of the preceding layer using what is termed as a kernel or filter. This highly reduces the parameter space, and enables it to scales well with data of high dimension. Each layer of a CNN transforms multi-dimensional input volume to another multi-dimensional output volume of neuron activation. However, there exists a layer called pooling which is often sandwiched between one or two convolution layers to enable down sampling of the output. Finally, the last hidden layers of CNN architecture usually employ fully connected layers [13].

C. Recurrent Neural Network (RNN)

A neural network which has a self-recurrent connection in addition to forward flow of information is referred to as Recurrent neural network. It is a form of artificial neural networks in which the self-recurrent connection acts as some kind of memory that allows it to store temporal information. In this architecture, the output of a recurrent neuron at time step t is a function of all the inputs from previous time steps. This feature of the RNN makes it more suited for sequential data such as time series prediction and speech recognition in which good performance has been recorded in a number of literatures. The long-short term memory (LSTM) was introduced to tackle the gradient problem associated with Conventional RNN when training long sequences. LSTM are capable of detecting long-term dependencies in a data and also converge faster. Thus, making them more preferable than the traditional RNN [14].

D. Autoencoder

Another form of artificial neural network is the Autoencoder. This ANN learns to reproduces a given input as its output. The network is composed of Encoder function , a feature extraction function which is a hidden layer and a decoder function . The internal representation of the input data is learnt by the Encoder function while the decoder function reconstructs the input from the output of the encoder function.

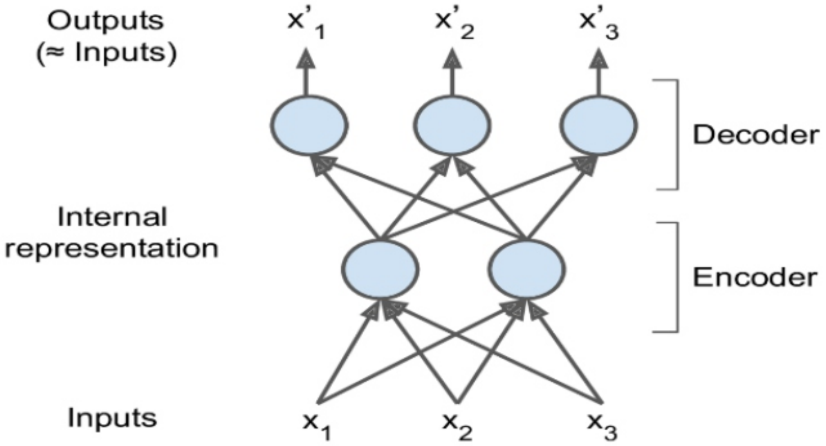


Fig. 3 Autoencoder

It is worth noting that the output is not an exact replica of the input but an approximate value even though the Autoencoder constructs a copy its input as its output. The model is constrained such that it prioritizes which aspect of the input data to learn. As an analogy, noise could be added to the input the network will be trained to recover the original input. The presence of the constraints forces the Autoencoder to learn efficient representation of the input data instead of copying the input directly to the output. This feature makes the Autoencoder suitable for dimensionality reduction as the learned representation which are referred to as codings have much lower dimensionality than the original input data. Autoencoders find suitable application in model where new data that resembles the training data is randomly generated [15].

E. Generative Adversarial Network (GAN)

GAN is a recently developed by Goodfellow et al [citation]. The model comprises of a combination of two neural networks which are trained in adversarial setting. The first network composes of A generator which takes in a random noise and generates new data instances, while the second neural network, receives input from both the generator and the original training data and is termed as discriminator. Each data instances are then reviewed by the discriminator and a decision is made on whether the data is from actual training dataset (real) or from the generator. Theoretically, there exist a point where the generator captures the whole training data distribution and which the discriminator becomes unable to ascertain whether the inputs are from the generator or not. Hence, the GAN is said to be fully trained at this point.

3. Taxonomy of Deep Learning for Encrypted Traffic Classification

This work will employ five criteria to categorize research works in literature that apply deep learning techniques for encrypted traffic classification problem

- Approach
- Features
- Model type
- Classification objective
- Learning mode

A. Approach

This refers to manner the deep learning algorithm is applied to encrypted traffic classification problem. In this category, we have two popular approaches. These are:

- End-to-end approach
- Divide-and Conquer approach

a) End-to-end deep learning approach;

The End-to-end approach leverages the automatic feature learning capability of deep learning models to perform traffic classification. Raw network packet is passed directly to the deep learning model after preprocessing. Thus, the approach eliminates the need of handcrafted features.

b) Divide-and Conquer approach

The divide-and-conquer approach is similar to the way classical machine learning methods are used to handle traffic classification. Therefore, network traffic features are carefully selected, and then feed to the deep learning model. The approach takes advantages of high feature-discriminative ability of deep learning models to offer improve classification accuracy over classical machine learning model.

B. Features

The feature refers to the traffic attribute, which is used as the input to the deep learning model. It mainly comprises the following:

- Packet-based features: this mainly consist of layer 3 and layer 4 header fields such as port numbers, protocols, flags etc. Since, there are several combinations of these fields, the useful ones are carefully selected by domain expert to serve as features to deep learning techniques. However, in a situation where the approach is an and end-to-end, the whole packets can be used as input to the deep learning model
- Flow based features: network flow is described as comprising packets sharing the following five tuples: source IP address, destination IP address, port numbers and protocols. Flow based features comprises mainly of Flow statistics such as minimum packet length, average packet length, volume of packet exchange in forward directions etc. These attributes are obtained after completion or termination of a flow. There exist many combinations of these attributes to be used as features.
- Time-series properties: these are similar to flow-based features; however, time-series features are derived when an arbitrary number of consecutive packets in a given flow are observed instead of an entire flow. The packets can be sampled in any part of a flow not necessarily at the beginning. The features derived may comprises properties such as inter-arrival time between consecutive packets, direction of consecutive packets, packets length etc. One advantage of time-series features over flow-based features is that, they could be used for real-time classification, since features can be generated before completion or termination of a flow. In recent studies [17] where time-series features were employed, as few as 20 packets in a flow were used to achieve a reasonable accuracy.

C. Model type

This refers to the actual deep learning algorithm used in the traffic classification task. Several models and architectures such as MLP, CNN, RNN, LSTM, AE and GAN have been employed. One can refer to Section 2 for a detailed explanation about these models.

D. Classification objective

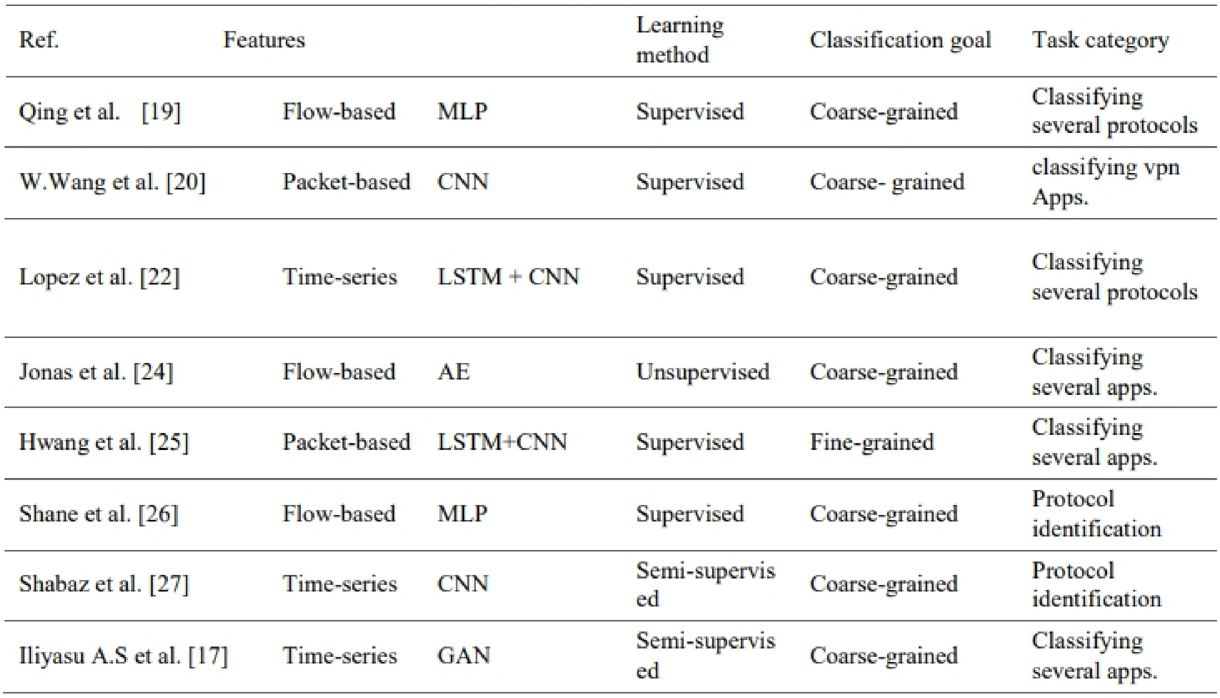
In this category, models are classified based on the granularity level of their classification task. This mainly falls within the following:

