Comparative Analysis of Signal Classification using Machine Learning and Neural Networks

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***Abstract*—Radar signals play an important role in modern defence and surveillance systems as they enable the identification of targets. The RADAR receives signals of many kinds, and hence its classification becomes pivotal. This paper aims to propose the best model for radar signal classification by conducting a comparative analysis of machine learning algorithms, such as convolutional neural networks (CNN), recurrent neural networks (RNN), support vector machines (SVM), XGBoost, LightGBM, random forest, and artificial neural networks (ANN), for a dynamic dataset with simulated using MATLAB having features like SNR, PRF vs pulse width, Doppler shift, centre frequency and bandwidth. The results suggest that the conventional deep learning models, i.e., RNN with 97% and CNN with 95% accuracies, outperform the machine learning models, such as RF and SVM, with 65% and 75% accuracies, respectively, even after boosting their performance with hyperparameter tuning.**

Keywords—Radar Signal Classification, Machine Learning, Modulation Recognition, Electronic Warfare.

I. Introduction

Radar signal classification is very important for national defence and the battlefield. Radar systems transmit a variety of signals — from those of aircraft and drones to those of ground defences and jammers — and must be identified accurately. Conventional manual or rule-based decision-making methods would be obsoleted because of complex threats such as frequency hopping, stealth emissions, and jamming. In order to overcome above-mentioned problem, such as the marked change of the target over time, machine learning technology is used for the automated processing of the radar signal parameters, while ensuring a high level of flexibility and accuracy for the detection of patterns their measurable parameters such as bandwidth, pulse width, PRF [1][2], SNR [3][4], modulation types [5], and Doppler shift [6]. This project focuses on classifying radar signals using machine learning to build models that can accurately classify them such as search radar, fire control radar, missile seekers, surveillance drones, active jammers, passive emitters, and friendly IFF beacons. The radar signal classification [7] has been studied by many researchers and organizations with different methods. Few methods are discussed below. In early systems, experts would define threshold and rule-based decision-making, which would not work well in the presence of noise and signal overlap, as well as adaptive adversaries. The other method is learning using Bayesian classifiers and decision trees was proposed to integrate uncertainty, but their performance was poor on high-dimensional and non-linear features.[8] Recent progress has achieved good results with Support Vector Machines (SVM) [5] and Random Forests [2], especially when features are extracted based on time-domain and frequency-domain properties. Convolutional Neural Networks (CNNs) [3][4][9][10]and Recurrent Neural Networks (RNNs) [11][12] have demonstrated strong performance when applied to spectrograms or raw I/Q samples of radar signals, though they require large labeled datasets and computational power. Real-world Applications: Defence systems such as ELINT (Electronic Intelligence) platforms, missile defence radars, and surveillance networks rely on real-time signal classification to differentiate between friendly and hostile emissions, prioritize threats, and guide responses. Combat and radar systems cover a wide frequency range intended to fit the particular purpose. Long-distance voice/data in ships & ground comm: HF Radio (3–30 MHz): VHF (30–88 MHz) and UHF (225–512 MHz) allow for tactical troop and multi-unit coordination using devices such as the PRC-77, SINCGARS, and UHF SATCOM. The L-band (1–2 GHz) is used for GPS and drone operations, with the S-band (2–4 GHz) providing for radar and telemetry, along with NASA tracking. C-Band (4 to 8 GHz) is crucial for long-range radar, with military radar systems in use at these frequencies. Other radars: X-Band (8–12 GHz) for fire control and SAR, Ku-Band (12–18 GHz) for UAV video. Ka-Band (26–40GHz) supports high-speed SATCOM through AEHF satellites, and V-/E-Bands (40–75GHz) are used to test high-speed data and jamming systems. Every band provides specific bandwidth in a range from kHz to GHz and meets the applications required for modern national defence. Classifying signals allows defence systems to determine whether a radar is part of a targeting system (e.g., fire control) or merely scanning (e.g., search radar). Understanding the type of radar enables smarter jamming and spoofing strategies. Signal classification helps commanders understand the electronic environment and adapt tactics

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