4^{th} URSI AT-RASC, Gran Canaria, 19 – 24 May 2024

Machine Learning technique based Direction of Arrival (DoA) estimation in radio source localization for Search and Rescue application

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The Direction of Arrival (DoA) denotes the direction of incident radio waves on an array antenna, playing a vital role in applications like radar, sonar, wireless communications, and search and rescue operations [9, 8]. For accurate DoA estimation, the antenna array must meet specific conditions, operating in a narrowband and receiving plane waves. The angle between the plane wave's direction vector and the array normal defines DoA. A time delay, resulting from the separation between array elements, introduces a phase difference, facilitating the estimation of azimuth and elevation [2]. Traditional techniques such as Multiple Signal Classification (MUSIC), root-MUSIC, and ESPRIT rely on eigendecomposition, necessitating spatial smoothing. In contrast, beamforming-based methods demand a uniform array, offering high resolution for narrowband signals but incurring computational costs [3, 4, 5, 6, 7]. The Matrix Pencil (MP) method, operating directly on data, excels in handling correlated signals and non-stationary settings without spatial smoothing [10, 7, 1]. Another widely-used method is Time Difference of Arrival (TDOA), applied in systems like the search and rescue satellite (SARSAT) localization, where the arrival time difference from two locations forms hyperbolas defining the source's location [8]. These methodologies, supported by proper citations, significantly contribute to the diverse field of DoA estimation.

This study explores a novel and elementary machine learning (ML) technique as a way to improve and estimate Direction of Arrival (DoA), leveraging a tri-axial antenna arrangement for radio source localization. The research utilizes a basic emission and receiving antenna model, training an artificial neural network (ANN) with synthetic radio signals. The synthetic signals cover a range of incoherent frequencies (0.3 to 30 MHz) and signal-to-noise ratios (0 to 120 dB). The resulting ANN, with eight layers including six hidden layers, achieves high accuracy in training ($\sim$ 95%), validation ($\sim$ 85%), and testing ($\sim$ 91%). Notably, the ML-based approach offers significantly faster inference times ($\sim$ 5 ms) compared to analytically derived DoA methods ($\sim$ 2 s), demonstrating its feasibility for radio source localization with limited sensors.

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