X-band Doppler Weather Radar Velocity Unfolding Using Convolutional Neural Network

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Doppler weather radar measures the return power and radial velocity from weather targets such as rain, snow, hail, etc. One of the long lasting issues is the Doppler dilemma, which means that the maximum unambiguity range (r_a) and the maximum unambiguity velocity (v_a) cannot be improved at the same time owing to their opposite relationship to the pulse repetition time (PRT). This can be mitigated with dual pulse repetition frequency (PRF) or staggered PRT. However, these would take approximately twice more time than using the single PRT or lead to the low data quality. Even with dual PRF or staggered PRT, aliased velocities can still be observed during events of strong winds. Traditionally, unfolding the aliased velocities can be performed from a priori knowledge of background wind that can be obtained from other instruments. However, which direction to unfold or how many times to unfold can still be challenging due to the complexity of various weather phenomena. Additionally, the background wind field might not be representative within the radar volume in both space and time, which can lead to additional errors. In this work, the convolutional neural network (CNN) is introduced to unfold the aliased velocities without reducing the maximum unambiguity range for a single and uniform PRT operation.

Unlikely to the general programming which needs input data and algorithms, machine learning makes the model by itself with training datasets. In machine learning, the machine trains the model with good datasets and find the optimal model by itself. In this paper, it is proposed to unfold aliased velocities based on deep learning. Deep learning is one of the machine learning methods using a neural networks approach. The hidden layers contributes to the classification of the complicate datasets. The most representative method for deep learning is the CNN model and this method can extract features from the training datasets using convolution. It has been widely used in the field of image processing to classify the data. In this paper, in a similar way, a CNN model is introduced to classify the velocity folded status. Specifically, three labels are designed to represent the folding status: label 1 is for the positively folded velocity (i.e., folded velocity plus $2v_a$), label 2 is for the negatively folded velocity (i.e., folded velocity minus $2v_a$), and label 3 for the not aliased velocity. The training datasets are generated from the S-band NEXRAD radar velocity to simulate the X-band radar velocity because S-band radar velocity has higher v_a than X-band given the same PRT and the folding conditions are known. To achieve good training results, it is essential to collect a large amount of diverse data to represent all possible scenarios the model will encounter such as different types of the precipitation such as stratiform, convective, tornado, and so on to reflect the various wind conditions.

In this presentation, the CNN will be introduced and the architecture of CNN for velocity unfolding will be discussed in detailed. The performance of CNN velocity unfolding will be demonstrated and quantified for different meteorological conditions. The aspect of real-time implementation and future improvements will also be discussed.

Keywords: Velocity Unfolding, Convolutional Neural Network