- Binary classification: the main objective here is to classify traffic as belonging to two difference classes. For instance, classifying traffic as either normal or malicious.
- Protocol identification: here traffics are categorized as belonging to a specific protocol. e.g. classifying traffic as HTTP, TCP, TLS, etc.
- Service identification: the task here is to identify a broad category of services to which network traffic belong to. For example, identifying traffic as belonging to streaming services, chat services, etc.
- Application identification: the traffics are tagged as belonging to a specific application. For example Google search, Facebook, YouTube, etc

E. Learning Mode

The learning mode refers to the way in which the deep learning algorithm is trained. The most popular deep learning mode used in network traffic classification is the supervised learning. However, unsupervised learning and semi-supervised learning methods are also significantly employed.

Table Error! No text of specified style in document.**.1** Taxonomy of recent representative studies of DL techniques in encrypted traffic classification



Ref.	Features		Learning method	Classification goal	Task category
Qing et al. [19]	Flow-based	MLP	Supervised	Coarse-grained	Classifying several protocols
W.Wang et al. [20]	Packet-based	CNN	Supervised	Coarse- grained	classifying vpn Apps.
Lopez et al. [22]	Time-series	LSTM + CNN	Supervised	Coarse-grained	Classifying several protocols
Jonas et al. [24]	Flow-based	AE	Unsupervised	Coarse-grained	Classifying several apps.
Hwang et al. [25]	Packet-based	LSTM+CNN	Supervised	Fine-grained	Classifying several apps.
Shane et al. [26]	Flow-based	MLP	Supervised	Coarse-grained	Protocol identification
Shabaz et al. [27]	Time-series	CNN	Semi-supervised	Coarse-grained	Protocol identification
Iliyasu A.S et al. [17]	Time-series	GAN	Semi-supervised	Coarse-grained	Classifying several apps.

4. Open Challenges

This section highlights some of the open challenges associated with encrypted traffic classification.

A. Large dataset collection and labeling of encrypted traffic

The issue of large data collection and labeling, to apply deep learning models, large and representative dataset is required.The dataset should also be diverse enough to avoid severe overfitting. It is well known that; large dataset collection and labeling is a challenging and non-trivial task. For example, researchers often use DPI (deep packet inspection) tools to label a network flow; however, the proliferation of encryption in today’s Internet traffic makes such approach unfeasible. Therefore, labeling is mostly conducted in an isolated environment such as or network edge. One drawback of such approach is model may severely overfit to features peculiar to the user rather than traffic- specific features as the dataset often contains interactions of only one or few users.

B. Multiplex stream

Another issue is that of multiplexed streams where a single flow consists of several traffic classes. This can be pictured in situation where tunneling is in place. The traffic that passes through the tunnel may contain many applications with same source IP address, destination IP address, and protocol and port numbers. One of the challenges is capturing and labeling such traffic. To the best of our knowledge there is no method in the literature that addresses the issue.

5. Conclusion

Network traffic classification serves as the basis for task such network management and security. Several methods have been employed to perform traffic classification. However, emergence of complex challenges such as encryption has paved the way for deep learning models which are better equipped to capture complex patterns than classical machine learning. In this paper, we have reviewed commonly used deep learning models in the domain of network traffic classification, and also highlighted the current research gap in the literature.

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Design of Self Adaptive Fuzzy Sliding Mode Controller for Robot Manipulators

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ABSTRACT

This paper intends to design and develop an adaptive fuzzy sliding mode controller (SMC) for robotic manipulator. Since it is not viable to pair the SMC operations with the system model every time, this paper adopts a Fuzzy Inference System (FIS) to replace the system model. It effectively achieves the experimentation in two phases. Accordingly, in the first phase, it attains the accurate features of the system model based on varied samples to characterize the robotic manipulator. In the second stage, it represents the derived fuzzy rules based on adaptive fuzzy membership functions. Moreover, it establishes the self-adaptiveness using Grey Wolf Optimization (GWO) to attain the adaptive fuzzy membership functions. The analysis distinguishes the efficiency of the adopted technique with the optimal investigational scheme and the traditional schemes such as SMC, Fuzzy SMC (FSMC) and GWO-SMC. Moreover, the comparative analysis is also performed by including the noise and validates the effectiveness of the proposed and conventional models.

Keywords- Sliding Mode Control; Robot manipulators; Controller; Noise;

I. INTRODUCTION

In general, robotic manipulators are widely applied in the industrial environment for executing dangerous or routine works. Robotic manipulators have been encounter nonlinearities and various uncertainties in their dynamic models, such as friction, disturbance, load change due to which it is very difficult to reach excellent performance when the control algorithm is completely based on the robotic plant model [1]. The trajectory tracking accuracy is the most important function of an industrial manipulator. Thus, a robot motion tracking control is one of the challenging problem due to the highly coupled nonlinear and time varying dynamics. Robotic control system design has been an important issue in control engineering. Several kinds of control schemes have already been proposed in the field of robotic control over the past decades [2]. Feedback linearization technique can compensates some of the coupling nonlinearities in the dynamics. Although a global feedback linearization is theoretically possible, a practical insight is restricted. Uncertainties also arise from imprecise knowledge of the kinematics, dynamics and also due to joint and link flexibility, actuator dynamics, friction, sensor noise, and unknown loads [3].

These dynamical uncertainties make the controller design for manipulators a difficult task in the framework of classical control method. Conventional control techniques for robotic manipulators include the computed torque control, adaptive control, sliding mode control, and fuzzy control [4]. The adaptive control has a fixed structure and adaptable parameters and is very effective in coping with structured uncertainties and maintaining a uniformly good performance over a limited range, but it does not solve the problem of unstructured uncertainties. The sliding mode control is a robust nonlinear control scheme that is effective in overcoming the uncertainties and has a fast transient response. However, chattering problem is a major drawback of sliding mode control. Hence boundary layer is used to avoid chattering phenomenon [5].

Recently the development of artificial intelligent control for robotic manipulators has received considerable interest. The most popular intelligent-control approaches are the neural network control and fuzzy control. The merit of the fuzzy control is that it can explicitly use human knowledge and experience in its control strategy. The drawback is the less theoretical analysis of stability for the general fuzzy controllers [6]. To overcome the demerits and take advantage of the attractive features of conventional control and intelligent control, this research proposes an adaptive fuzzy sliding mode controller (AFSMC) for the trajectory control of robotic manipulators. Besides advantage of stability and robustness of sliding mode control, the proposed method suppresses the input chattering in sliding mode by using the fuzzy control with adaptive tuning algorithm [7].

