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Deep Learning Approach for Automatic Modulation Recognition in Cognitive Radio

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Abstract –
Intelligent radios collect information by sensing signals within the radio spectrum, and the automatic modulation recognition (AMR) of signals is one of their most challenging tasks. Although the result of a modulation classification based on a deep neural network is better, the training of the neural network requires complicated calculations and expensive hardware. The proposed system consists of Convolutional Neural Network (CNN) combined with a deep learning-based method, to achieve higher-accuracy AMR that are trained on different datasets. The proposed system adopt dropout instead of pooling operation to achieve higher recognition accuracy. The proposed system is combined with CNNs and is designed for recognition of eight modulation modes of BPSK, QPSK, 8PSK, GFSK, CPFSK, PAM4, 16QAM, and 64QAM.These modulation modes are widely used in modern communication systems, including optical communications and satellite communications. When unknown signals are detected, the initial CNN trained on IQ samples is employed to recognize easily distinguishable modulation modes except 16QAM and 64QAM. This CNN does not have the capacity to distinguish between them, but it can separate them from other modulation modes. Therefore, they are categorized into the same class (QAMs), from which the other CNN trained on constellation diagrams can distinguish 16QAM and 64QAM. The experimental results show the efficiency of each of the modulation modes. The system reveals that BPSK modulation has 97% accuracy, PAM4 has 91% accuracy, PAM8 has 88%, PSK4 and PSK8 both have 93% accuracy, QAM4 has 94%, QAM16 has 81% and the final one QAM64 has 87%. The overall system undergoes 90% accuracy which the best value to be measured.

***Keywords** – Deep Learning, Convolutional Neural Network, Automatic Modulation Recognition (AMR), Cognitive Radio (CR)*

I. INTRODUCTION

After a long time in development, wireless communication technology has derived a variety of types of signal modulation methods for different application scenarios, mainly divided into analog modulation and digital modulation. With the gradual popularization of the digital signal, digital modulation has become the main research topic in this field. Therefore, this paper focuses on the identification of digital signal modulation methods. The modulation recognition of digital signals is divided into two cases: cooperative conditions and non-cooperative conditions. In a Non-cooperative environment, modulation recognition is a technology between signal detection and signal demodulation. Its main purpose is to determine the modulation method of the signal to be detected, which is also the subsequent estimation of the parameters of the signal to be detected (carrier frequency, symbol rate and so on). The modulation and identification of signals under non-cooperative conditions has a wide range of applications in the civilian and military fields. In the civilian field, modulation identification of signals is mainly used for signal confirmation, interference identification and interference confirmation for radio spectrum management. In the military field, it is

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mainly used for radio communication countermeasures in software radio technology and electronic countermeasures. A cognitive radio (CR) is a radio device capable of sensing, learning, and adjusting to adapt to external wireless environments. There are many types of modulation technologies, and one of the most essential functions in CR is to automatically select these modulation modes according to external environments. So, a precondition of receivers in demodulating received signals is to confirm signal modulation modes in CR; otherwise, the signals cannot be demodulated correctly, and transmission can't be completed. Therefore, automatic modulation recognition (AMR) is a function that must be solved in the CR receiver.

Recent years have witnessed an ever-increasing demand for multimedia communication applications. World Wide Web applications have extensively grown since the last few decades and it has become a requisite tool for education, communication, industry, amusement etc. All these applications are multimedia-based applications consisting of images and videos. Images require enormous volume of data items, creating a serious problem as they need higher channel bandwidth for efficient transmission. Thus, the need for image compression arises for resourceful storage and transmission. Image compression techniques aim at reducing the amount of data needed to accurately represent an image, such that the image can be economically transmitted or archived. The approach presented in this offers great potential in complete lossless compression of the biomedical image under consideration, with the reconstructed image being mathematically identical to the original image. The method comprises getting rid of the redundant data and encoding the non-redundant data for the purpose of regenerating the image at the receiver section without any observable change in the image data. Most compression algorithms are independent of specific file format. Indeed, much format support a number of different compression types. They are important parts of digital image creation, transmission and storage. Among them some algorithms are more efficient in compressing monochrome images whereas some are good at a compression colour and medical images. In this project, the main focus is given on medical images.

II. MOTIVATION

In classification of different modulation formats. It plays an important role both in military and civil applications. There is an urgent need to investigate the different methods of modulation estimations, discuss the challenges in cognitive radio environment, and understand the distinct requirements in real-time modulation classifications. The cognitive radio networks, automatic modulation recognition (AMR) is a fundamental step to perform the first approach deals with classifying distinct QAM modulations. As just seeing towards scatter plots human can identify the type of modulation technique, but machine can't so for the sake we are implementing this system.

