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Ph.D. Research Proposal

Doctoral Program in "Department Name"

DeepNet: A Novel Automatic Signal Modulation Classifier Using Attention Module Aided Deep Learning

by

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I. INTRODUCTION / BACKGROUND

Automatic Signal Modulation (ASM) has drawn a much intention among researchers due to its amenities in detecting modulation type of the signal. The significance of the AMC has enhanced in both military and civil communication. Since, many military applications require automatic detection of modulation schemes utilized by signals from adversaries. For example, application encompasses signal interception and jamming. Hence, AMC attains great prominence for both military and civil applications [1-3]. In AMC, two conservative approaches are exists: i) Likelihood based ii) Feature based. In Likelihood based method, maximum likelihood algorithm is used to estimate the likelihood function for each modulation format [5].

After carrying out likelihood function calculation, decision is gained based on the maximum of this function. The main drawback of this method is that high computation complexity. In feature based method, the problems encountered in the likelihood based method is overwhelmed [6]. The feature based method contains two processes to detect the modulation scheme that are feature extraction and classification. Initially, it extracts the features from the given signal. Then, it processes the extracted signal into the classifier to detect the modulation type. The performance of the feature based method is based on the extracted features and its quantity [7]. In order to tackle the problem of the feature based method, deep learning based method is evolved [8]. Here, neural learning algorithms such as Artificial Neural Network (ANN) and Convolutional Neural Network (CNN) are used.

II. RESEARCH GAPS

2.1 Problem Definition

A deep learning approach (CNN) is used to detect the modulation scheme of the given signal [1]. In this, Convolutional Neural Network (CNN) is used to classify the digital modulation signals. The CNN automatically acquire features from the raw signals to classify the different digital modulation signals. Here, the two inputs are given as input to the CNN that are

preprocessed signal and estimated Signal to Noise Ratio (SNR). The transfer learning algorithm is used to train the CNN algorithm.

Problems

- However, the CNN algorithm is not robust to the deviations of the input signals that reduce the classification accuracy.
- Here, CNN cannot able to capture the spatial information of the given signal that affects the feature extraction efficiency.

Proposed Solutions

- We propose Deep Net to extract features from the input signals which is highly robust to the deviations and spatial informations. Thus, increases the feature extraction efficiency and classification accuracy.

The curriculum learning is used to learn the features from the signal to detect the modulation scheme [2]. Here, three sequential processes are performed that are sampling, preprocessing and classification. For classification, two algorithms are used that are StudentNet and MentorNet. Here, StudentNet is trained under the supervision of the MentorNet algorithm. In this paper, StudentNet is trained with twice i.e. with or without supervision of the MentorNet algorithm. The features are learned by the StudentNet algorithm to predict the label of the given signal.

Problems

- The introduced curriculum learning algorithm provides less classification accuracy at low SNR rate that shows its inefficiency towards generalization.
- The lack of blind equalization (ISI mitigation) in preprocessing reduces the quality of the signal that in turn affects the recognition accuracy.
- Training time is too large while predicting the modulation scheme of the given signal. (Since it train both StudentNet and MentorNet where StudentNet trained twice).

Proposed Solutions

- Our proposed classification system performs well even in low SNR rate hence it is increases the generalization ability. Besides, it also has less training time for classification modulation scheme.

The local binary histogram features and extreme learning based classification is used to detect the modulation classification [3]. This paper is proposes AMC with extreme learning machine along with local binary pattern histogram features. The modulated signals are directly given to the feature extraction phase. Here, LBP algorithm is used to extract the features from the given signals. The extracted features are normalized afore to the classification process. In classification, Extreme Learning Machine algorithm is used to detect the modulation scheme of the given signal.

Problems

- LBP based feature extraction provides high false positive results that affects the classification accuracy.
- In addition, Evaluation speed of the Extreme Learning Machine algorithm is low that affects performance of the classification system.

Proposed Solutions

- The DeepNet increases the classification accuracy since it provides optimal results in feature extraction and it has faster performance.