Sliding Mode Controller has been widely applied to various types of non-linear systems. SMC's popularity is due to its robustness against the change in parameters and the external disturbances in both theoretical and practical applications. However, the action of discontinuous part in traditional SMC leads the whole controller to face a troublesome condition known as "chattering" and the traditional type of SMC requires the whole dynamic functions of the system. Moreover, in order to achieve the non-chattering SMC, the sign function should be changed to saturation function to employ the adaptation of a thin boundary layer close by the sliding manifold to minimize or attenuate the chattering. However, this method damages the perfect tracking of the SMC; hence, the steady state error will always exist [8]. Furthermore to overcome the mentioned problem, some adaptive strategies recommended which can compensate the disturbances in order to increase the tracking performance.In recent decades, the Fuzzy Logic as a technique based on expert knowledge has been applied to a wide range of controllers for solving the complex problems. Although Fuzzy controller is free from huge mathematical operations but sometimes more mathematical treatment is needed. However it should be noted that sometimes Fuzzy Logic Controller is much more tranquiller [9]. Today's, applying techniques that combine the fuzzy theory with nonlinear controllers, for instance using fuzzy sliding mode controller are most common. The applications of fuzzy logic controller can not only be used in the systems with hard modeling, but they can also be used for systems with high mathematical analysis. The robust model of fuzzy combination, so called adaptive fuzzy sliding mode was introduced to reject the chattering phenomenon and compensate unknown dynamic parameters in the systems by another fuzzy logic controller [10].

2. Literature Review

For tracing control of non-linear structure, Kung and Liao [7] had presented the strategy of fuzzy SMC. In the hitting stage of unadventurous SMC, the chattering singularity is reduced by the fuzzy SMC and the sensitivity is reduced to plant uncertainties.

For nonlinear MIMO systems, Lin and Chen [8] had developed the adaptive fuzzy SMC. The main objective of this study is to solve the issue of controlling an unknown MIMO nonlinear affined system. With unknown nonlinear dynamics, Fuzzy controller is employed for the route tracing of MIMO system according to the sliding mode.

The adaptive fuzzy SMC scheme was developed by Kao et al [9]. Moreover, the distance based fuzzy sliding mode controller (D-FSMC) was presented in this work. Through Lyapunov stability system, the stability of the intended control structure is verified.

Using SMC, the design of robust control system was established by Ha [10] which utilizing a fuzzy tuning approach. The switching control, equivalent control and fuzzy control is superposed by the law of control. By the way of pole placement, a corresponding control law is intended. In the occurrence of constraint and disturbance hesitations, the Switching control is included to assurance the state reaches the sliding mode. In the sliding mode, to decrease the chattering and to enhance the control performance. The fuzzy tuning approaches are utilized.

For robotic manipulators, an adaptive FSMC was developed by Guo and Woo [11]. Through Lyapunov technique, the constancy and the conjunction of the entire structure is verified. In the classical SMC, it is a better solution to the issue of chattering. Moreover, it is considered that the designated components of the controller have influence on the network performance.

3. The Proposed Self Adaptive FSMC Controller

AFSMC is a controller that controls the uncertainties of non-linear systems without high-frequency switching. AFSMC helps to enhance tracking performance [8]. It is a widely used technique. It adjusts the SMC key parameters, inorder to eliminate or minimise the chattering. AFSMC improves the system robustness and get rid of the parameter perturbation [7][9]. The structure of AFSMC is represented in figure 1

A Design of an AFSMC

A 1.1 Design of sliding surface

The error state can be represented as [8],

$$c_i = a_i - b_i \qquad (1)$$

Where i =1, 2, 3 …

$$\mathrm{P}(c_1, t) = \mathrm{P}_a(a_1, t) - \mathrm{P}(c_1 + a_1, t) \qquad (2)$$

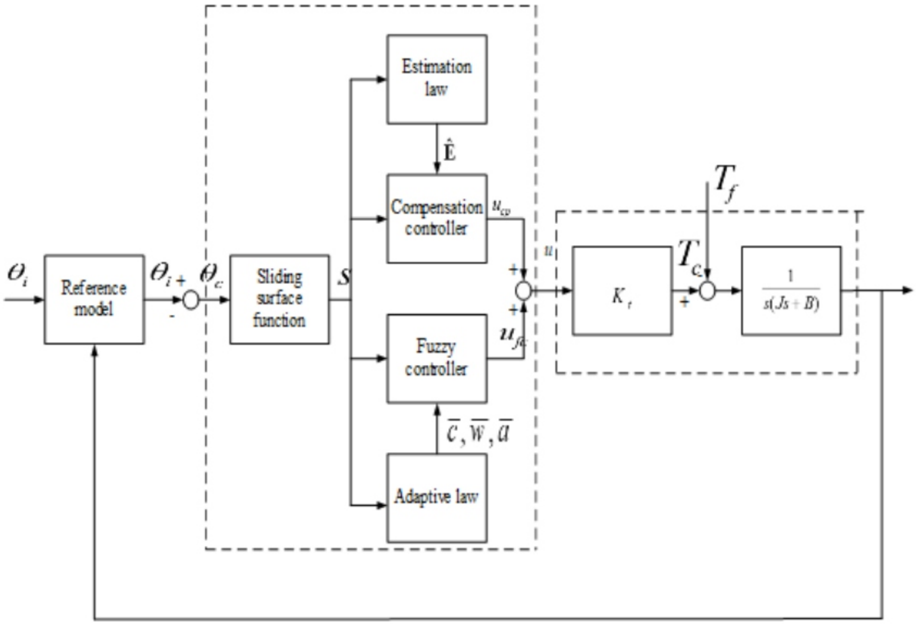


Figure 1: Structure of adaptive fuzzy compensate control

$$\Upsilon() = \Upsilon_a(t,a) - \Upsilon_b(t,b) \qquad (3)$$

The equations of error dynamic are:

$$\dot{c}_1 = c_2 \qquad (4)$$

$$\dot{c}_2 = c_3 \qquad (5)$$

$$\dot{c}_3 = -xc_3 - c_2 + \mathrm{P}(c_1,t) + \Upsilon(\cdot) - v \qquad (6)$$

Standardized state space equations of error states can be found as,

$$\dot{c}_1 = c_2 \qquad (7)$$

$$\dot{c}_2 = c_3 \qquad (8)$$

$$\dot{c}_3 = -xc_3 - c_2 + \mathrm{P}(c_1,t) + \Upsilon(\cdot) - v = c_4 \qquad (9)$$

$$c_4 = -xc_4 - c_3 + \mathrm{P}(c_1,t) + \dot{\Upsilon}(\cdot) - \dot{v} \qquad (10)$$

The sliding surface is given by,

$$u = c_4 - c_4(0) + \int_0^t \sum_{k=1}^{4} e_k c_k dt = 0 \qquad (11)$$

Where $c_4(0)$ represents initial state of c_4 Differential of the equation (13) can be written as,

$$\dot{c}_4 = -\sum_{k=1}^{4} e_k c_k \qquad (12)$$

The following is the matrix that defines the error states in equation (12).

$$\dot{\underset{-}{c}} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -e_1 & -e_2 & -e_3 & -e_4 \end{bmatrix} c = \mathrm{M}e \qquad (13)$$

Where $\dot{\underset{-}{c}} = [c_1 \quad c_2 \quad c_3 \quad c_4]^T$. c_j can be found by selecting the eigen values of M in which the characteristic polynomial

$$\mathrm{H}(c) = \dot{c}_4 + \sum_{k=1}^{4} e_k c_k \qquad (14)$$

$H(c)$ is Hurwitz. Speed of the system response and eigenvalues are relative.

