Water Level Prediction Model for the Port of Baltimore

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Information and Background

The Port of Baltimore, located in the northeast portion of Chesapeake Bay, ranks 12th in the US for the total dollar value of cargo and 15th for the cargo tonnage. Predicting water levels is important for ships with a large draft to avoid grounding. In many locations water levels can be predicted using tide charts. For the Port of Baltimore, atmospheric forcings are often important and are responsible for large errors in tidal predictions. Other methods to predict water levels include hydrodynamic models such as the Chesapeake Operational Forecast System. The goal of this study is to investigate if a neural network approach developed for the Texas coast can be adapted to predict water levels in Chesapeake Bay. A trained neural network has the advantage to compute predictions in real time using the latest information available. The modeling approach includes removing the tidal component and conducting correlation analyses with lag to identify potential inputs to the model. Inputs identified include past water levels and wind measurements at both Port of Baltimore and at the entrance of Chesapeake Bay as well as inflow data from the Susquehanna River and the Chesapeake Delaware Canal. The most effective neural network configuration was determined to consist of three hidden neurons with inputs lagging up to six hours. The performance of the neural network is then compared to tidal predictions and a persistence model.

Data and Methods

- Acquiring data: Downloaded over five years of data from NOAA and USGS.
  - Data used: Canal current, river discharge, Observed and Predicted water levels from Baltimore, Windmill Point, Bridge Tunnel, and Reedy Point, wind speed, gust, and direction from Baltimore and Bridge Tunnel. (figure 1)
- Matlab Data Processing: Coding in Matlab to format data, graphed the times series, removed the tidal component to obtain surge time series and ran statistical analysis for predictions.
- Graphical Analysis: Generated graphs to compare the water levels from each station. Compared the water level to the surge, and the water entering the bay from the Atlantic Ocean, Susquehanna river and Chesapeake/Delaware canal with the Port of Baltimore. (figure 2 and 3)
- Statistical Analysis: Used the Pearson product-moment and Spearman rank correlation while introducing lags between time series to compare potential predictors and lags. (figure 4)
- Neural Network: Used the neural network GUI in Matlab to run numerous trials to get the best results forthe Port of Baltimore. The neural net was trained using Levenberg-Marquardt Backpropagation and the design was determined by varying the number of hidden neurons and lagged inputs. (figure5)
- Performance Assessment: the performance was assessed using the central frequency (15cm). For each trial the central frequency, maximum and minimum error, root mean squared error and the average absolute error were computed to determine the optimum neural net design.

