INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
PhD-17 SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

Automatic Modulation Classification (AMC) is the task of identifying the modulation scheme of an unknown communication signal, and it forms a critical component of cognitive radios, intelligent receivers, spectrum surveillance, and modern adaptive communication systems. AMC has been studied extensively, with early work focusing largely on Single-Input Single-Output (SISO) systems. Two broad families of techniques dominate the literature: the likelihood-based (LB) approach and the feature-based (FB) approach. The LB approach formulates AMC as a multiple-hypothesis testing problem, in which each of the candidate hypotheses corresponds to a distinct modulation type; while statistically optimal, it requires accurate prior information and is computationally demanding. FB methods are more efficient and need less prior knowledge, relying instead on discriminative features such as higher-order moments (HOMs) and higher-order cumulants (HOCs) extracted from the received signal.

The rapid progress of deep-learning (DL) algorithms in computer vision has opened the possibility of eliminating handcrafted feature extraction in AMC altogether. By representing complex baseband signals as two-dimensional inputs—separating the in-phase and quadrature (real and imaginary) components into distinct channels—standard convolutional neural network (CNN) architectures can be applied directly to signal classification. Subsequent studies have consistently shown that DL-based classifiers outperform traditional LB and FB methods in both accuracy and generalization. However, AMC is generally deployed on resource-constrained platforms, which makes it essential to minimize the size and computational complexity of the classifier. Motivated by this requirement, this thesis develops accurate yet lightweight AMC solutions built on **shallow convolutional neural networks (SCNNs)**, and addresses four problems.

1. AMC of digital modulations over a Rician channel. The classification of eight digital modulation schemes—BPSK, QPSK, 8-PSK, GFSK, CPFSK, PAM4, 16-QAM, and 64-QAM—over a Rician fading channel is studied using shallow CNNs. A widely used classifier, the dropout CNN (DrCNN), is found to classify six of these classes reliably but fails to separate the QAM schemes. To overcome this limitation, a modified architecture, the **dense-layer dropout CNN (DDrCNN)**, is proposed. The DDrCNN classifies the complete set of modulations, including the previously confused QAM signals, while keeping the network complexity low. The roles of dropout and batch normalization (BN) on this dataset are analyzed in detail to explain the performance improvement.

2. Cooperative AMC through node cooperation. In practical communication systems, the availability of multiple receiver nodes can be exploited to improve classification accuracy through cooperation. This thesis studies the enhancement of CNN-classifier performance via cooperation among communicating nodes. A decision-fusion scheme with a centralized architecture is adopted for evaluation, and popular cooperation strategies—voting-based and averaging-based decision-making—are compared. The results quantify the accuracy gains achievable from cooperation and identify the conditions under which each fusion rule is preferable.

3. Direct AMC of MIMO signals. The application of DL techniques to the AMC of Multiple-Input Multiple-Output (MIMO) signals remains limited, and most existing FB methods require channel estimation prior to classification. This thesis addresses the direct AMC of MIMO signals using a modified version of the shallow CNN developed for SISO classification. When trained on the in-phase and quadrature representation of the combined inputs from all receive antennas, the classifier achieves less than 90% accuracy. To improve this, a cooperative mechanism across the receiving antennas is introduced. Both **decision-fusion** and **feature-fusion** cooperation schemes are implemented, and their performance is compared against similar works reported in the literature. The modified DDrCNN is shown to deliver superior accuracy for the AMC of MIMO signals over fading channels, without the need for explicit channel estimation.

4. Robustness over MIMO keyhole channels. Cumulant-based AMC methods perform poorly for MIMO signals in rank-deficient channels such as keyhole channels, because accurate cumulant estimation depends on reliable channel state information (CSI). Under keyhole conditions, the fading process introduces complex mixing and distortion that lead to unreliable cumulant estimates. The proposed DL-based approach is evaluated on MIMO keyhole-channel signals to test its robustness. The classifier built on the modified DDrCNN architecture and trained on full-rank MIMO signals exhibits strong generalization, achieving satisfactory performance even under keyhole-channel conditions, thereby demonstrating robustness to severe channel degradation.

In summary, this thesis demonstrates that compact shallow-CNN architectures—particularly the proposed DDrCNN—combined with cooperative decision- and feature-fusion strategies, can deliver high classification accuracy at low computational cost across a range of realistic SISO and MIMO fading scenarios, including challenging rank-deficient keyhole channels. These contributions advance the goal of deploying accurate, low-complexity AMC in practical, resource-constrained communication systems.