Automatic Modulation Classification using Deep Learning Techniques

A Thesis submitted by

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Conclusion and Future Scope

Wireless communication is one of the important areas of research where technology is changing rapidly. Currently, efficient spectrum utilization and reliable communication are being considered prime research topics. For reliable communication, some extra information needs to be transmitted to the receiver to adapt the system with the transmitted signal configuration. Adaptive modulation is one of the techniques which enables the receiver to identify the received modulation scheme and increases the spectral efficiency with reliable communication. In this thesis, modulation identification has been done using different types of deep learning-based algorithms. In this section conclusion of the research work conducted as well as possible future directions are included.

In this thesis, the first contribution to our research is modulation classification using constellation structure. All the required parameters for constellation extraction i.e. carrier frequency, symbol rate, and CFO have been calculated. Linear regression has been applied for the classification of ASK from PSK and QAM as ASK has a linear constellation whereas in the second step PSK has been separated from QAM using circle fitting to the constellation. As a result, the method is getting reliable classification accuracy above 5 dB SNR. Apart from constellation-based modulation classification, deep learning-based modulation classification methods are reliable and efficient. Most of the research portion of this thesis includes deep learning-based modulation classification methods.

In the second contribution to this thesis, a new method has been proposed for the classification of nine modulation schemes using ResNet-50 and Inception ResNet V2 models trained with the SDP color images generated by density distribution of SDP points. The hierarchy and driving parameters of SDP have been optimized for reliable performance. Training of the model is done with a large number of images generated with a wide range of SNR values. The proposed method works better for modulation schemes having variation in amplitude or frequency (MASK, MQAM, and MFSK) in comparison to phase (MPSK) because amplitude or frequency variation shows the effect on SDP image for whole symbol duration but phase variation shows only for one sample at which symbol changes. Results of the developed method are compared with the existing researches, which shows the superiority of the developed method. In this work, SDP-based modulation classification of digital signals has been done considering the AWGN channel. In further studies, we shall consider non-cooperative channel conditions to find the robustness of the method in a practical channel environment. Apart from that, we will try to develop another deep learning model for better performance with lower computation complexity.

In the third contribution, a modulation classifier is developed based on ResNet-50 and Inception ResNet V2 deep learning models using transfer learning. The Constellation density of the received signals has been passed through some filters consisting of three masks to generate color images. These filters contain the inherent properties of the target classes in the spatial view. Modulation classification has been done in three stages by training both models with generated color images. Comparison results show better performance of the proposed method than most of the methods available in the literature.

In the fourth contribution, a modulation classification approach enabled by a deep convolution network is proposed. 2D-FFT has been used for the transformation of complex baseband signals in the frequency domain, which works significantly well for classification. A convolution network extracts the important features from 2D-FFT for classification. Simulation results show the adequate performance of the model than most of the feature-based methods. From all five modulation schemes, the proposed DCNN model provides reliable classification results for BPSK, QPSK, and 8PSK at 5dB SNR while for 16QAM, and 64QAM it works reliably above 16dB SNR. To validate the developed model with the practical environment, performance with phase offset is also evaluated. Apart from CNN, LSTM is also a potential solution for modulation classification using time series base-band signals. In our future research, we will focus on LSTM based classification methods in a more complicated non-cooperative environment.

Apart from the DL methods, a software-defined radio (SDR) based automatic modulation classification method has also been proposed in this research. A LabVIEW-based Field Programmable Gate Array (FPGA) implementation of a modulation classification algorithm is included. A detailed explanation of method implementation is given so that readers can replicate the work, as well as method improvement, can be further implemented on top of it. The developed algorithm is implemented on NI-FlexRIO-7975 FPGA module with NI-5791 adapter and signals for testing are generated using NI-PXIe-5673.

The thesis research work can be extended by considering newer DL models such as Long short term memory (LSTM) and transformers to improve classification accuracy. SNR improvement of the received signal always helps increasing classification performance, which can be done by Autoencoders and Generative Adversarial Networks (GAN). As OFDM is widely used in communication systems, once the parameters of the OFDM system are known, modulation classification methods applied in this thesis can be used in multi-carrier modulation classification.

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