Aerosol Size Density Estimation Using Artificial Neural Network

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Abstract

Climate models, in their effort to predict the weather properly, among other variables, require the aerosol size density (ASD). The determination of ASD from aerosol optical thickness (AOT) is an ill-posed problem. A typical mathematical inversion approach consists of using a linear regularization method, which requires a smoothing operation on the penalty term associated with the regularization method.

We propose solving this type of ill-posed problem using an artificial neural network (ANN), which will be trained to learn the local pattern between AOT and ASD. The network will be used to take AOT data and generate ASD data on a continuous basis. This "typical pattern" may vary too drastically from season to season, so two networks may be used, to account for Puerto Rico's two major seasonal wind patterns. The network's reliability rests in obtaining the best training data possible that describes a relationship between AOT and ASD in a given area of Puerto Rico. As a first attempt to generate size density, the training of ANN will be presented using AERONET data from nearby La Parguera for both AOT and ASD.

Method

In order to start off with a well-implemented, efficient neural modeling environment, Matlab's Neural Network Toolbox was used to create the network. Raw AERONET AOT and ASD data text files were translated into two Matlab matrices using some Java code that was written, which basically consists of a parser and a translator.

The network (shown in Fig. 1) consists of five inputs (which correspond to five wavelengths in an AOT reading), and 22 outputs, which correspond to 22 points on an AERONET density vs. size plot. These plots have 22 density values which are variable, and 22 size values which are constant, so only the density values need to be calculated. Between the input and output is a hidden layer containing 13 neurons with log-sigmoid transfer functions. Fig. 2 shows the general neuron architecture. The output layer transfer function is linear. The reason the hidden layer does not have a linear transfer function as well, is the fact that networks in which all layers are purely linear, can only learn linear patterns.