III. LITERATURE SURVEY

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Automatic Modulation Recognition is the algorithm that recognize modulation of unknown signal without auxiliary information. Modulation is the process of converting data into radio waves by adding information to an electronic or optical carrier signal. RFML Ecosystem is used in the RFML application space, which are not by and large present in the picture, sound, and additionally text application spaces. [1] Test an advanced sign adjustment mode recognizable proof strategy, to recognize recurrence tweak (2FSK and 4FSK) from one perspective and abundancy and stage regulations (ASK, BPSK, QPSK and 16QAM) [2]. M.Venkata Subbarao et al. proposed new order calculations for AMR utilizing directed Decision Tree (DT). DT Classifiers (DTC's) are non-parametric classifiers which give fast and low complex arrangements in characterization. Fine Tree (FT), Medium Tree (MT) and Coarse Tree (CT) classifiers were carried out. [3].

Generative Adversarial Networks-Based Semi-Supervised Automatic Modulation [4] show that contrasted and notable profound learning strategies, their strategy improves the order precision on a manufactured radio recurrence dataset by 0.1% to 12%. Hao Gu et al. proposed a visually impaired channel distinguishing proof (BCI) supported summed up AMR (GenAMR) strategy dependent on profound realizing which is directed by two free convolutional neural organizations (CNNs). Reenactment results affirm that their proposed summed up AMR strategy is altogether better compared to previous framework. [5]. Automatic modulation for cognitive radios using cyclic feature detection is rehashed more occasions to build the profundity of neural organization and the model's capacity to learn highlights.[6]

IV. SYSTEM METHODOLOGY

Figure 1 Shows basic block diagram of the system. Our system is combined with two CNNs and is designed for recognition of eight modulation modes of BPSK, QPSK, 8PSK, GFSK, CPFSK, PAM4, 16QAM, and 64QAM. These modulation modes are widely used in modern communication systems, including optical communications and satellite communications. When unknown signals are detected, the initial CNN trained on IQ samples is employed to recognize easily distinguishable modulation modes except 16QAM and 64QAM. This CNN does not have the capacity to distinguish between them, but it can separate them from other modulation modes. Therefore, they are categorized into the same class (QAMs), from which the other CNN trained on constellation diagrams can distinguish 16QAM and 64QAM.

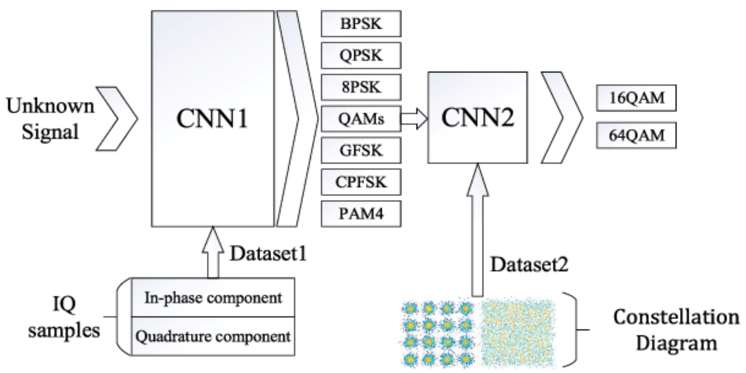

Fig.1 Architecture of the system

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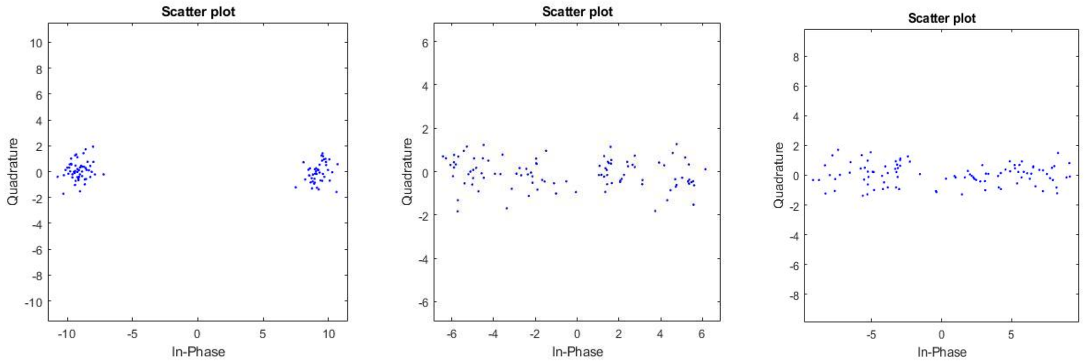
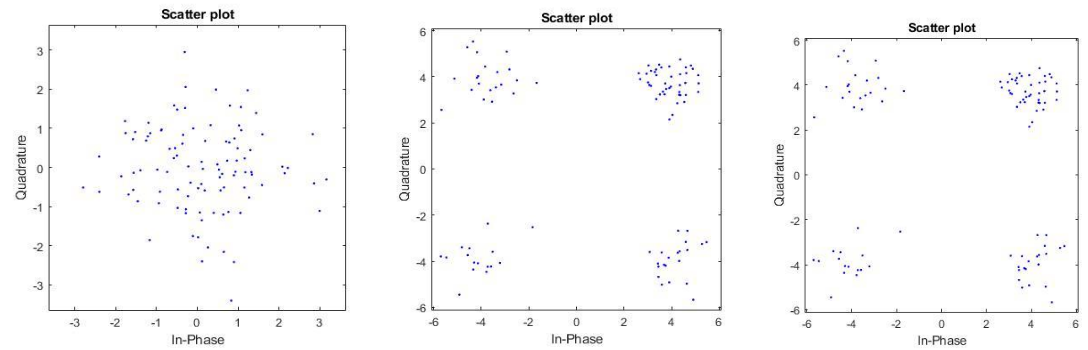
V. RESULT AND EXPERIMENT