A robust CNN based modulation classification is introduced [4]. In this paper, CNN is used to detect the modulation scheme of the given signal. Initially, it performs preprocessing where sampling and quantization process are executed. The features of the given signal are learned using the CNN algorithm. Here, CNN is trained with the different SNR level to increase its robustness level. The learned features mapped to the 2D-axis using the Multi-Dimensional Scaling (MDS) where same category features are clustered. At last, Support Vector Machine (SVM) algorithm is used to detect the modulation scheme of the signal.

Problems

- Though CNN is robust to SNR variations, it lacks in extracting position information of the given signals.
- Thus induces difficulties in classifying the modulation scheme.
- The instantaneous related features such as phase, amplitude and frequency are not extracted from the given signal that reduces the classification accuracy.
- Furthermore, MDS algorithm cannot generate optimal results in high dimension of data that reduces the classification efficiency.

Proposed Solutions

- Our proposed DeepNet highly robust to position variations thus reduces the difficulties in classification.

An efficient statistical model is used to detect the modulation scheme [5]. This paper proposes a new robust AMC model using Generalized Autoregressive Conditional Heteroscedasticity (GARCH). In this, three sequential processes are performed that are feature extraction, feature selection and classification. Initially, the given signals are processed into the Discrete Wavelet Transform (DWT) which transforms signal into the wavelet coefficients. From wavelet coefficients, GARCH algorithm extracts statistical features that are further processed into the Principal Component Analysis (PCA) to select the optimal features. Finally, SVM classifier is used to classify the modulation scheme of the given signal.

Problems

- More features are required to improve the performance of the classifier.
- Here, statistical features only extracted to detect the modulation scheme that degrades the performance of the classifier.
- The absence of preprocessing in modulation scheme detection tends to reduce the performance of classifier.
- Here, DWT is used to decompose the given signal which loses the edges and curves of the input that reduces the feature extraction accuracy.

Proposed

- Our work performs preprocessing afore to the modulation classification that is sampling, quantization and blind equalization.
- Our proposed method extracts eight different features from the input signal that increases the performance of the classifier.

III. RESEARCH CONTRIBUTIONS

The proposed model addresses the problems present in the existing modulation classification techniques. The main purpose is to increase the accuracy while classifying modulation type. To attain this, four sequential processes are performed such as Preprocessing, Feature Extraction, Feature Clustering and Modulation Type Classification.

4.1. Preprocessing

The preprocessing is performed to increase the signal quality that increases the classification accuracy. The preprocessing comprises of three significant processes that are blind equalization, sampling and quantization. Initially, the blind equalization is performed using the **Double Continual Modulus Scheme (DCMS).** The purpose of blind equalization is to reduce the Inter Symbol Interference (ISI). In addition, proposed DCMS energetic to the impulsive noise. And then, sampling and quantization are executed to improve the quality of the signal. Here, sampling is used to reduce the aliasing effect and quantization is used to reduce the bits required for signal representation. By performing these steps in preprocessing enhances the quality of the signal.

4.2. Feature Extraction

The feature extraction is used to extract the effective features from the given signal to enhance the performance of the classifier. For this purpose, we propose **Capsule Network** to extract features from the given signal. The prime advantage of Capsule network over CNN is that, it robustness in extracting the position and orientation information of the given signal which is required to classify the signal accurately. The input to the Capsule network is two that are preprocessed signal and estimated SNR of the given signal. It extracts feature from both real and

imaginary parts of the signal in order to enhance the classification accuracy. Since, real and imaginary parts are affected by the amplitude and phase changes induced by the modulated signal. Here, we extract succeeding features from the signal that are Instantaneous amplitude, Instantaneous phase, Instantaneous frequency, Time domain features, frequency domain features, Transformation domain features and Higher Order Statistics (HoS) features (Cumulant and Moment). Here, the HoS features are robust to the SNR variations thus increases the generalization ability of the classification system.

4.3. Feature Clustering

The features from the real and imaginary part of the signal are clustered in this section to reduce the complex classification process. Here, the clustering is performed using the **Fuzzy Neutrosophic C-Means (F-NCM)** algorithm. The proposed FNCM algorithm solves the individual problems of fuzzy c means and neutrosophic set. This way of clustering tends to easier the process of the signal classification.