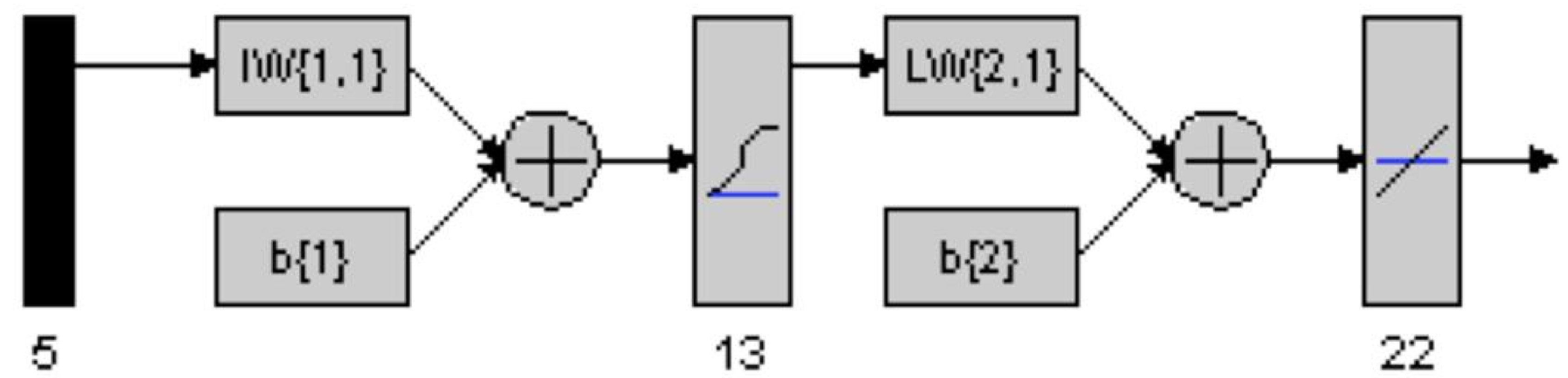

Fig. 1: Neural Network Architecture Overview

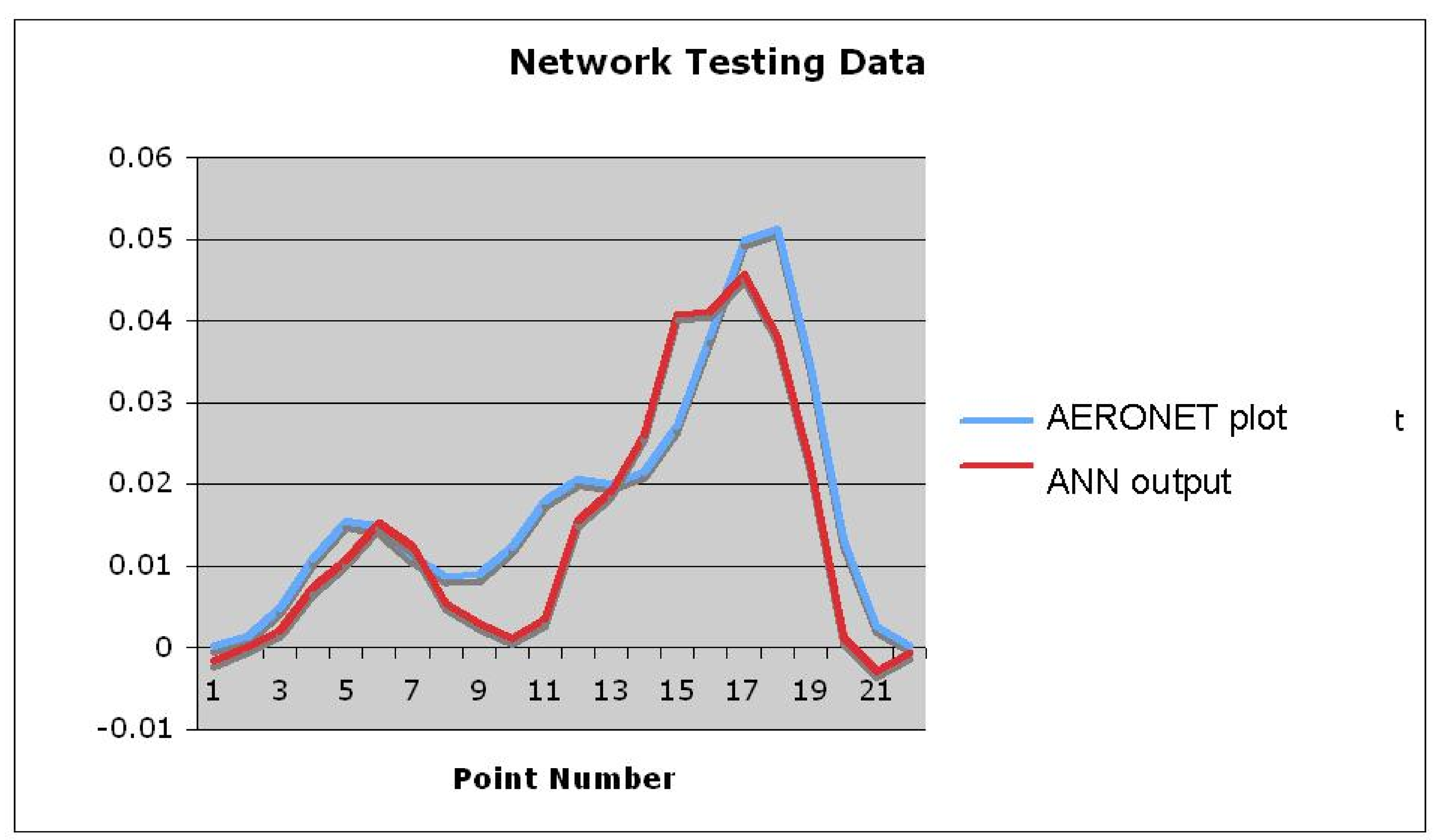

Fig. 3: Results of ANN Trained using Aug. to Nov. data, applied to an unknown random day in Oct. 2007.

