Multilayer Perception Hyperparameter Fine-Tuning for Ionospheric VLF Amplitude Data Exclusion

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Abstract: The analysis of ionospheric amplitude data is affected by various factors, including the influence of solar flare events, instrument malfunction, and other sources of error. These factors collectively contribute to a decrease in the overall quality of the data. The removal of such data is performed manually by researchers, a process that is characterized by its labor-intensive nature and time-consuming requirements. This research paper presents a procedure for fine-tuning of the learning rate (LR), number of epochs and the momentum in Multilayer Perception (MLP) classification models. The proposed method can be utilized as a benchmark for optimizing other hyperparameters in the future.

INTRODUCTION

• **Problem:** Very low frequency (VLF) ionospheric amplitude data is adversely affected by solar flare events and instrumental errors, including malfunctions. In order to render the VLF amplitude data applicable for further analyses by researchers, it is imperative to eliminate those effects.

• **Solution:** Automating this process using machine learning (ML) classification techniques such as Multilayer Perception (MLP) models. MLP models necessitate the fine-tuning of multiple hyperparameters, including the learning rate (LR), momentum, and the number of epochs among others.

• **Research goal:** This study aims to demonstrate the process of fine-tuning the LR, number of epochs and the momentum in MLP models utilized for ionospheric VLF amplitude data exclusion.

METHODS AND DATA

• **Data:** The data employed for this study consists of VLF amplitude measurements obtained during the months of September and October of 2011. The transmitters and receivers utilized were NAA, NAU, NLK, NMP, NML and Oklahoma East and South, Sheridan and Walsenburg. The data processing workflow is displayed in Figure 1.

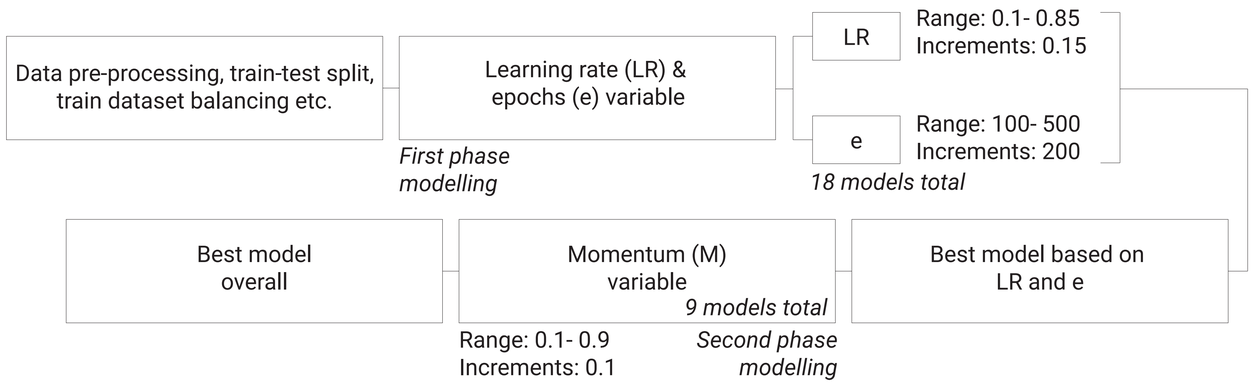

Figure 1. Research workflow

RESULTS AND DISCUSSION

First phase modelling

• The model trained with an LR value of 0.85 and 500 epochs achieved the highest MCC value among all the models tested.

• The TP rate for the anomalous data class ranged from 0.94 to 0.73, with the best model achieving a TP rate of 0.843. The average weighted F-measure for all 18 models was found to be 0.753 (Figure 2).

Second phase modelling

• Among the models considered in the second phase, the model with a momentum value of 0.2, emerged as the best model overall.

• The satisfactory classification example (Figure 3a), it is evident that the model successfully classified erroneous data points.

• In the case of the poorer classification example (Figure 3b), the model misclassified a significant number of data points that were determined to be non-anomalous and also inaccurately interpreted the duration of the anomaly.

RESULTS AND DISCUSSION

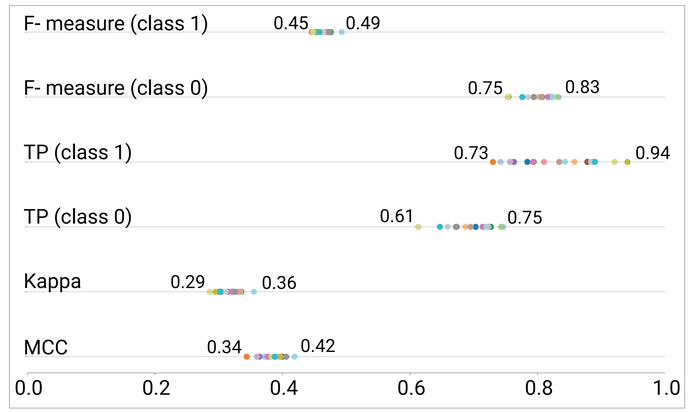

Figure 2. Evaluation metrics for the first phase of the hyperparameter tuning

• When compared to other ML methods, such as the Random Forest (RF) model, the MLP model requires more extensive fine-tuning and computational resources.

• The RF model can be considered a more favorable initial alternative for assessing the suitability and solvability of a given task using ML methods.

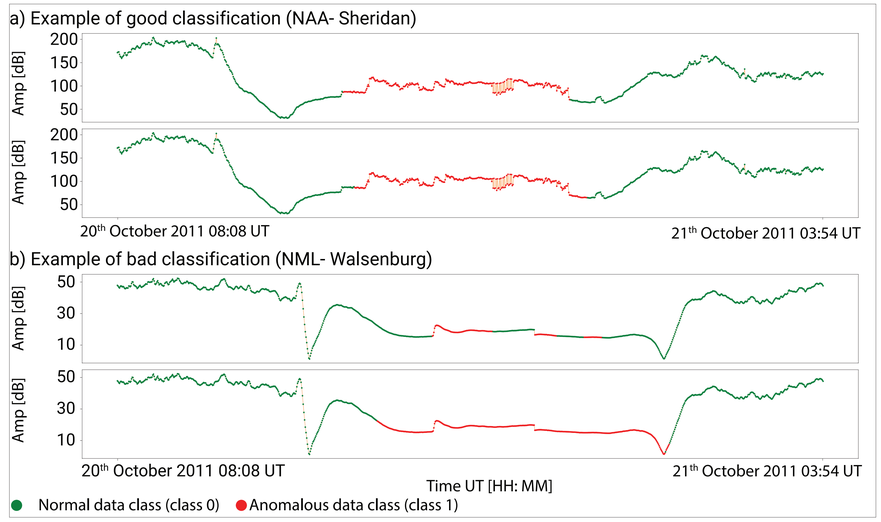

Figure 3. Examples of good and bad classifications made by the model

Confusion matrix

		Predicted	
		0	**1**
Observed	**0**	6004	982
	1	211	2495

Confusion matrix

		Predicted	
		0	**1**
Observed	**0**	4563	3896
	1	147	1058

CONCLUSIONS

• Multilayer Perceptron models exhibit the potential for further refinement and future research in optimizing parameters.

• **Results:** Model with a LR of 0.85, 500 epochs, and a momentum value of 0.2 performed the best among all MLP models.

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