A 1.2 Design of adaptive SMC

The control law is designed as,

$$r = r_{eq} + r_{afz}(t) \qquad (15)$$

Where r_{afz} represents the AFSMC and r_{eq} represents hitting control. Sliding surface, u and derivative of sliding function, $\dot{u}$ serves as the input to the fuzzy controller. Overall AFSMC is chosen as,

$$r_{afz} = \hat{\beta}F(\dot{u},u) \qquad (16)$$

Where $F(\dot{u},u)$ indicates the functional characteristics of fuzzy linguistic decision schemes. $\hat{\beta}$ represents estimated value. The estimated error can be defined as,

$$\dot{\underline{c}} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -e_1 & -e_2 & -e_3 & -e_4 \end{bmatrix} c = \mathrm{M}e \qquad (17)$$

Where $\dot{\underline{c}} = [c_1 \quad c_2 \quad c_3 \quad c_4]^T$. c_j can be found by selecting the eigenvalues of M in which the characteristic polynomial

$$\mathrm{H}(c) = \dot{c}_4 + \sum_{k=1}^{4} e_k c_k \qquad (18)$$

$H(c)$ is Hurwitz. Speed of the system response and eigenvalues are relative.

$$\tilde{\beta} = \hat{\beta} - \beta \qquad (19)$$

Estimation law is designed as,

$$\hat{\beta} = \gamma \left| F(\dot{u},u) \right| \qquad (20)$$

Where γ represents a positive constant. The reaching law can be determined as,

$$\dot{u} = -\hat{\beta}F(\dot{u},u) \qquad (21)$$

From equations (13) and (18),

$$\dot{u} = \dot{c}_4 + \sum_{k=1}^{4} e_k c_k = -\hat{\beta}F(\dot{u},u) \qquad (22)$$

and control input of slave system

$$v = \int_0^t \left[-xc_4 - c_3 + \mathrm{P}(c_1,t) + \mathrm{Y}(\cdot) \right] dt + \int_0^t \left[\sum_{k=1}^{4} e_k c_k + \hat{\beta}F(\dot{u},u) \right] dt \qquad (23)$$

4. Results and Discussions

A. Experimental Procedure

This paper introduces a fuzzy system model that restores the system model. Mainly the proposed work helps to achieve the objectives. The optimization of each mechanism is used to determine the performance parameters of the proposed controller. This system includes a self-adaptive property into the GWO technique [12]. The SAGWO-FSMC scheme helps the fuzzy model to support the SMC model in the robotic manipulator. It is stimulated based on MATLAB, and the output isobtained. To analyze the efficiency of the proposed method, it is compared with the conventional experimental technique such as SMC, FSMC, and GWO-SMC [12].

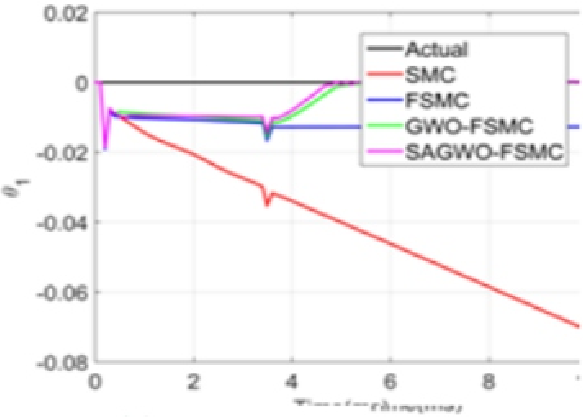
In this SAGWO-FSMC system, the required characteristics are acquired based on fuzzy rules. Then obtained fuzzy rules represent in the form of adaptive fuzzy membership functions. During the procedure establishment, the number of iteration assigned for this model is 100. Then the required parameters are set based on the algorithm. Then its performance is comparedwith known methods.

B. Analysis on Angles

Performance analysis in terms of three joint angles such as 1 ,2and 3is conducted and illustrated in Fig. 2. The analysis was limited to 10 ms and the movement of joint angles to be controlled were observed. On comparing the actual joint angle1with the desired 1as shown in Fig. 2(a), the performance of SAGWO-FSMC is 1%, SMC is 3%, FSMC and GWO-FSMC is 1.9% varied from the desired angle 1. Thus SAGWO-FSMC model resembles the desired model than the conventional GWO-FSMC in controlling1. Likewise, from the analysis on joint angle 2as shown in Fig. 2(b), the actual 2of SAGWO-FSMC is 4.41% deviated from the desired 2, which is better than the other models. Furthermore, the actual 3of SAGWO-FSMC is4.41% deviated from the desired, as given in Fig. 2©. Therefore, the proposed SAGWO-FSMC controls the joint angles that exhibit high correlation with the desired joint angles and so it records the superiority over the conventional SMC methods.

C. Analysis on displacement

Consider three displacements such as X, Y, Z, and the analysis on these three displacements is shown in the figures given below. The implemented SAGWO-FSMC system displacement performance is compared with traditional models like SMC, FSMC, and GWO-FSMC. The measured values will be near to the displacement of desired model.



(a)

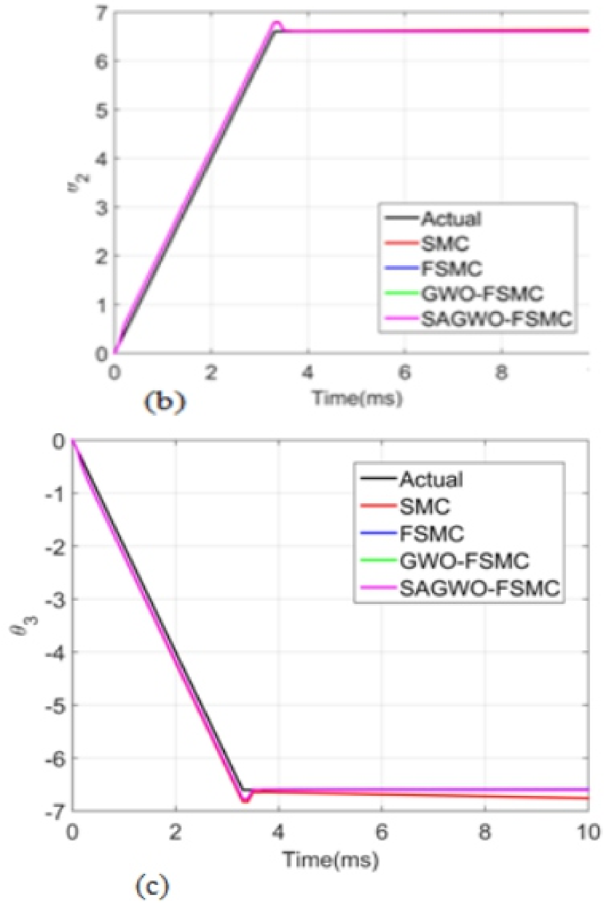


Fig 2. Performance analysis on three angles of joints with respect to time namely, (a) (b) and (c) θ1 , θ2 and θ3

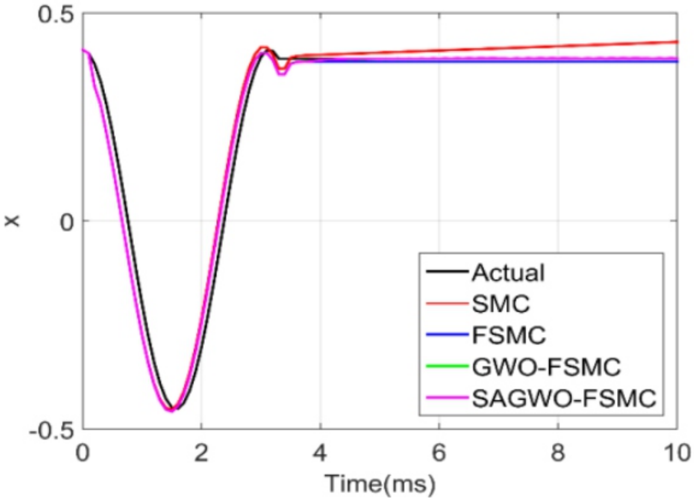


Figure 3: Analysis on displacement x with respect to time

Consider the case of displacement X from figure 3, the difference from desired displacement performance for SMC is 9.52% and for FSMC is 2056% and for SAGWC-FSWC is 2.56%. Thus it shows that the SMC produces a movement far away from the actual value, while other methods are close to the actual value.