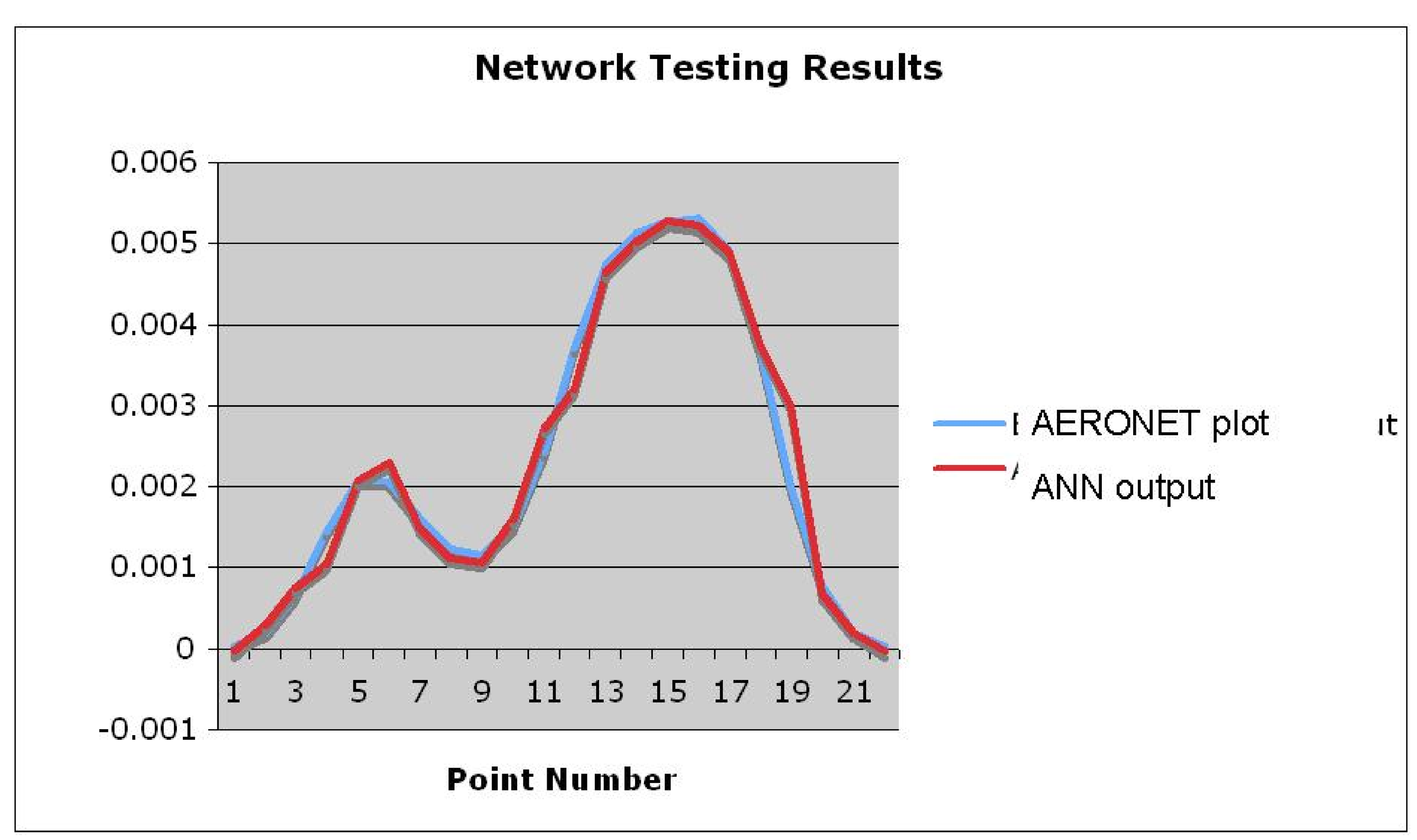

Fig. 4: Results of ANN Trained using Oct. data, applied to an unknown random day in Oct. 2007.