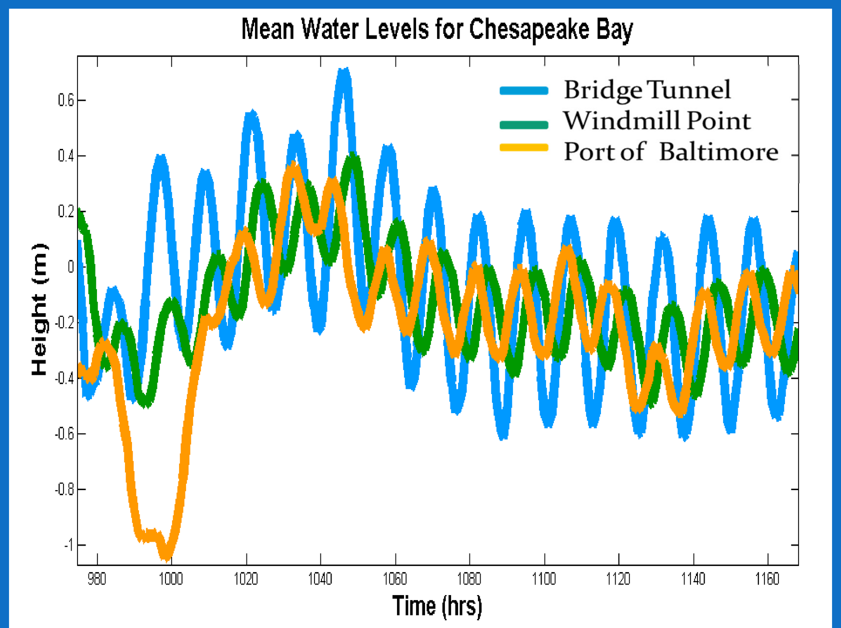

Figure 2: Observed water levels between the different stations in Chesapeake Bay

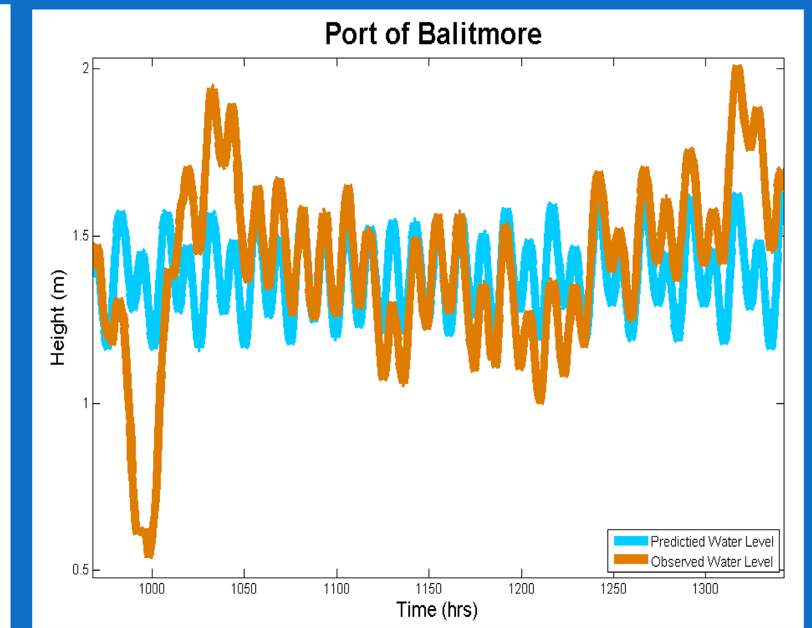

Figure 3: Water levels in the Port of Baltimore

Results

The best performance of the neural net for both 12 and 24 hour predictions is three hidden neurons and 1 – 6 hour lags. (figure 6 and 7) Our neural network had considerable improvements over the tidal predictions and satisfies the National Ocean Service requirement for operational models, CF(15cm) > 90%, for predictions up to 12 hours.

Figure 1: Map of Chesapeake Bay and the stations used.

