

Introduction

A method of weapon detection for the Comprehensive Nuclear-Test-Ban-Treaty (CTBT) consists of monitoring the amount of radionuclide in the atmosphere by measuring the activity concentration of ^{131m}Xe , ^{133}Xe , ^{133m}Xe , and ^{135}Xe . Machine learning algorithms allow improved task performance without being explicitly programmed. Approaches based on machine learning aim to build classification algorithms automatically by capturing statistically robust patterns present in the analyzed data. In the present work, we set to investigate a range of advanced machine learning methods for optimal Activity classification of radionuclide isotopes (^{131m}Xe , ^{133m}Xe , ^{133}Xe , ^{135}Xe) and discrimination of each others and from ^{214}Pb .

Methods and materials

Data sets used were two-dimensional spectra of radionuclides and ^{214}Pb which were obtained from simulation in the GATE 7.0 code using The INGAS (Iranian Noble Gas Analyzing System) geometry. The activity concentration range of simulated spectra were 1 to 150 mBq/M³ with this assumption that 1cc xenon was injected to beta cell.

Machine learning process

A range of robust classification algorithms (CA) such as MLP_BP, KNN, RNN were selected amongst various families of learner algorithms, in addition, we considered a feature extraction algorithm (FEA) such as FCM (Fuzzy C means) for initial feature extraction. We subsequently add features extracted by the FCM to inputs features (Gamma and Beta Coincidence with different activity) to classify. We utilized ten folds cross validation as an evaluating models of classifiers.

Eventually, the average measures of 10 times running for accuracy, sensitivity, etc, for each method were reported and compared. The Activity and isotope type for a passive spectrum were the classified as outcome measures.

Result

The typical simulated 2D radionuclide isotopes spectrum that is used for training and testing ANN is illustrated in fig 1. The Results are averaged on all folds and are shown for each algorithms in table1. Accuracy (the ratio of number of correct predictions of classes to the total number of input samples) for MLP was 0.85 also as shown in figure 2, performance measures of some classes was obtained lower values than other algorithms, whereas the accuracy reported for other classifiers were more than 0.96 also the values for other performance measures were higher. In fact, both RNN and KNN algorithms resulted in appropriate performances because of large number of input data. For the activities classification, all the classifier including traditional classifier (MLP) and the machine learning techniques were very well as they obtained high values for performance measures and high accuracy (above 0.97).