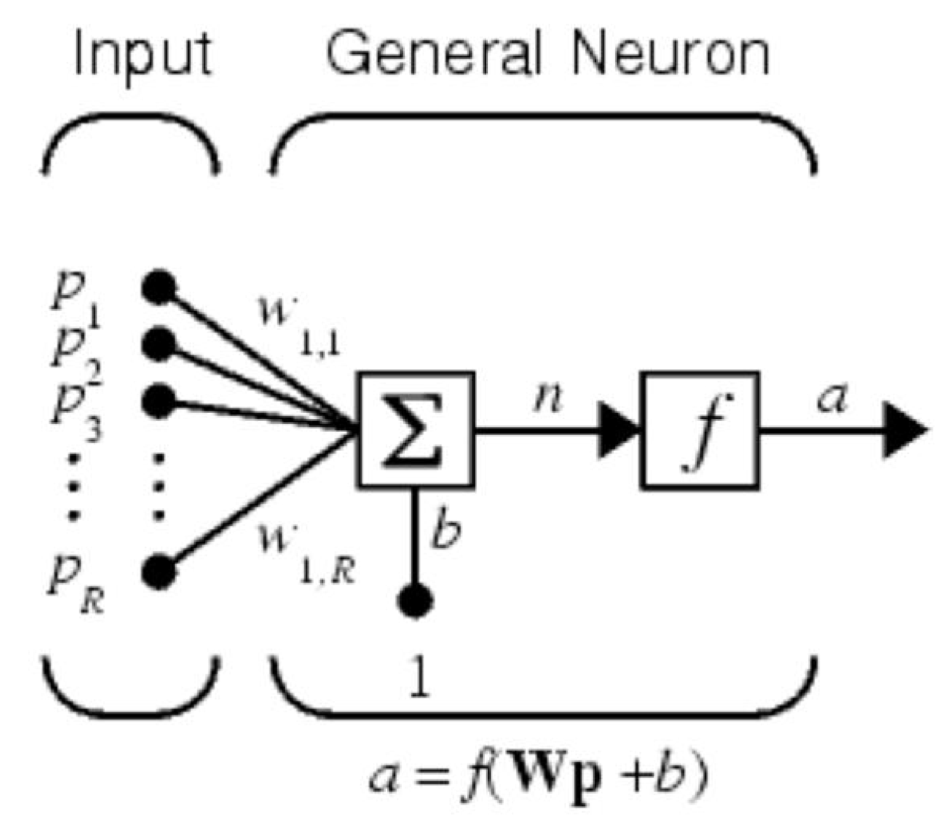

Fig. 2: Neuron Architecture Overview

Observations

So far, training the network with weekly, bi-weekly, or sometimes monthly data causes the network to converge upon a suitable set of weights and biases, with the lowest output error interpretable by Matlab (along the order of 10^{-27}). More general data set containing seasonal or yearly data have not succeeded at training a network with an output error lower than 10^{-4}. However, these initial results were obtained by initializing the network weights and biases to random positive and negative numbers within a certain range. These initial guess conditions can definitely be improved, and the network error should decrease, since the Levenberg-Marquardt algorithm being used as a training algorithm works best and often converges quickly when applied to a network with a good initial guess. Fig. 3 shows the network test results when asked to predict the ASD for a random day in October 2007, after being trained with Fall 2007 data. Fig. 4 shows the network test results when asked to predict ASD for a random day in October 2007 after being trained with October 2007 data.

Future Work

An algorithm must be developed to initialize the network weights and biases to values which make sense for our specific problem, yielding an output that is somewhat within the range of the expected output. Once the network error is minimal for a seasonal data set, the network may be used to validate aerosol size distribution measurements made at UPRM LIDAR lab.

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