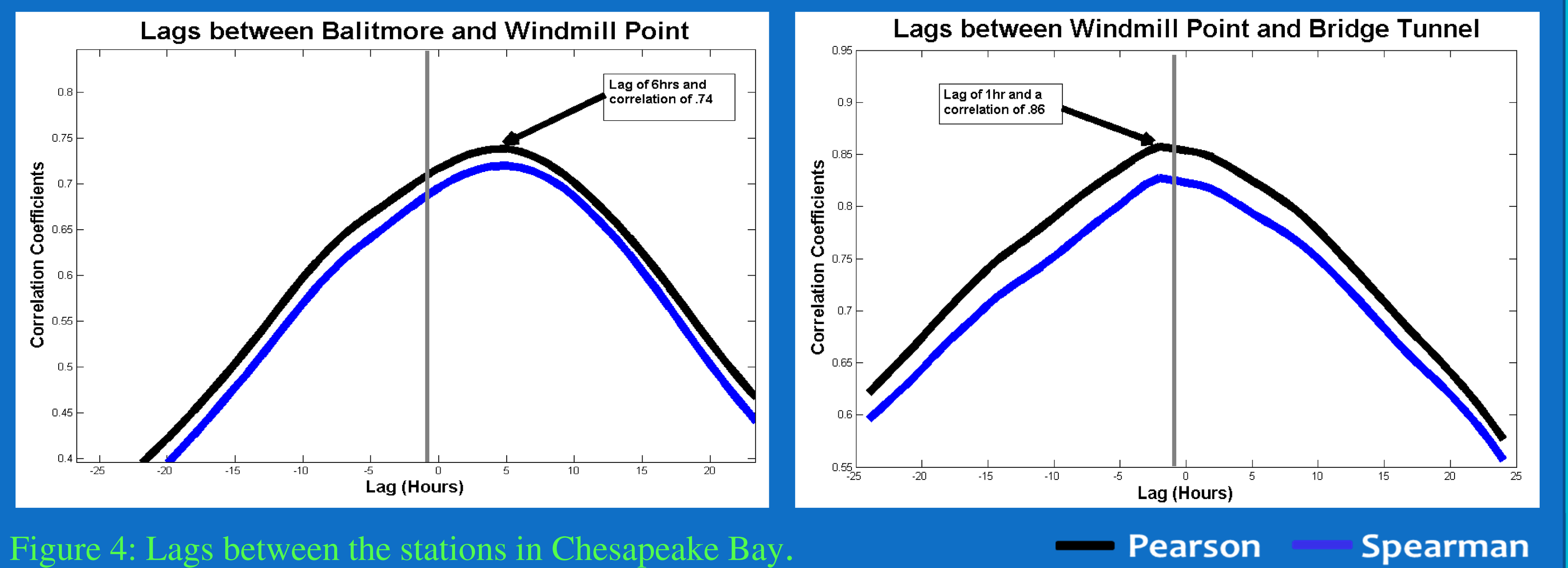

Figure 4: Lags between the stations in Chesapeake Bay.

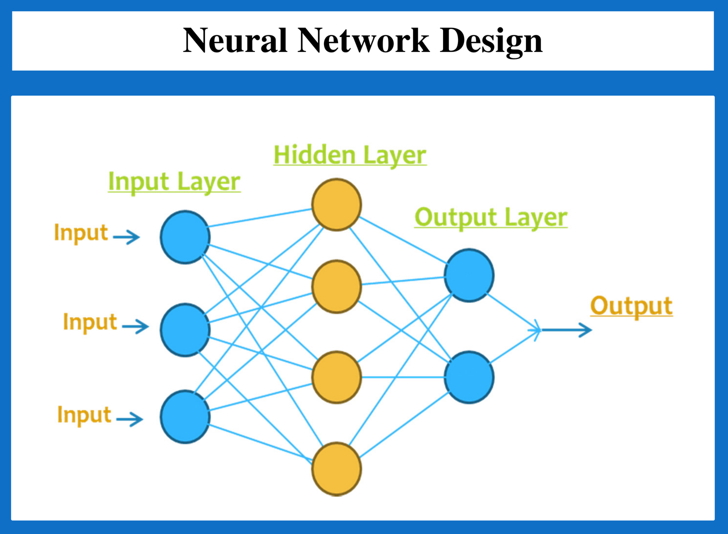

Figure 5: Neural Network Design.

