Automatic Digital Modulation Classification Signals using Statistical Parameters with Neural Networks and Fuzzy Logic

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Abstract: Automatic Modulation Recognition is considered significant in Communication Intelligence (COMINT) knowledge about the signal modulation type. The work at the output stage is concerned with information extraction, recording and exploitation and begins with signal demodulation that requires accurate modulation type. Recently many algorithms have been proposed to distinguish digitally modulated signals. In this paper, we present and evaluate some problems related to automatic recognition of digital modulation signals by using maximum likelihood algorithm to find feature extraction and simulation by using statistical parameters on ASK, PSK, FSK, QAM and OFDM in presence of some Additive White Gaussian Noise (AWGN). Automatic Modulation Recognition of Communications Signals describes in depth by using artificial neural networks with pattern recognition for trained the digital modulation signals features and find efficiency with MSE. For performance and comparison, in this paper we present fuzzy logic for Adaptive Network Based Fuzzy Inference System (ANFIS) with Discrete Wavelet Transform (DWT).

Keywords: Intelligence (COMINT), Orthogonal Frequency Division Multiplex (OFDM), Additive White Gaussian Noise (AWGN), Pattern Recognition (PR), DWT, Neural Networks, Fuzzy Logic.

I. INTRODUCTION

Automatic modulation recognition can be used in many civil as well as military applications such as electronic warfare, electronic support measure, spectrum surveillance and management, identification of non license transmitters, etc. Modulation types are considered as the signal signature in the field of COMMunication INTelligence (COMINT). When modulation type is identified, an appropriate demodulator can demodulate the signal to recover the information. Therefore, modulation recognition is an indispensable essential step to retrieve the exact transmitted signal. Intercepted communication signals have a high degree of uncertainty due to unidentified modulation types and noise. Therefore, many modulation classification algorithms have been established based on statistical methods. The features of intercepted modulated signals, such as carrier frequency, can be derived from the known statistical characteristics of the signal. Higher order statistics has been studied previously in many communication applications. There is a very few attempts to recognize OFDM modulation. OFDM is a promising technique for high data rate wireless communications because it can reduce inter symbol interference (ISI) caused by the fading channel.

In this paper, firstly, we have compared a pattern recognition approach based on statistical properties for some classic digital modulations including ASK(Amplitude Shift Keying), PSK (Phase Shift Keying ), FSK (Frequency Shift Keying), QAM(quadrature Amplitude Modulation), etc.

To estimate the statistical features of signals, various types of windows and different segment of samples have been taken into consideration. Then for the second part, OFDM signal has been generated in presence of AWGN. Then a new statistical method has been applied to recognize the OFDM signal from the other digitally modulated signals. Automatic modulation recognition is a rapidly evolving area of signal analysis. In recent years, interest from the academic and military research institutes has focused around the research and development of modulation recognition algorithms. Any communication intelligence system comprises three main blocks: receiver frontend, modulation recognizer and output stage. Considerable work has been done in the area of receiver front-ends. The work at the output stage is concerned with information extraction, recording and exploitation and begins with signal demodulation that requires accurate knowledge about the signal modulation type. There are, however, two main reasons for knowing the current modulation type of a signal; to preserve the signal information content and to decide upon the suitable counter action, such as jamming. Automatic Modulation Recognition of Communications Signals describes in depth this modulation recognition process. Drawing on several years of research, the authors provide a critical review of automatic modulation recognition. This includes techniques for recognizing digitally modulated signals.
The book also gives comprehensive treatment of using artificial neural networks for recognizing modulation types. Automatic Modulation Recognition of Communications Signals is the first comprehensive book on automatic modulation recognition. It is essential reading for researchers and practicing engineers in the field. It is also a valuable text for an advanced course on the subject. Automatic modulation recognition (AMR) is an essentially interesting problem with a variety of regulatory and military communication applications (Wu, Ren, Wang, & Zhao, 2004). AMR is used for military communication intelligence studies such as spectrum surveillance, threat estimation, etc. In previous studies, modulation recognition was performed by using human operator’s interpretation of measured parameters to classify signals (Wu, Wang, Liu, & Ren, 2005). In these studies, modulated signal properties such as signal spectrum features, instantaneous amplitudes and instantaneous phase were evaluated for modulation recognition. Then, a lot of methods have been developed for Automatic Digital Modulation Recognition (ADMR).

