Tidal Currents Speed Forecasting Using a Hybrid of ANN and Least Square Model

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Introduction
Forecasting is the first step for dealing with the future generation of the tidal current power. Artificial neural network is one of the most commonly used models for forecasting. It is generally constructed from input, output and hidden layers. In this study tidal current models based on combining an artificial neural network (ANN) and the least squares method (LSM) were developed and evaluated for forecasting tidal currents over a future month. The results of the least squares model are compared with those of the artificial neural networks. A hybrid model of ANN and least squares is proposed and this model gives good results compared to either the ANN or LSM alone. This study was done using data collected from the Bay of Fundy in 2008.

ANN Structure

![ANN Structure](image)

The ANN consists of an input layer which in our case is the time during the month and one output which is the tidal speed and one or more hidden layers.

Least Squares Model Structure

This method depends on minimizing the residuals which is the difference between the exact and the estimated values. The estimated data may be defined as:

\[
Z_{\text{estimate}}(k) = DC + \sum_{i=1}^{N} \left( a_i \sin(\omega_i k + \theta_i) \right) + H_x \cdot \Theta(k)
\]

Where: DC= Constant value depending on the data, K=discrete time, \( \omega = \) amplitude, \( i = \) number of harmonics in the wave, \( \Theta = \) the phase shift.

Now let us define the actual data as \( Z = DC + H_x \cdot \Theta(k) \), \( \epsilon(k) \) is the error (residuals), then we may apply the least squares model as follows:

\[
X_0 = (H^H \cdot H)^{-1} H^T Z \quad Z_{\text{estimate}} = DC + H_x \cdot \Theta(k) + \epsilon(k)
\]

Least Squares Model Forecasting

In this section we use the least squares model for tidal current estimation. The (relative) percentage error is used for comparing different proposed methods. Applying the LSM method resulted in a 9.04 % percentage of error for 70% of the data and 0.817 for the remaining 30% of the data. Figure (2) shows the exact and the estimated data using the least squares model for 70% of the available data and figure (3) shows the results for the other 30%. The data is spaced ten minutes apart. The length of the data record in figure (2) is 3000 points. The second graph corresponds to data subsequent to that of the first figure.

![ Least Squares Model Structure](image)

![ Least Squares Model Forecasting](image)
ANN Model Forecasting

From the results of the Least Squares model the error is pretty high and we examine using the ANN. After using the direct data as an input to the ANN without any modifications and after 20000 epochs, 225 neurons in the first layer, the mean squared error became 0.000336. The percentage of error of the trained exact data is 0.3899 and for the estimated data is 19.0535. The trained data and the ANN data is plotted in figure (4). Figure (5) shows the exact data and the ANN not trained data.

Hybrid Model Forecasting

The LSM and ANN give a high error percentage for the estimated data. Here we use a hybrid of the ANN and LSM. We find the innovation data resulting from using the LSM and use this innovation as the input to the ANN. After using the innovation data as the input to the ANN and after 20000 epochs, 225 neurons in the first layer, the mean squared error became 0.000380. The percentage of error for the innovation of the trained exact data is 0.3569. The exact trained data versus ANN for the hybrid model has an error percentage of 0.3419 and is shown in figure (7). The prediction of the exact not trained data using the hybrid model has a percentage of error of 0.4845 and is shown in figure (8).

Conclusion

We can summarize the results in Table (1). As the data size increases and includes all changes the error will decrease. Tidal currents are easily predicted. The error for the hybrid model is the smallest error for the trained and predicted data. Using the LSM or ANN alone for the prediction is not recommended. The hybrid of ANN and LSM is good technique for high accuracy prediction of the tidal currents speed.

<table>
<thead>
<tr>
<th>Type of comparison</th>
<th>Least square model</th>
<th>ANN model</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>% error for the exact data (70%)</td>
<td>9.0339</td>
<td>0.3899</td>
<td>0.3569</td>
</tr>
<tr>
<td>% error for the predicted data (30%)</td>
<td>0.861</td>
<td>19.0535</td>
<td>0.4845</td>
</tr>
</tbody>
</table>

References


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