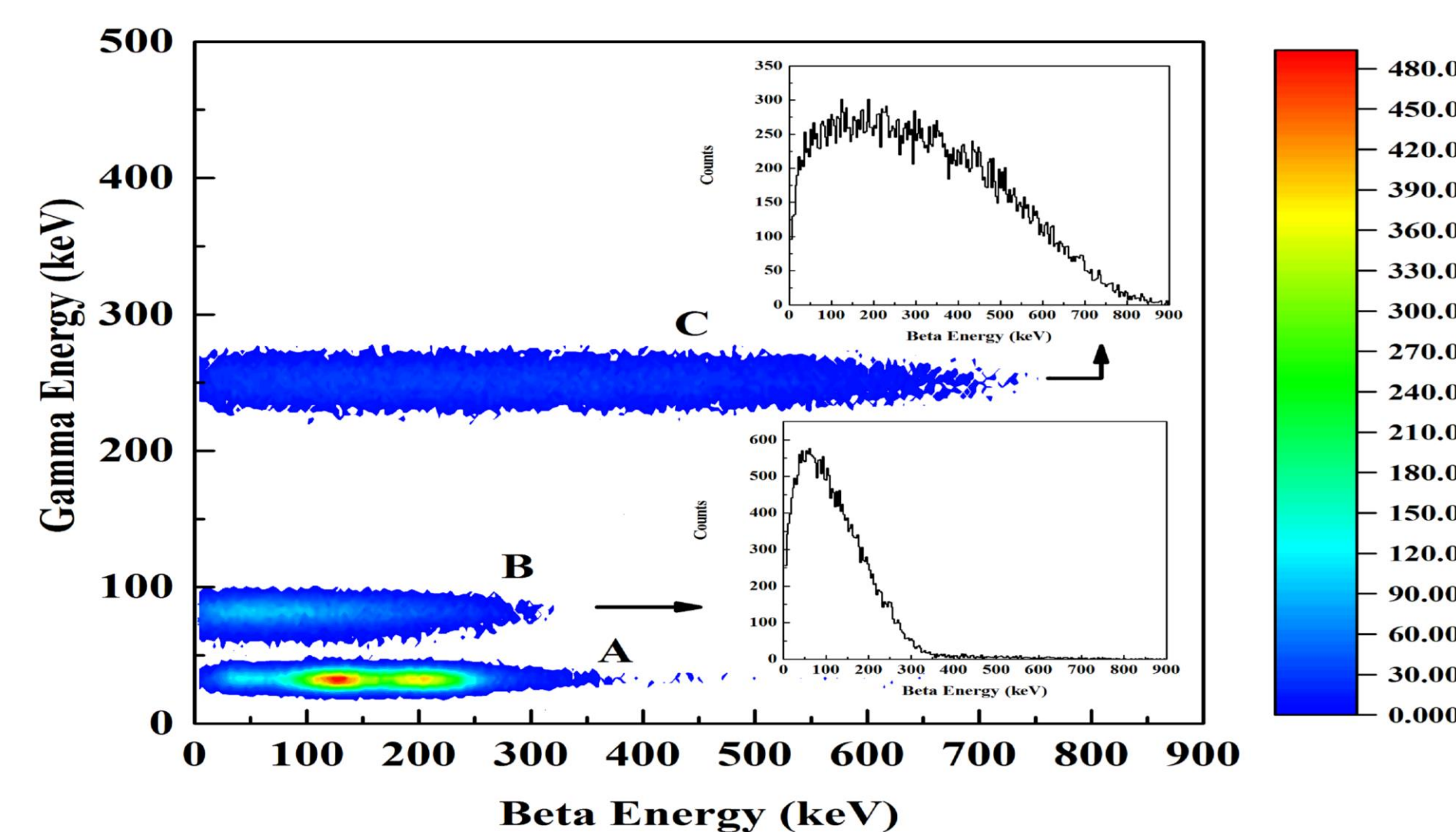


Fig1. Beta-gamma spectrum of radionuclide isotopes simulated via the Gate code

Table 1. Average calculated accuracy of all folds with standard deviation: classification of different isotopes (Left panel), classification of different activities (Right panel)

Accuracy	KNN	RNN	MLP
Mean	0.965	0.962	0.85
Standard deviation	0.0037	0.00449	0.02633

Accuracy for classification of activity	KNN	RNN	MLP
Mean	0.989	0.99	0.97
Standard deviation	0.00217	0.00158	0.00998

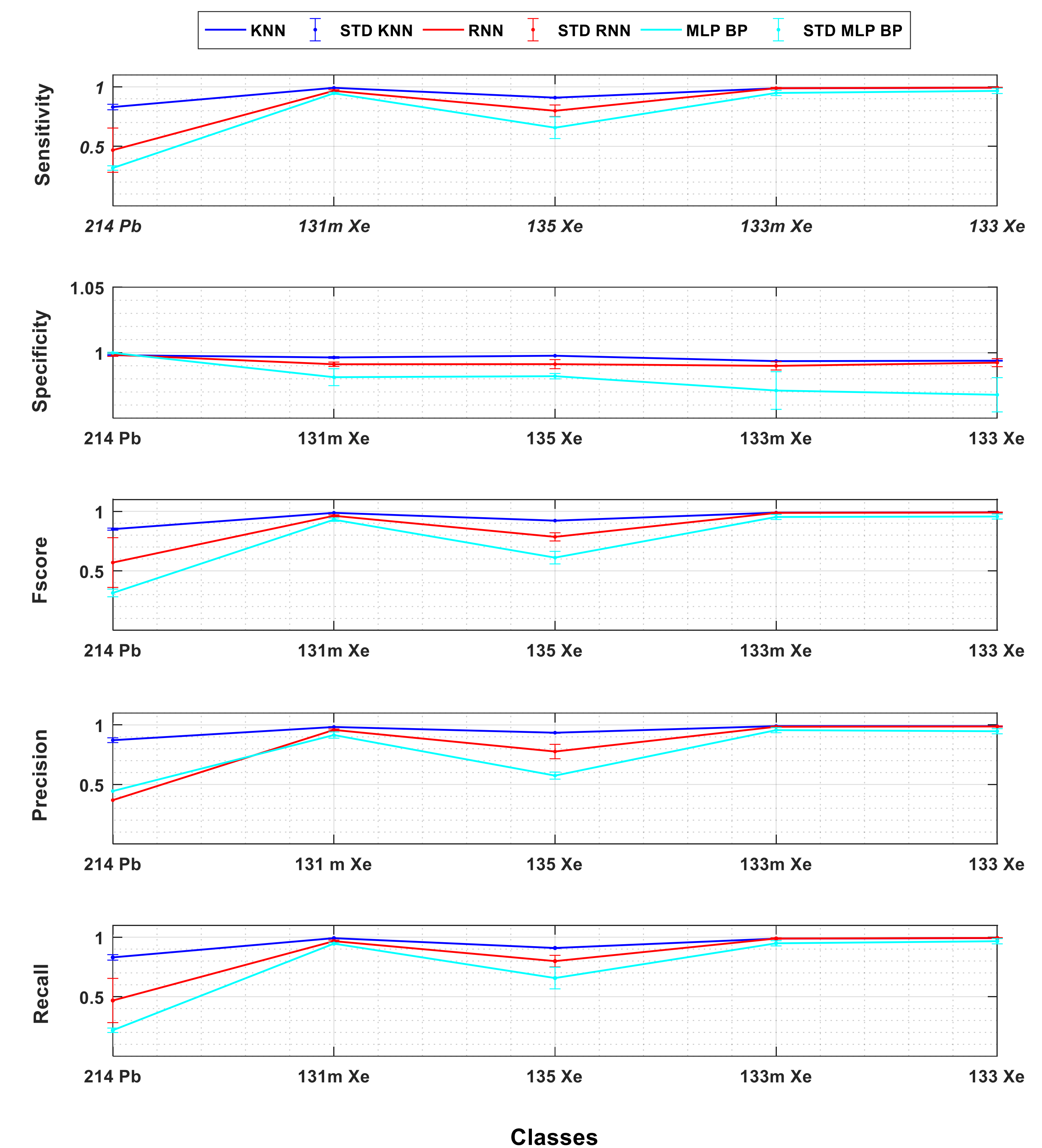


Fig 2. Diagram of performance measures for different algorithms(Mean ± STD)

Conclusions

It has been demonstrated that using various neural network algorithms, it was possible to solve the problem of interference of the activity calculation and discriminate Beta-gamma coincidence spectrum of radionuclide and ^{222}Rn (^{214}Pb) and correctly classify these events.