Similarly, in the case of displacement y from figure 4 the difference from desired displacement performance for SMC is 1%, FSMC, GWO-FSMC, and SAGWO-FSMC is 0.04%. From this analysis the placement Y shows that the FSMC, GWO-FSMC, and SAGWO-FSMC are near to the actual value, and it shows that the proposed method is superior to other methods.

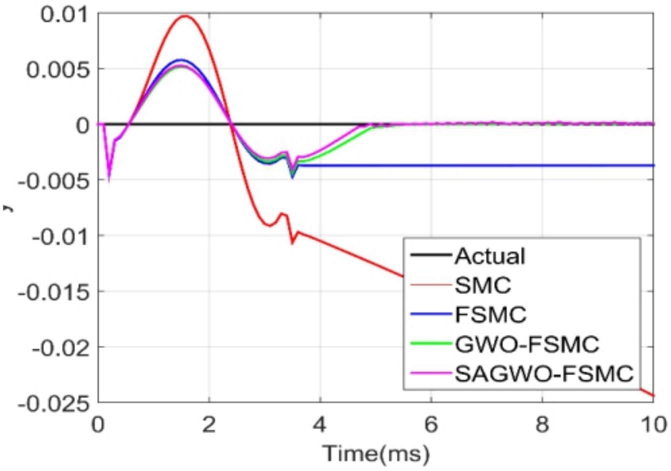


Figure 4: Analysis on displacement Y with respect to time

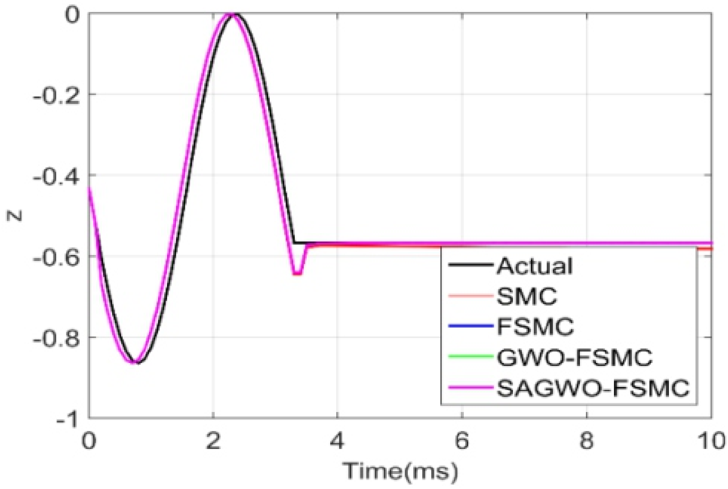


Figure 5: Analysis on displacement Z with time

Besides in the case of displacement z from figure 5, the deviation from displacement performance for SAGWO-FSMC is 14.49%. Therefore the desired displacement will be near to the displacement of the original model. While the displacement of SMC is away from the actual value. It shows that the suggested model should be closer to the desired model to assuring the performance. For better displacement performance the SAGWO-FSMC model is used.

D. Impact of Noise

The three displacements X, Y, and Z with respect to time can be varied by the presence of noise, and is shown in figures given below. By the analysis of figure 6, at 10ms, the original displacement value is 0.4 and the suggested work has achieveda displacement of 0.3. Therefore the proposed model found the displacement near to the actual value. From this, it shows the enhancement of proposed model. The proposed method is superior to other conventional method.

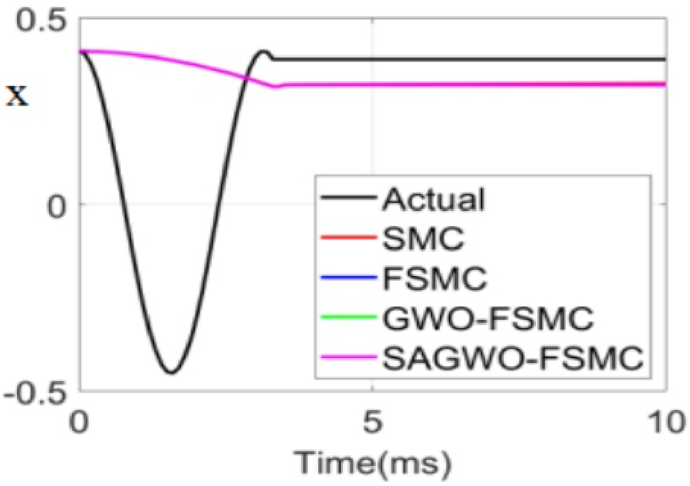


Figure 6: Analysis on displacement X based on impact of noise

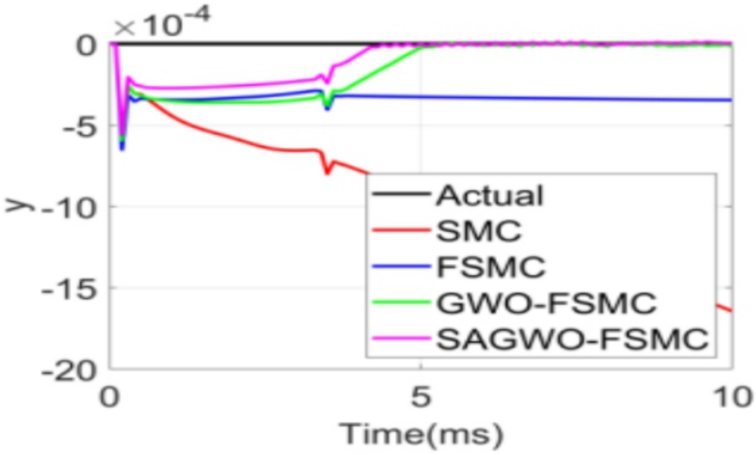


Figure 7: Analysis on displacement Y based on impact of noise

Likewise, from figure 7, at 2ms, the original displacement value is 0, the SMC, FSMC, and GWO-FSMC have achieved a displacement of 4 4 10, While the suggested SAGWO-FSMC has achieved a displacement of 4 3 10. The displacement Y shows the proposed method is superior to other convolutional methods. The SMC produce a movement far away from the actual value, while other methods follow a constant movement nearly to the actual value.

Similarly from figure 8, at 0ms, the original displacement value is -0.43, and the suggested SAGWO-FSMC has achieved a displacement equal to the original value. So, the suggested model displacement value is closer to the original displacement value in the presence of noise, shows the superiority over the traditional method. If there is a presence of noise, the proposed technique follows a constant movement which is near to the actual value.

