The Efficiency of Neural Networks to Model and Predict Monthly Mean Sea Level from Short Spans Applied to Alexandria Tide Gauge

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1. Introduction (Mean Sea Level)
• Mean sea level MSL has been considered as a stable reference datum representing the vertical datum i.e. geoid.
• MSL is required to determine the appropriate location of the engineering constructions and other activities relative to it along the coastlines.
• Sea level varies spatially due to sea surface topography and temporally due to changing of local and global meteorological conditions.
• Sea level rise has been estimated globally to be between 10 cm and 20 cm per century.

1. Introduction (Sea Level Variation)
• Sea level variation represents one of the main factors affecting the design of the coastal structures, and adopting the legal property line.
• Sea level variation leads to increasing shoreline erosion and wave overtopping, both factors contributing to failure of a structure.
• Sea level variation can be determined by using the available monthly mean sea levels and the associated meteorological data.

1. Introduction (Sea Level Status in Egypt)
• In Egypt, the sea levels and the sea levels variations have affected many related applications. The mean sea level was established at Alexandria harbor in 1906 by taking the average of daily sea level for seven years.
• Various efforts have been done to monitor the sea level variations, for the purpose of controlling the continuously increasing number of established new coastal constructions, as well as controlling the marine transportation.
• Along the coastlines of Egypt, most of the new development requires the exact information about the adopted mean sea level at the place to build safe constructions.
• Such information also helps in defining the set back line of the constructions, the property line, and the foundation level for the structures from the coastline.
2. Modelling of Mean Sea Level Using Least Squares Technique

- The suggested mathematical model:

\[ y(t) = a_1 + a_2(t) + a_3(t) + a_4(t) + a_5(t) + \sum \left( \cos \omega_j t \right) \]

- where: \( y(t) \) is the observed MSL relative to the zero datum of the tide gauge at time \( t \); \( a_1 \) is the datum bias; \( a_2 \) is the linear trend; \( A_j, \phi_j \) are the amplitude and phase of the periodic components with frequencies \( \omega_j \) corresponding to the following five periods:
  - 1. Annual (elliptic) tide with a period of 1 solar year.
  - 2. Semiannual (declination) tide with a period of 5 solar years.
  - 3. Lunar nodal tide with a period of 18.613 years.
  - 4. Lunar perigee tide with a period of 8.847 years.
  - 5. Chandler wave (oscillation of the Earth’s poles) with a period of 435 solar days.

Data size was only limited for 60 records and the other data were used based on sufficient available data and strong mathematical model.

2.1 Data Used (Alexandria Tide Gauge)

<table>
<thead>
<tr>
<th>City</th>
<th>Tide gauge Location</th>
<th>Spans of The Timeseries</th>
<th>Significant Peaks</th>
<th>Economic Uses</th>
</tr>
</thead>
</table>

2.2 Decision Making (Neural Network)

- The basic building block of neural network is the simulated neuron.

- Neural network technology imitates the brain’s own problem solving process. Just as humans apply knowledge gained from past experience to new problems or situations, a neural network takes previously solved examples to build a system of “neurons” that makes new decisions, classifications, and forecasts.

- The network processes a number of inputs from the outside world to produce an output, the network’s classifications or predictions.

- The neurons are connected by weights which are applied to values passed from one neuron to the next.

- A group of neurons is called a slab. Neural networks look for patterns in training sets of data, learn these patterns, and develop the ability to correctly classify new patterns or to make forecasts and predictions.
3. Neural Network (Basis)

- Neurons are also grouped into layers: the input layer, the output layer, and additional layers in between. A layer may contain one or more slabs of neurons.

3.1 Neural Network Development

- The neural networks were developed using the Neuroshell 2 neural-network development program.
- To use the program, a set of inputs and outputs must be defined, and a suitable training set must be developed.
- The available monthly mean sea level were considered as output.
- The inputs in the neural networks problem represent all the known variables that may affect the output, i.e., MSL data in the current problem.
- The available meteorological data, tides, and time were considered to be the input.
- It is advised here to choose the inputs as minimum as possible and to study the effect of removing the non-significant inputs.
- The data in neural networks are categorized into three sets: training, testing, and production sets.

3.2 Neural Network Results

- The data sets were examined using all the neural networks method offered by neuroshell2: the results of the best six models are illustrated.
- The modelled MSL versus Measured MSL is presented for only two sets and small deviation for the production set.

3. Neural Network (Basis)

- Each hidden or output neuron has weighted input connections from each of the units in the preceding layer.
- The unit performs a weighted sum of its inputs, and passed through a sigmoid activation function to determine output.
- An activation function in the output neurons should suit the distribution of the target values.
- The method of determining the weights and biases is called learning.
- The learning process requires a set of patterns in the input-target output space.
- During the learning process, the weights and the biases of a network are iteratively adjusted to minimize the network performance function.
3.2 Neural Network Results

- Fig. 4 shows the results of Jump Connection Net compared to measured MSL.

4. Conclusions

- The mean sea level along the coastlines is variable from place to place and from time to time, according to the change in the weather conditions, temporal variations, and Sea Surface Topography SST influences.
- Accordingly, MSL can not be used in different applications without considering the main sources of its variations.
- The long period variation of MSL should be taken into consideration during the design, construction, and maintenance of Coastal Structures.
- These long period variations may be modelled with sufficient records of sea levels taken at a certain tide gauge using e.g. Least squares method.
- In case of insufficient data records for sea levels the least squares does not give accurate results.

4. Conclusions

- The available MSL data for seven years at Alexandria associated with the available meteorological data were used to model and predict MSL.
- The mathematical model of the sea level variations was used and the estimated mean square error from least squares results is 19 cm².
- The neural network methods were applied for the MSL at Alexandria as output data while the meteorological data and tide effect were considered as inputs.
- The data were trained by different methods. The method of general regression neural networks gave mean square error 11.9 cm².
- The other method of training show reasonable values better than least squares except Jump Connection Net.
- It is recommended to Use GRNN method to model and predict MSL.