In these studies, the demodulator banks designed for each of special modulation types were used for ADMR (Wu et al., 2005). The demodulator bank method is called as semi-automatic because of a human operator is still required to listen outputs of these demodulator banks (Wu et al.,2005). In Liedtke (1984), an ADMR method is presented for some types of digital modulation. The types of digital modulation are ASK2, FSK2, PSK2, and PSK4, PSK8. In this study, universal demodulator technique is used for recognizer. For this reason, amplitude histogram, the frequency histogram, the phase difference histogram, amplitude variance, and the frequency variance key features are used. In DeSimio and Glenn(1988), an adaptive technique is used for ADMR. Some types of digital modulation are used in this study. These digital modulation types are ASK2, PSK2, PSK4, and FSK2. In this study, the key features derived from the signal envelope, the signal spectra, the signal squared and the fourth power of the signal are used to decide type of modulation.

A. OFDM Modulation
In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-channels or subcarriers, which are transmitted in parallel, divide the available transmission bandwidth. The separation of the subcarriers is theoretically minimal such that there is a very compact spectral utilization. Multicarrier modulation generates two effects: frequency selective fading and inter symbol interference (ISI). In OFDM technique, as the symbol rate is very low, the symbols are much longer than the channel impulse response. It reduces the ISI effect. The addition of an extra guard interval between consecutive OFDM symbols can reduce the effects of ISI even more. An OFDM symbol consists of a sum of subcarriers that are modulated by using PSK or QAM modulation. If the complex QAM symbols, is the number of subcarriers, is the symbol duration and is the carrier frequency, then one OFDM symbol starting atc an be written.

### II. PROBLEM CHARACTERIZATION

A. Maximum Likelihood Approach
In the maximum likelihood approach, the classification is analysed as a multiple hypothesis testing problem, for finding feature extraction.

1. The maximum value of the spectral power density for normalized centred instantaneous amplitude, \( \gamma_{\text{max}} \). It is given by,

\[
\gamma_{\text{max}} = \frac{1}{N_s} \max_{i} |DFT[a_{\text{cm}}(i)]|^2
\]

Here, DFT is the Discrete Fourier Transform of the RF (Radio Frequency) signal, \( a_{\text{cm}} \) is the normalized centred instantaneous amplitude and, \( i=1,2,........ N_s \).

2. The standard deviation of the absolute value of the centred non linear component of the instantaneous phase, \( \sigma_{\text{ap}} \) is,

\[
\sigma_{\text{ap}} = \frac{1}{N_s} \left( \sum \varphi_{\text{NL}}(i) - \frac{1}{N_s} \sum \varphi_{\text{NL}}(i) \right)^2
\]

Here, \( \varphi_{\text{NL}} \) is the centred non linear component of instantaneous phase.

3. The standard deviation of the centred non linear component of the direct instantaneous phase, \( \sigma_{\text{dp}} \) is,

\[
\sigma_{\text{dp}} = \frac{1}{N_s} \left( \sum \varphi_{\text{NL}}(i) - \frac{1}{N_s} \sum \varphi_{\text{NL}}(i) \right)^2
\]

4. The spectrum symmetry about the carrier frequency, \( P \) is given by,

\[
P = \frac{P_L - P_U}{P_L + P_U}
\]

It is calculated by the difference of the power in the upper and the lower sidebands normalized by the total power. The lower sideband power.

5. The standard deviation of the absolute value of the normalized centred instantaneous amplitude, \( \sigma_{\text{aa}} \) is,

\[
\sigma_{\text{aa}} = \frac{1}{N_s} \left( \sum |a_{\text{cm}}(i)| - \frac{1}{N_s} \sum |a_{\text{cm}}(i)| \right)^2
\]

6. The standard deviation of the absolute value of the is, normalized centred instantaneous frequency, \( \sigma_{\text{af}} \) is

\[
\sigma_{\text{af}} = \frac{1}{N_s} \left( \sum f_{\text{cm}}(i) - \frac{1}{N_s} \sum f_{\text{cm}}(i) \right)^2
\]