The overall implementation of proposed system is designed based on MATLAB and Python. Python uses Keras with tensor flow for implementation of proposed network. Firstly, we collect the dataset for various 8 signals. 1000000 samples are collected and trained for system. The acquired dataset is trained using Convolutional Neural Network Algorithm (CNN). The random signals are generated in MATLAB and been passed to python, and based on the noise it identifies the category of noise. CNN is used for classification likes CPFSK, PAM4, 16QAM, 64QAM. BPSK, QPSK, 8PSK and GFSK. The complexity of a convolutional neural network is divided into time complexity and space complexity. The time complexity includes the number of convolutional layers and channels in the network (i.e., the number of convolutional kernels), and the overall time complexity is the sum of the time complexity of all convolutional layers. The space complexity includes the total number of parameters and the characteristic graph of each layer. The result and confusion matrix of various network in the data are given below.



BPSK PAM4

PAM8



PSK4 PSK8 QAM4

Fig. 2 scatter plot of modulation techniques

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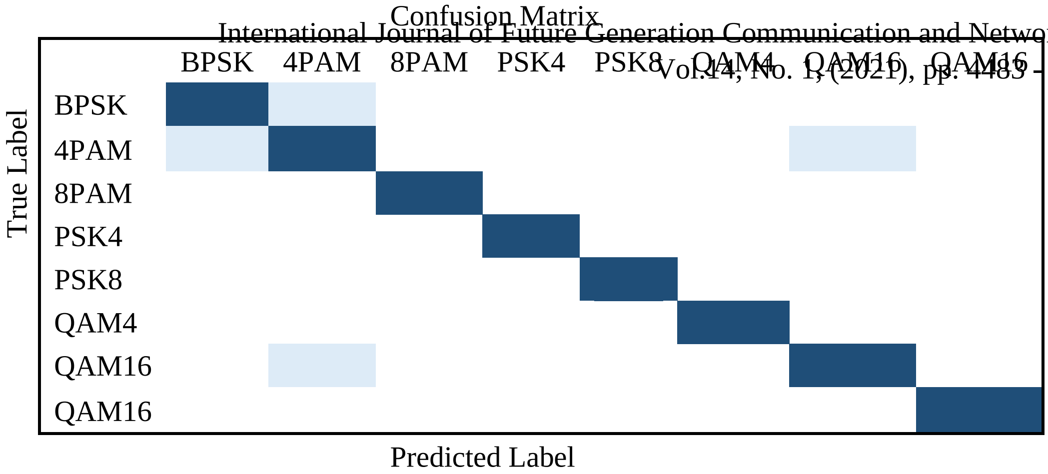

Fig. 4 precision matrix describing accuracy

```
[[96  1  1  0  0  0  1  1]
 [ 1 85 12  0  1  0  1  0]
 [ 2  7 91  0  0  0  0  0]
 [ 0  0  0 92  0  2  4  2]
 [ 0  0  0  3 85  3  8  1]
 [ 0  0  0  1  1 90  4  4]
 [ 0  0  0  1  1  1 91  6]
 [ 0  0  0  2  3  0  4 91]]
              precision    recall  f1-score   support

        bpsk       0.97      0.96      0.96       100
        4pam       0.91      0.85      0.88       100
        8pam       0.88      0.91      0.89       100
        psk4       0.93      0.92      0.92       100
        psk8       0.93      0.85      0.89       100
        qam4       0.94      0.90      0.92       100
       qam16       0.81      0.91      0.85       100
       qam64       0.87      0.91      0.89       100

    accuracy                           0.90       800
   macro avg       0.90      0.90      0.90       800
weighted avg       0.90      0.90      0.90       800

0.90125
>>>
```

Fig. 3 Confusion Matrix

VI. CONCLUSION

This Automated Modulation Recognition System can recognize eight modulation modes with high identification accuracy. CNN trained on constellation diagrams with a density window can detect sufficient differences to distinguish 16QAM and 64QAM, which cannot be differentiated in the former CNN. Due to the excellent performance of our method, we believe our approach can be directly employed in CRs if networks are trained by more signals with different modulation modes under different SNRs.

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