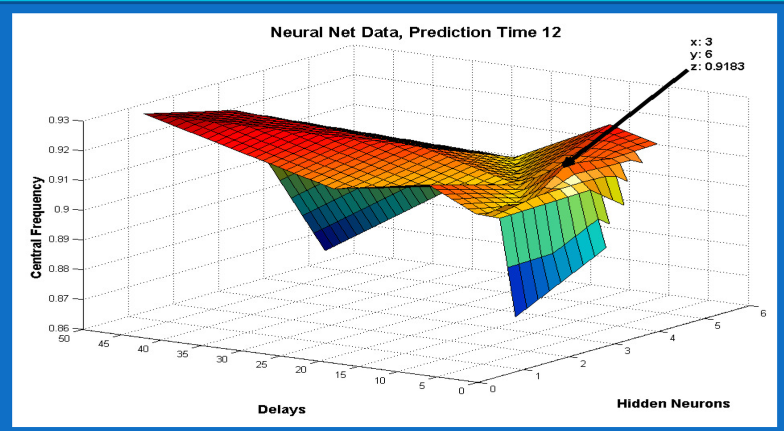

Figure 6: Performance graph, prediction time 12

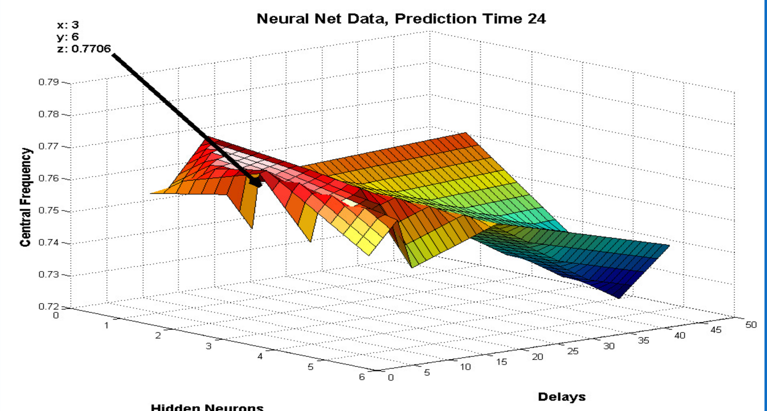

Figure 7: Performance graph, prediction time 24

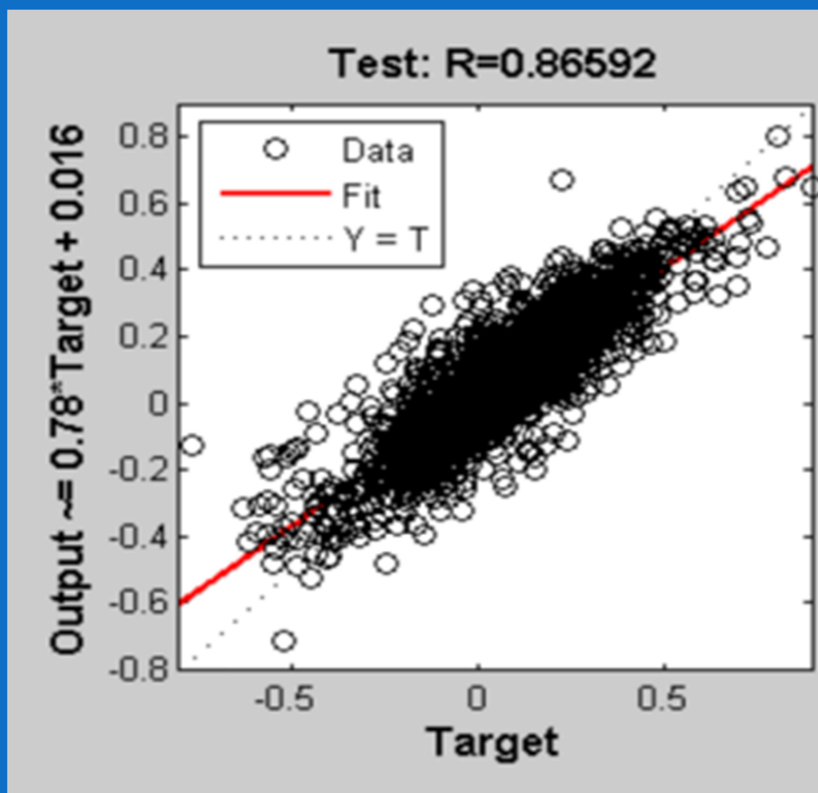

Figure 9: Regression plot for the testing set.