7. The standard deviation of the normalized centred instantaneous amplitude, \( \sigma_{a} \) is computed by,

\[
\sigma_{a} = \frac{1}{N_s} \left( \sum |a_{\text{cm}}(i)| - \frac{1}{N_s} \sum |a_{\text{cm}}(i)| \right)^2
\]

8. the kurtosis of normalized center frequency \( k_{\text{a}} \) is given by,
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\[
k_d = \frac{\mathbb{E}[F_n(0)]}{\mathbb{E}[F_n(1)]}
\]  

(8)

9. The kurtosis of the normalized centred instantaneous frequency, \( k_f \) is given by,

\[
k_f = \frac{\mathbb{E}[F_f(0)]}{\mathbb{E}[F_f(1)]}
\]  

(9)

where, \( F_f \) is the normalized-centred instantaneous frequency.

B. Artificial Neural Networks

The neural network chooses the threshold at each node automatically in DT algorithms, at a time only one key feature is considered which means that the time ordering of the key features plays an important role in probability of the correct decision. While in ANN algorithms all the key features are considered at the same time. So the time order of the consideration of the key features doesn’t affect the probability of the correct decision. Therefore, ANN is a preferred method for deducing the modulation type as compared to DT method as shown in Fig.1. The simulations performed for this project have been carried out in MATLAB. The signals have been taken in a specific order i.e. ask,psk,fsk,qam and ofdm. The recognition based on ANN approach is divided into three blocks. These are 1) pre processing, 2) the training phase, 3) the testing phase. The neural network used for training and testing will consist of 2 hidden layers with different number of neurons in each layer with different SNR levels.

![Fig.1. Artificial Neural Networks.](image)

C. Fuzzy Logic

EDWANSIS structure developed in this study of recognition on digital modulated signal. this sysyem is separated in two layers, which is feature extaction training and classification layers, the feture extraction layer of EDWANSIS system is the most important component of designing the automatic system based on digital modulation recognition. The tree structure is used \( m = 7 \) as level for DWT of the digital modulated signals. Four various digital modulation types (ASK8, FSK8, PSK8, and QASK8) are used to obtaining the digital modulated signals. Two hundred simulated signals for each of these four types digital modulation are generated. Hundred of these 200 modulated signals for each of these four types digital modulation are generated for training layer of the EDWANFIS automatic digital modulation recognition system. Others 100 of 200 digital modulated signals for each of these four types digital modulation are generated for testing layer of the EDWANFIS automatic digital modulation recognition system as shown in Fig.2. In this way, totally 800 digital modulated signals are generated for the training and testing layers of EDWANFIS automatic digital modulation recognition system developed in this study.

![Fig.2. Fuzzy Logic circuit.](image)

III. RESULTS

Results of this paper is as shown in bellow Figs.3 to 13.

![Fig.3. ASK Modulation Signal.](image)

![Fig.4. PSK Modulation Signal.](image)
Fig. 5. FSK Modulation Signal.

Fig. 6. QAM Modulation Signal.

Fig. 7. OFDM Modulation Signal.

Fig. 8. Feature Extraction using Maximum Likelihood method.

Fig. 9. Standard Deviation Vs SNR of modulation signals using AWGN.

Fig. 10. Signal Power Density Vs SNR of modulation signals using AWGN.

Fig. 11. Neural network training performance.
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Fig.12. Neural Network validation performance.

Fig.13. Fuzzy Logic validation performance.

IV. CONCLUSION

In this paper, a literature review of the previous method for modulation classification has been carried out and one of the most well known approaches has been surveyed with more details. The comparison for modulation classification has been emphasized by using statistical process, different estimations of windows and different number of samples. A new method has been developed to classify OFDM modulation from some other digital modulations in presence of significant amount of noise. Our upcoming works will be focused on developing statistical methods to classify OFDM signal in a more complex environment including delays and mixture of signals. And in this paper introduced artificial neural network for trained the feature extraction of digital modulated signal and finds the validation performance based on mean square error with effectively. And also here i did on work about fuzzy interface system to find validation performance for comparison with artificial neural networks performance. Finally in this paper we concluding that artificial neural network efficiency performance is better than fuzzy logic in Automatic digital modulation classification.

V. REFERENCES


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