4.4. Modulation Type Classification

The classification is significant process in the modulation detection of the given signal. In this, **J48** algorithm is used to classify the modulation scheme. Based on the given input, Proposed J48 classifies the modulation scheme of the given signal. In our proposed work, we consider six modulation schemes that are QPSK, FSK, 16 QAM, BPSK, ASK, and 64 QAM.

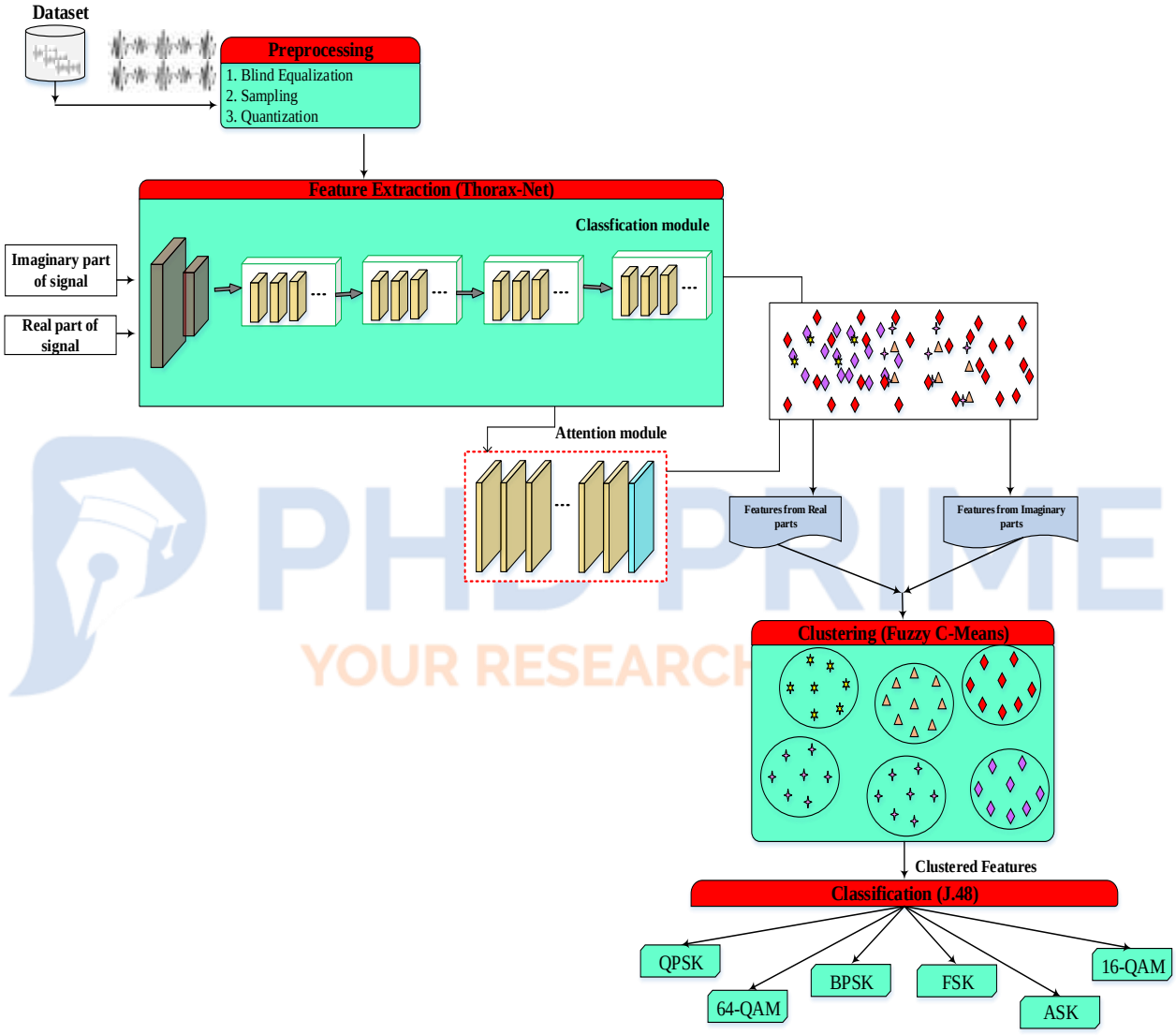
Performance Evaluation

At last, the performance of the proposed model is evaluated with the aid of below metrics,