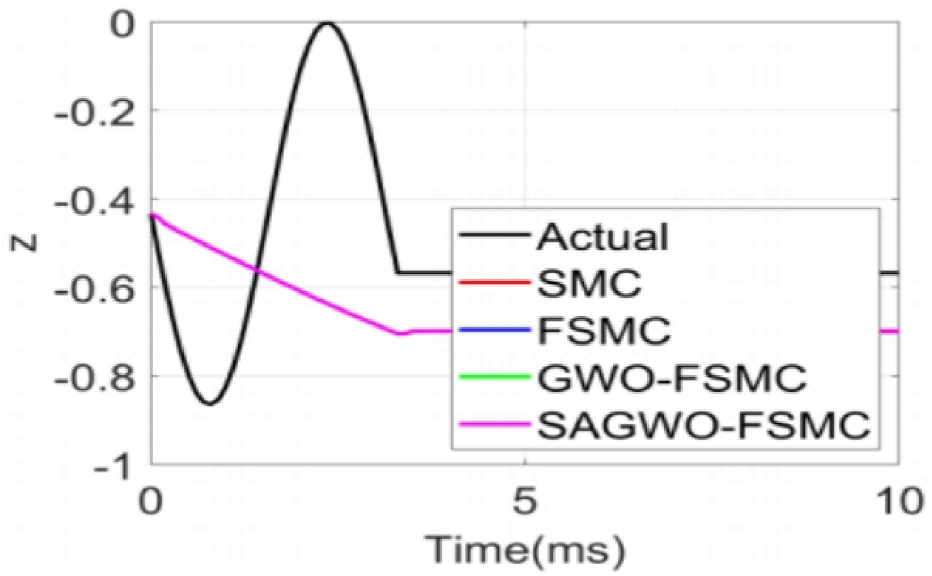


Figure 8: Analysis on displacement Z based on impact of noise

5. Conclusion

Adaptive FSMC was implemented for the robotic manipulator. In general, a system model was not possible to combine with the operation of SMC every time. Hence, fuzzy interference system was employed here to replace the system model. Here, the experiment was performed based on two stages. The accurate characteristics from the system model under various samples were acquired in the first stage to represent the robotic manipulators, where the acquired characteristics were assigned as fuzzy rules. On the contrary, adaptive fuzzy membership function was used to determine the derived fuzzy rules in the second stage, using the SAGWO algorithm. To the next, the performance of the SAGWO-FSMC was compared with the desired experimental model and the conventional methods like SMC, Fuzzy SMC (FSMC) and GWO-SMC. Thus the experimental analysis has revealed the superior performance of SAGWO-FSMC, in tuning the optimum joint angles in the robotic manipulator. Adaptive FSMC was executed for the robotic manipulator on concerning the external noise. Finally, the valuable comparative analysis was done by validating the performance of proposed over conventional models while adding external noise in the manipulator.

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Biomedical Applications using Hand Gesture with Electromyography Control Signal

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ABSTRACT

Wearables developed for human body signal detection receive increasing attention in the current decade. Compared to implantable sensors, wearables are more focused on body motion detection, which can support human–machine interaction (HMI) and biomedical applications. In wearables, electromyography (EMG), force myography (FMG), and electrical impedance tomography (EIT) based body information monitoring technologies are broadly presented. In the literature, all of them have been adopted for many similar application scenarios, which easily confuses researchers when they start to explore the area. Hence, in this article, we review the three technologies in detail, from basics including working principles, device architectures, interpretation algorithms, application examples, merits and drawbacks, to state-of-the-art works, challenges remaining to be solved and the outlook of the field. We believe the content in this paper could help readers create a whole image of designing and applying the three technologies in relevant scenarios.

Keywords- FMG; EMG; EIT; biological signal; human–system interactivities.

I. INTRODUCTION

In recent years, with the development of material science and electronic information technology, wearable devices have made great progress. Nowadays, wearable devices can be mainly used in two fields, HMI and medical. Among various wearable technologies, EMG, FMG, and EIT are commonly used to detect biological signals related to nerve and limb movement. When an action occurs, nerves send electrical signals to drive muscles. Then, muscle contraction causes changes in muscle volume and internal impedance. The posture and acceleration will change during the action. The electrical signals can be detected by EMG [1], while the changes in muscle volume can be detected by FMG [2], and internal impedance by EIT [3]. As a technique for detecting electrical activities caused by the muscles, wearable EMG systems are used widely. Forinstance, J. Qi et al. used EMG technology to recognize different hand gestures, as a result, a long-term recognition accuracy of 79% was achieved [4]. Because EMG detects electrical signals from superficial muscles, its performance is limited by the skin impedance changes caused by sweating and contact [5,6], which cause a decrease in the accuracy of pattern recognition. FMG is an alternative technology that directly captures changes in skin surface pressure due to changes in muscle volume caused by muscle activity [7,8]. Compared to EMG, FMG is robust to electrical interference and sweating, whilst also being non-invasive and inexpensive [9,10]. In the work of Islam et al. [11], the performance of motion detectionwith FMG and surface electromyography (sEMG) were compared in a daily scenario. They tested four different limb motions in five healthy male subjects. As a result, in one-day training, the day-to-day classification accuracy reaches 84.9% while the accuracy of sEMG reaches 77.8%. However, it is not EMG–FMG sensing armband which can detect FMG signal and EMG signal simultaneously. Five healthy subjects performed gestures of ten American sign language (ASL) digits 0–9. The accuracy of EMG-only gesture recognition was 81.5%, while FMG-only was 80.6%, and co-located EMG–FMG had the best performance of 91.6%. Another potential human–machine interaction technology is EIT. It is an imaging technology that detects the internal structural impedance distribution of objects by external electrical excitation signals. To obtain the internal resistivity of the object, EIT uses electrodes on the boundary to apply a high-frequency alternating signal and measure the response signal. For instance, Zhang et al. [3] designed a wearable hand ring called tomography based on 4-pole EIT, which achieved high accuracy in gesture. We also hope that researchers can further develop the three techniques to overcome their existing problems. The generation, processing, and application of FMG, EMG, and EIT signals are showed in Figure1.

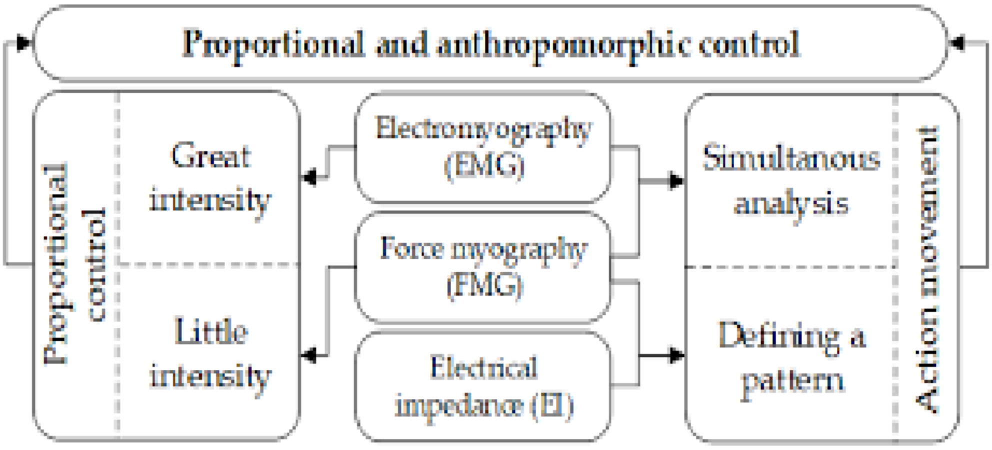


Fig 1: The generation, processing, and application of FMG, EMG, and EIT signals.

2. Principle

EMG, FMG, and EIT are emerging methods to obtain human information in recent years. The advantage of the three techniques is that all of them can be measured non-invasively and harmlessly, which means that they have great potential for human-machine interaction. In this section, we will introduce the principles of FMG, EMG, and EIT.

2.1. FMG

FMG is an approach to collecting motion signals by sensing changes in muscle volume. Its basic principle is that different muscle activities cause different movements. When an action occurs, the volume of the underlying musculotendinous complex changes, which results in a change in the distribution of surface mechanical forces. Different movements are encoded into different force images. By decoding these images, original motion information can be obtained, which has been widely used in gesture recognition [2], human–machine collaboration [16], prosthetic control [17], and operational force estimation [12].

Generally, researchers can use force sensors matrix/array to detect the mechanical force in the FMG technique [18]. The force sensor reflects the magnitude of the force applied to the sensor. When a socket with many sensors is wrapped around a part of the limb, the muscle force map can be obtained. With some algorithms, such as machine learning [9], the original motion information (type of movement and magnitude of force) can be obtained by using the FMG signal. An example of FMG signal output is shown in the relax–grasp–relax process.