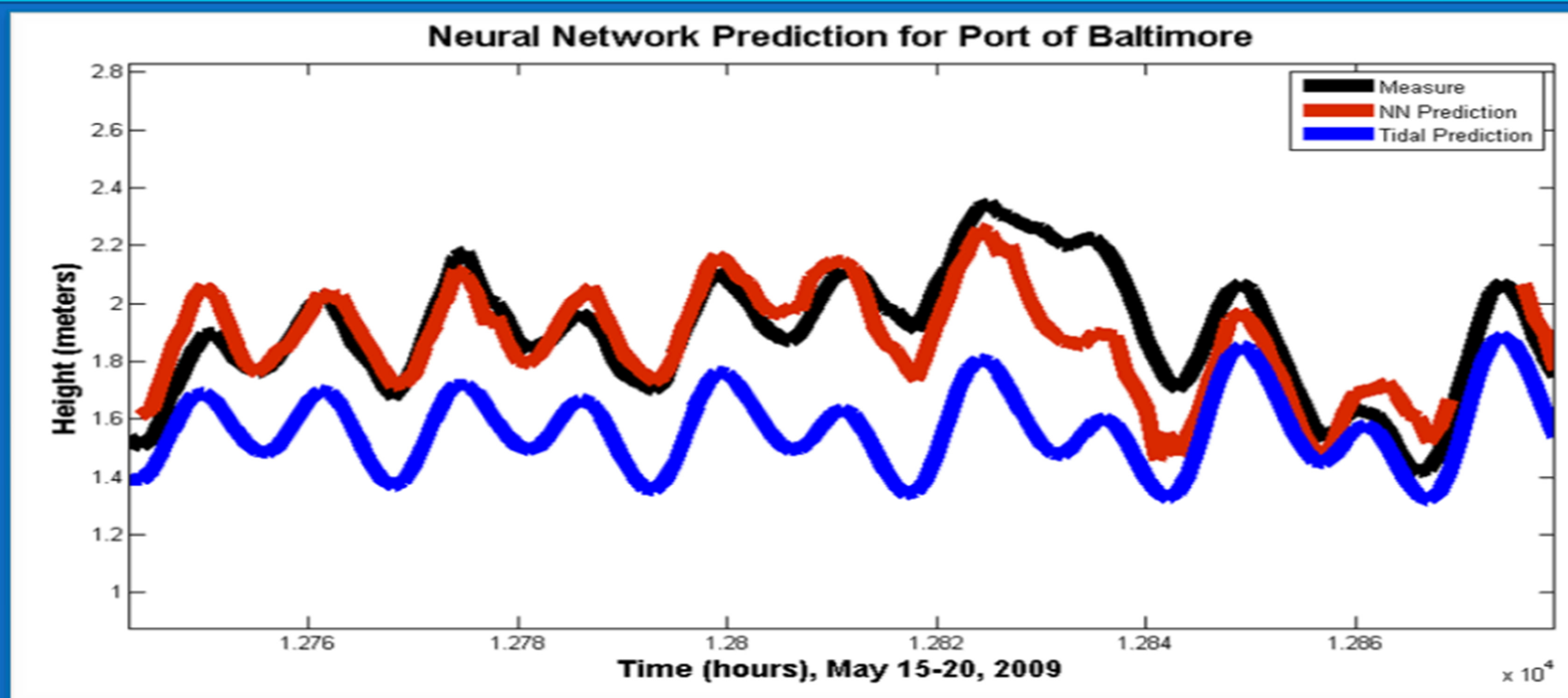

Figure 8: Comparison of Neural network predictions with tidal predictions and measurements.