- Classification accuracy with respect to SNR
- Precision with respect to SNR
- Recall with respect to SNR
- F-score with respect to SNR
- Computational Time
    - Preprocessing
    - Feature Extraction

- Feature Clustering
- Modulation Type Classification

SYSTEM ARCHITECTURE



IV. PREVIOUS WORKS & LIMITATIONS

Paper 6

Title - A Novel Hybrid Cuckoo Search-Extreme Learning Machine Approach for Modulation Classification

Concept

Authors have introduced hybrid cuckoo search based machine learning approach for modulation detection. The features are extracted using the GLCM algorithm. And, the extracted features are optimized using the cuckoo search algorithm. Finally, extreme machine learning algorithm is used to classify the modulation scheme of the signal. At the end, signals are classified into three classes such as Phase, Shift Keying (PSK), Frequency Shift Keying (FSK), and Quadrature Amplitude Modulation (QAM).

Paper 7

Title-Deep long short-term memory networks-based automatic recognition of six different digital modulation types under varying noise conditions

Concept

This paper proposes the automatic modulation recognition under varying noise conditions. Here, a new deep long short term memory networks are used to recognize the modulation type of the signal. In this, modulated signals are directly given as input to the LSTM network without performing any feature learning process. Here, the soft max activation function is used to detect the modulation type of the signal.

Problem

- The LSTM has high training time while classifying modulation scheme of the signal.

Proposed

- Our proposed capsule network has less training time to extract features from the given signal.

Paper 8

Title-Automatic modulation classification of digital modulation signals with stacked autoencoders

Concept

This paper proposes the digital modulation classification using the tacked auto encoders. In this, auto encoder is used to learn features from the given signal. The features learn from the auto encoder layers are given as input to the soft max classifier. In this, features are extracted from the both I and Q components of the signal. Here, softmax classifier is used to classify the modulation scheme accurately.

Problem

- The performance of the auto encoder is decreased for large scale dataset due to high computation processes.

Proposed

- The performance of the proposed capsule and mahalanobis SVM are high even for large scale dataset.

Paper 9

Title- Performance Evaluation of Feature-based Automatic Modulation Classification

Concept

In this paper, performance of the feature based automatic modulation classification scheme is evaluated. In this, three sequential processes are performed that are preprocessing, feature extraction and classification. In preprocessing, the quality of the given signal is improved and processed into the feature extractor. Here, five different features are analyzed to attain better results in the classification. Finally, SVM classifier is used to classify the given signal to detect the modulation scheme.

Paper 10

Title- Modulation Classification Based on Extensible Neural Networks

Concept

This paper proposes the Extensible Neural Network (ENN) for classifying the modulation type of the given signal. It learns three informations from the given signal that is amplitude, phase and frequency. The learned features are further processed into the soft max layer to detect the correct modulation scheme of the given signal. Finally, the modulation scheme of the given signal is detected.

Problem

- The absence of preprocessing afore to the modulation recognition process affects the performance of the classifier.

Proposed

- Our work performs three processes in preprocessing to enhance the quality of the signal and performance of the classifier.

Paper 11

Title- Likelihood-Based Automatic Modulation Classification in OFDM With Index Modulation

Concept

In this paper, the likelihood based automatic classification is performed to classify the given signal. In this, two classifiers are used to detect the modulation scheme of the given signal such as Average Likelihood Ratio Test (ALRT) and Hybrid Likelihood Ratio Test (HLRT). The performance of the both classifiers including ALRT and HLRT are classified. With the use of these likelihood algorithms, the modulation scheme of the given signal is recognized.

Problem

- The maximum likelihood based feature extraction in modulation classification has high computation complexity.

Proposed

- Our proposed method executes feature extraction based modulation classification that avoids high computation complexity problem of the likelihood based method.