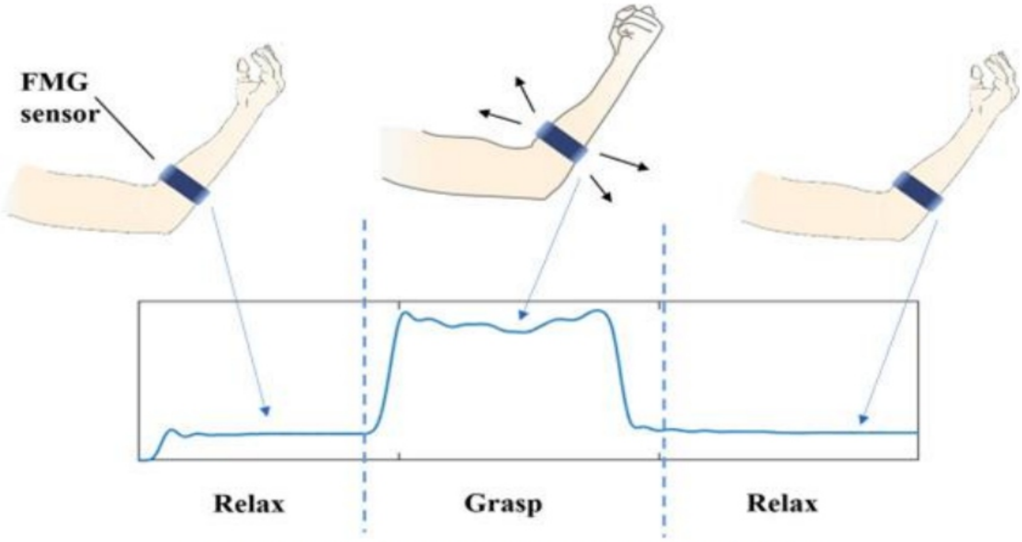


Figure 2. Single FMG sensor output signal during

2.2. EMG

EMG refers to a series of electrical signals associated with muscles due to neurological control and generated during muscle contraction. This signal is generally given by the experimental method, which can represent the physiological characteristics of muscles after amplification and processing [19,20].

EMG is derived from the brain to muscle control. It is based on three steps: resting potential, depolarization, and repolarization. Its formation is caused by the concentration difference of Na+ ions, K+ ions, and Cl− ions, but it is dominated by Na+ ions. When the muscle does not contract, the concentration of Na+ ions in muscle cells is greater than that out of muscle cells. With the ion pump, Na+ ions outflow forms a resting potential with positive external potential and negative internal potential on the membrane of muscle fiber. For example, when trying to move upper limbs, our brain sends movement control signals to the muscles, which are transmitted to the muscles through the nervous system. When the signal reaches the muscle fibres, chemicals such as acetylcholine are released at the nerve end, causing a large influx of Na+ ions, which rapidly form an action potential in the muscle fiber, a process known as depolarization. After the signal transmission,with the action ion pump, muscle fibers quickly return to the state of resting potential, which is called repolarization. The combination of all the muscles' action potentials of a motor unit is called a motor unit action potential (MUAP) [21]. The superposition of MUAP in space and time produces EMG. The EMG signal generation process is shown in Figure3.

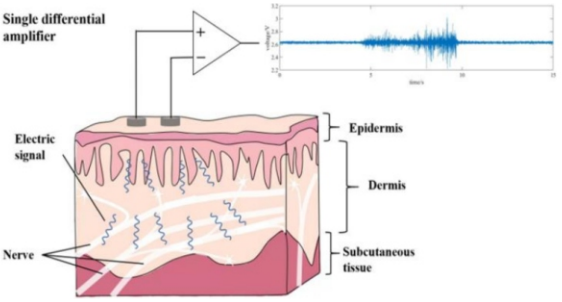


Figure 3. EMG refers to a series of electrical signals associated with muscles due to neurological control and generated

2.3. EIT

EIT is an imaging technology that detects the internal structural impedance distribu- tion of objects by external electrical excitation signals. By placing a set of electrodes on the surface of the conductive object to be measured, EIT applies a high-frequency alternating current to each electrode pair as the excitation signal and measures the electrical response signal on other electrode pairs in turn to obtain the internal resistivity of the object. Due to its advantages of non-radiation, non-damage, low cost, and simple structure, EIT has been widely used in non-destructive testing, geological exploration, and other fields. Nowadays, the application of EIT in biomedical imaging and human–machine interaction has been widely studied.

The human body is a complex structure with different electrical impedance distri- butions. There has been a lot of research on electrophysiology, which is concerned with the electrical properties of biological tissues, and the principle of them is very complex and influenced by frequency, temperature, and direction. This is closely related to the structure and function of the tissues. Generally speaking, the blood and muscle with high extracellular water content and electrolyte concentration have a relatively low electrical impedance. In contrast, fat, bone, and air increase impedance. This difference gives each tissue and state certain characteristics. For organisms, when controlling the amplitude and frequency of excitation signals within a safe range, the output signal and calculate impedance distributions can be harmlessly measured.

The impedance characteristics of organisms often change in certain situations. For example, the electrical impedance of the lungs depends to a large extent on the concen- tration of the internal air. When air is inhaled, the electrical conductivity of lung tissue concomitantly decreases. The flow or clotting of blood also causes impedance changes. When the body tissue is diseased, its electrical impedance may change significantly, which will be detected by EIT, to be applied to medical diagnosis and treatment. Similarly, the limbs in different postures also correspond to different impedance distributions. Therefore, the impedance distribution of the part of the body can be measured by EIT to realize posture detection.

According to the different imaging purposes, EIT can be divided into two types: static imaging and dynamic imaging. Static imaging calculates the absolute value of impedance distribution and has a wider range of applications. However, it is more computationally intensive and vulnerable to noise, resulting in low image resolution. In contrast, dynamic imaging computes the relative impedance distribution and produces a differential image, which suppresses noise very well. Depending on the measurement method, it can be further divided into time difference imaging technique and frequency difference imaging technique. Time difference imaging obtains the difference of impedance at two times, while frequency difference imaging obtains the difference of impedance at different frequencies at the same time. Dynamic imaging is less affected by noise and relatively simple to calculate, but it is essential to ensure that impedance changes exist, so the application is constrained.

EIT signal acquisition and reconstruction are shown in Figure4.

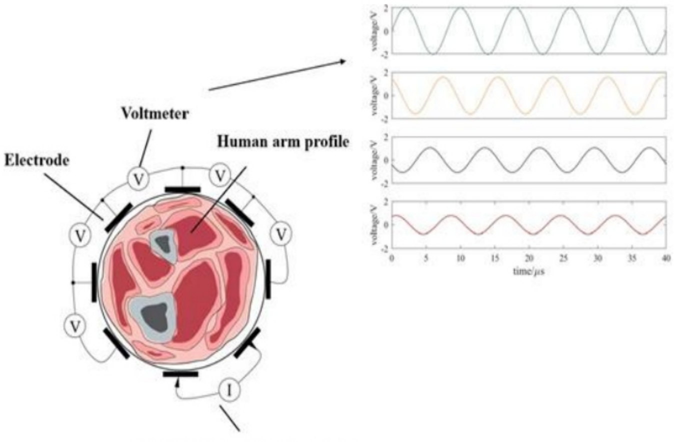


Figure 4. (a) EIT electrode distribution and four−channel voltage signal under high−frequency excitation;

3. Data Acquisition

In this section, we will introduce the signal acquisition methods of FMG, EMG, and EIT. We successively introduced the sensors used for FMG, the sampling frequency and channel number configuration, the EMG sampling method and electrode type, the sampling frequency, and channel number configuration, and finally, we introduced the electrode configuration of EIT and the drive pattern.