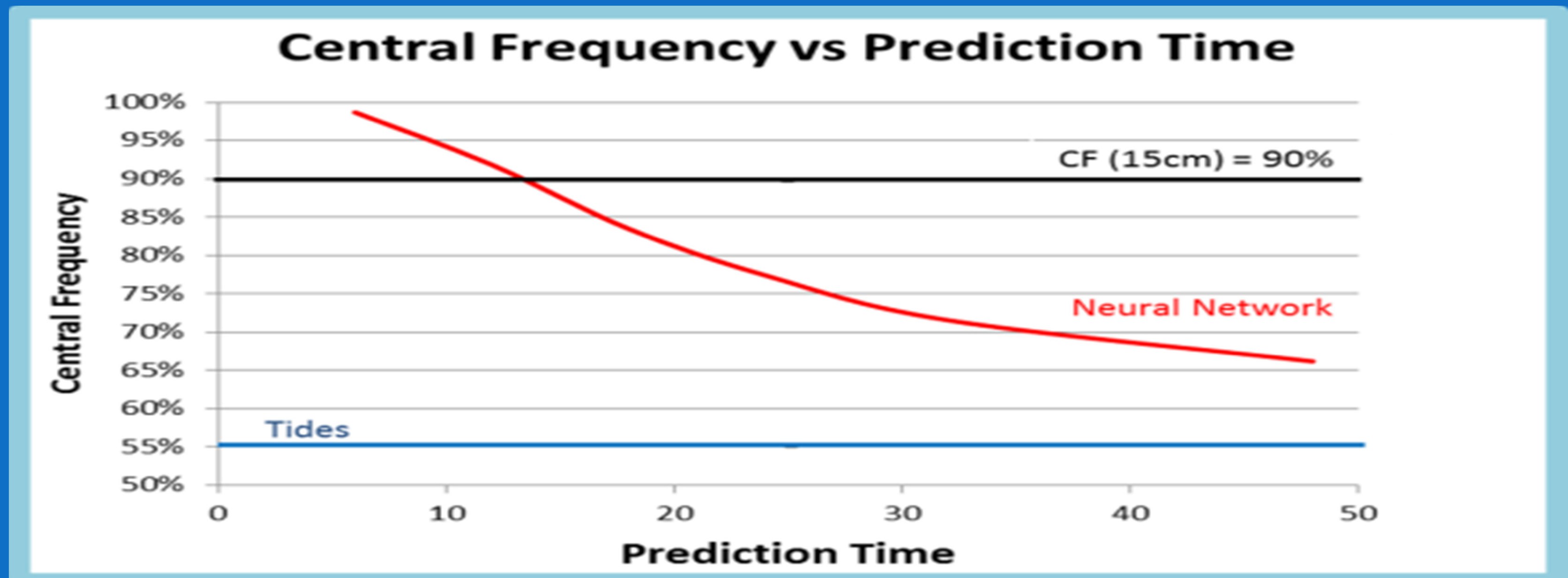

Figure 10: Comparison of the Central Frequencies of 15cm for the different models.

Discussion and Conclusion

As can be seen in figure 8, neural net predictions show as expected a considerable improvement over the tidal predictions. The neural network predictions are also analyzed based on a regression plot of predictions versus measurements (figure 9). The plot is only based on the test cases and shows good agreement over the full range of observations. Figure 9 also shows that the lowest measured water levels have the tendency to be over predicted while the highest measured water levels have the tendency to be under predicted. This indicates a conservative behavior of the model with respect to extreme events likely due to the training process (minimization of the root mean square error). Figure 10 displays a comparison of the central frequencies of the neural network and tidal predictions and shows that the former satisfies a NOS criterion for operational models for predictions up to 12 hours. The performance of the neural network can likely be further improved by including wind predictions similarly to models used along the Texas coast.

References and Acknowledgements

NOAA Environmental Cooperative Science Center, Grant #: NA06OAR4810164

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Chesapeake Bay Data: http://tidesandcurrents.noaa.gov/gmap3/index.shtml?type=TidePredictions&region=

Info on Chesapeake Bay: http://www.chesapeakebay.net/

Chesapeake Delaware Canal: http://www.nap.usace.army.mil/sb/c&d.htm