Paper 12

Title- A Novel Approach for Automatic Modulation Classification via Hidden Markov Models and Gabor Features

Concept

This paper proposes a novel approach to classify the modulation scheme of the given signal. Here, the hidden markov model and gabor features are used to classify the performance of the given signal. Initially, features are extracted using the gabor algorithm where genetic algorithm is incorporated. The output of the gabor filter is given as input to the hidden markov model based classifier. Here, baum welch algorithm is used to update the parameter of the hidden markov model.

Paper 13

Title - Automatic Modulation Classification Using Deep Learning Based on Sparse Autoencoders With Non-negativity Constraints

Concept

Authors have introduced sparse auto encoders based modulation detection. Here, deep neural network utilizes the three layers based on the auto encoders. In this, features are extracted and classified in the three fully connected layers. In this work, sparse autoencoder with non-negativity constraints improve the sparsity and also reduces the reconstruction error. Hence this AMC improves accuracy under constrained RSS and fading channel.

Paper 14

Title- Polar Feature Based Deep Architectures for Automatic Modulation Classification Considering Channel Fading

Concept

In this paper, deep architectures are used to classify the modulation scheme of the given signal. Here, the polar based deep architecture is proposed such as Channel Compensation Network (CCN). In this, polar transform network is used to transform the in-phase and quadrature information of the given signal. And, then features are learned to detect the modulation type of the given signal.

Problem

- The absence of preprocessing in modulation classification reduces the performance of the classifier.

Proposed

- Our proposed work performs three sequential steps in preprocessing to increase the classification accuracy.

Paper 15

Title- Fast Deep Learning for Automatic Modulation Classification

Concept

In this paper, the fast deep learning algorithm is used to classify the modulation scheme of the signal. Here, the three deep learning architectures are investigated to achieve better results in classification. They are, Convolutional Long short term Deep Neural Network (CLSDNN), LSTM and deep residual network (deep ResNet). In addition, it also analyzes the performance of the Principal Component Analysis (PCA) on modulation classification.

Paper 16

Title- Automatic Modulation Classification Architectures Based on Cyclostationary Features in Impulsive Environments

Concept

In this paper authors proposed AMC based on the cyclostationary features. Here, cyclostationary descriptors are used to extract cyclostationary features from the given signal. The extracted features are classified based on the correlation co-efficient estimation. Finally, the modulation scheme of the given signal is identified in the set of classes of signals based on the training set.

Paper 17

Title- Communication modulation recognition algorithm based on STFT mechanism in combination with unsupervised feature-learning network

Concept

In this paper, authors have proposed the modulation recognition based on the feature extraction and classification. Here, Short Time Fourier Transform (STFT) algorithm is used to learn the time frequency features from the signal. This STFT provides list of time frequency domain features effectively than PCA. In this, Convolutional Restrict Boltzmann Machine (CRBM) algorithm is used to detect the modulation scheme of the signal.

Paper 18

Title- A Novel Sparse Classifier for Automatic Modulation Classification using Cyclostationary Features

Concept

In this paper, authors have introduced novel sparse classifier for digital modulation recognition. Here, the sparse classifier performs based on the sparse signal decomposition with the aid of the composite dictionary. This paper follows the classifier principle to classify the RSS based signal modulation to reconstructed sparse coefficients after solving L1 norm minimization by means of over complete dictionary, which reduces the noise.

Paper 19

Title- Automatic Modulation Classification Using Compressive Convolutional Neural Network

Concept

In this paper authors have suggested AMC with Compressive Convolutional Neural Network (CCCN). Here, CCCN comprises of three modules such as feature extraction, feature fusion and classification. It focuses on different constellation images such as regular constellation images and contrast enhanced grid constellation images from obtained signals. With the use of CCNN model, high dimensional features are extracted for signal type modulation classification.

Paper 20

Title- Automatic Modulation Classification Using Contrastive Fully Convolutional Network

Concept

In this letter, authors proposed a novel grid constellation matrix (GCM)-based AMC method using a contrastive fully convolutional network (CFCN). We use GCMs as the input of the network, which are extracted from the received signals using low-complexity preprocessing. Moreover, a loss function with contrastive loss is designed to train the CFCN, which boosts the discrepancies among different modulations and obtains discriminative representations. Extensive simulations demonstrate that CFCN performs superior classification performance and better robustness to model mismatches with low training time comparing with other recent methods.

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