3.1. FMG Signal Acquisition

FMG technique uses force sensors to obtain information on the underlying mus- culotendinous complex changes during movements [7]. There are many types of force sensors used in FMG, for instance, piezoresistive- [22], capacitive- [23], piezoelectric- [24], optoelectronic- [25] and pneumatic-based [26] sensors.

3.1.1. Piezoresistive Sensors

To acquire effective biosignals, the sensor needs to be in close contact with the skin, and piezoresistive sensors have this characteristic. The most frequently used piezoresistive sensors are force-sensitive resistors (FSR), for instance, FSR 402 [27–29] and FSR 400 [16,30], which are based on resistive polymer thick film sensor (RPTF) technology. Because of their thin profile, flexibility, and low cost, they become a practical solution for prosthetic pressure measurement [31].

The structure of FSR 400 series is often composed of two layers, one is the printed semiconductor layer on the bottom layer and the other is the interdigitating electrode on the semiconductor layer. When pressure applied to the active area increases, the resistance values of the piezoresistive material will decrease. The force sensitivity range of FSR 400 is 0.2 N–20 N, and its hysteresis is 10% [32].

The advantage of the piezoresistive sensor is its simple structure and affordability, but it suffers from heating issues and high hysteresis [33].

3.1.2. Capacitive Sensors

Capacitive sensors are another sensor used to detect FMG signals [23,34]. The capaci- tive sensor reflects the force/pressure loaded on it by detecting the capacitance value of capacitance. To achieve this, an elastic material between two electric layers is necessary. When the pressure applied to the sensor changes, the distance between two electric layers changes, resulting in a change in the capacitance value of the sensor [35].

Polydimethylsiloxane (PDMS) is a frequently used material in dielectric layers. Lei et al. used PDMS as the dielectric layer in a 16:1 mix ratio. The sensor can measure the pressure up to 945 kPa, and obtain a high sensitivity of 6.8%/N [35]. Maddipatla et al. used silver (Ag) ink on a flexible polyethylene terephthalate (PET) as electrodes, and a 16:1 mixing ratio of PDMS as a dielectric layer to fabricate a force sensor. The sensor offered a sensitivity of 0.13%/N from 0 N to 10 N [36]. Capacitive sensors have the advantage of low power consumption and fast response, but they are sensitive to electromagnetic interference (EMI) noise and are not suitable for long-term use.

3.1.3. Piezoelectric Sensors

Piezoelectric sensors have good dynamic force-sensing performance. When pressure is applied to the sensor, a potential difference is generated between the upper and lower plates of the sensor. By measuring its voltage, the magnitude of the pressure can be obtained. Common piezoelectric materials can be divided into ceramics, films, and fibers [33].The acquisition of human biological information places high demands on the flexibility of sensors. The advantage of piezoelectric sensors is low hysteresis, strong sensitivity, and low power consumption. However, due to their characteristics, piezoelectric sensors cannot be used in static force sensing.

4. Data Processing

The original signal obtained by sensors cannot be used directly. In order to apply the collected signals to practice, we need to apply some signal processing steps, such as filtering and feature extraction, and then use algorithms, such as machine learning, to connect the original signals with practical applications. In this section, we will introduce some data processing methods for the three signals. All steps of data processing are shown in Figure5.

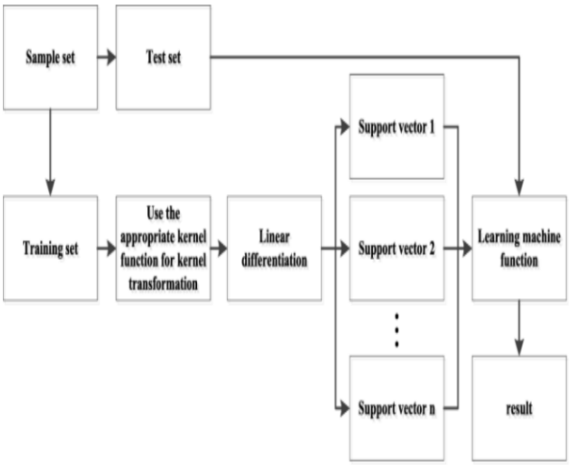


Figure 5. All steps of data processing.

4.1. Data Pre-processing

In the pre-processing stage, we mainly filter and amplify the signal. At the same time, for different signals, there are their own unique signal pre-processing methods, which will be mentioned in other pre-processing

4.2 Summary and Comparison of the Three Techniques

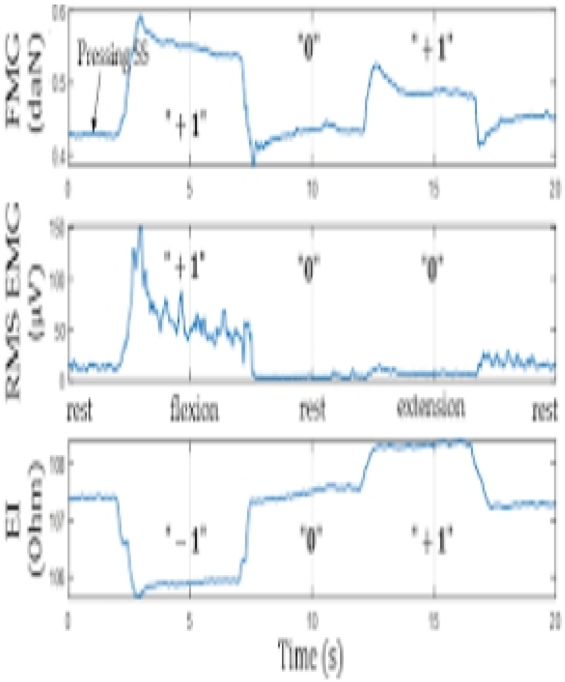


Figure 6. EMG, FMG and EI signals

5. Application

FMG, EMG, and EIT are three methods to obtain biological information of the human body, they can reflect different conditions of the human body. Therefore, they are widely used in human–machine interaction (HMI), medical, and healthcare. Some applications are shown in Figure7. In this section, we will introduce some applications of three techniques in HMI, medical, and healthcare.

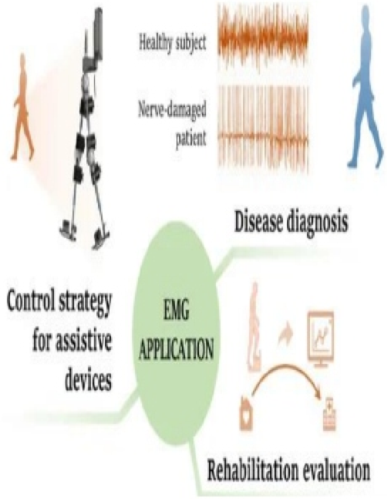
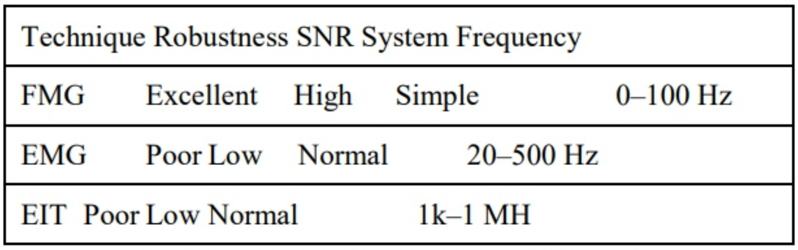


Figure 7. EMG different Applications

6. Conclusion

Despite their various advantages, they still have some problems to solve. In this section, we will analyze the current problems and challenges faced by these three technologies. The comparison of the three technologies is shown in Table5.



Technique	Robustness	SNR	System	Frequency
FMG	Excellent	High	Simple	0–100 Hz
EMG	Poor	Low	Normal	20–500 Hz
EIT	Poor	Low	Normal	1k–1 MH

Table 5. Comparison of three techniques.

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