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Building artificial neural networks to predict direction and magnitude of wind, current and wave for sailing vessels

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Abstract

Current, wind, wave direction and magnitude are important factors affecting the course of ships. These factors may act positively or negatively depending on the course of a vessel. In both cases, optimisation of the route according to these conditions will improve the factors such as labour, fuel and time. In order to estimate the wind, wave, current direction and magnitude for the region to be navigated, it is necessary to develop a system that can make predictions by using historical information. Our study uses historical information from the E1M3A float—a part of the POSEIDON system. With this information being used, artificial neural networks were trained and three separate artificial neural networks were created, which can predict wind direction and speed, direction and speed of sea current, wave direction and height. For different regions, it is necessary to use artificial neural networks trained using the historical information of those regions. This study is an example of prospective studies.

Keywords: Current, neural network, prediction, sailing vessels, sea, wave, wind.

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1. Introduction

The wave direction, wave height, current direction and speed on the area to be navigated play an important role in the route choice of the ships. In the literature, there have been studies aimed to calculate how weather and sea conditions affect the speed and course of the ship, and how the velocity of the ship can be affected in response to changing factors [5], [10].

Estimation of wind intensity is a subject that is often studied in areas such as wind power generation and agriculture [3], [8]. Various methods are used to estimate wind speed. When the studies are examined, it has been seen that linear prediction methods [1], methods using multiple architectures [2], methods based on probability [9], methods based on Kalman Filter [8] and methods based on artificial neural networks [3] [8] have been used. In the literature survey, it was seen that there have been studies on the estimation of wave height [11] used and is to predict the wave height in a certain area of Turkey [6] used the neural network, fuzzy and neuro-fuzzy methods to predict wave height for Lake Ontario. Artificial neural networks were used in our work. Using artificial neural networks, a system has been developed that predicts what the wind, current and wave conditions may be in the sea depending on the changing weather conditions. The information used to train artificial neural networks was derived from the E1M3A float, a float of the POSEIDON system. The information can be accessed on the IFREMER website [4]. The E1M3A flood is a flood in the 35.74474° north, 25.12606° east location, instantaneously sending to the POSEIDON system by measuring air pressure, air temperature, wind speed, wind direction, wave height, wave direction, flow direction and speed [7].

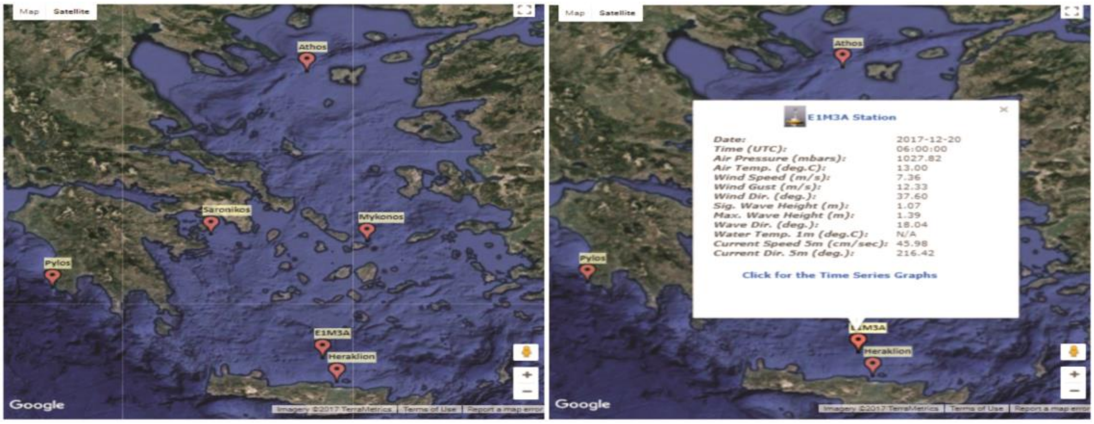

Figure 1A. Poseidon system floats, Figure 1B. Online information gathered from E1M3A

Figure 1A shows the float locations obtained from the POSEIDON system and Figure 1B shows the online data taken from E1M3A float.

2. Material and Methods

2.1. Information gathered from IFREMER system

The data used in the study were obtained from the IFREMER system in the form of nc extension files [9]. Files are read on this format and saved in excel files. This is the way to use nc extension files as it will affect the speed of reading and using the program at runtime. Just before the system works, the information is read from the excel file, converted into a matrix and transferred to the system. Figure 2 shows the information obtained. The information in the file includes air temperature, flow direction, flow velocity, wave direction, atmospheric pressure, wave height, wind speed, date and wind direction.

In addition to these, the wind category columns have been added by us so that we can express the lunar slope, wind or current directions as words to understand which month the data are obtained.

Air Temperature (	Current Direction (Degrees)	Current Speed (cm/sec)	Wave Direction (Degrees)	Atmospheric Pressure	Wave Height (m)	Wind Speed (m/s)	Date	Month	Wind Direction	Wind Direction (Degree
25,85899925	330,1170044	15,23400021	267,1879883	1006,343018	0,703000009	7,265999794	1.08.2007	8	WNW	272,8120117
25,76199913	341,7189941	12,30500031	267,1879883	1005,890991	0,703000009	7,031000137	1.08.2007	8	WSW	260,1560059
25,95700073	336,4450073	5,859000206	267,1879883	1006,703979	0,703000009	6,561999798	1.08.2007	8	WSW	267,1879883
26,34799957	337,8519897	9,375	278,4379883	1007,788025	0,625	5,390999794	1.08.2007	8	WSW	265,7810059
26,73800087	316,7579956	4,980000019	299,5310059	1008,059021	0,546999991	4,921999931	1.08.2007	8	WNW	307,9689941
27,03100014	271,0549927	12,30500031	319,2189941	1007,517029	0,546999991	3,516000032	1.08.2007	8	WNW	293,9060059
26,73800087	295,3120117	24,31599998	312,1879883	1007,517029	0,469000012	3,75	1.08.2007	8	WNW	291,0939941
26,44499969	313,9450073	26,65999985	300,9379883	1008,961975	0,391000003	3,046999931	1.08.2007	8	WNW	298,125
26,15200043	342,4219971	24,90200043	329,0620117	1009,504028	0,391000003	3,516000032	2.08.2007	8	WNW	312,1879883
26,25	7,382999897	12,59799957	4,218999863	1009,594971	0,469000012	3,280999899	2.08.2007	8	NNW	322,0310059
25,56599998	239,7660065	4,688000202	357,1879883	1011,039978	0,703000009	4,218999863	2.08.2007	8	NNW	336,0939941
25,56599998	252,4219971	19,33600044	337,5	1012,39502	0,781000018	4,921999931	2.08.2007	8	NNW	338,9060059
25,37100029	288,6329956	22,55900002	347,3439941	1012,846985	0,938000023	4,453000069	2.08.2007	8	NNW	331,875
25,85899925	289,3359985	22,85199928	348,75	1012,937012	1,172000051	5,390999794	2.08.2007	8	NNW	347,3439941
25,76199913	300,2340088	21,38699913	350,1560059	1012,575989	1,25	4,453000069	2.08.2007	8	NNW	336,0939941
25,76199913	305,8590088	14,06200027	343,125	1013,479004	1,406000018	7,265999794	2.08.2007	8	NNW	337,5
25,46899986	123,0469971	13,47700024	268,5939941	1004,174988	1,797000051	11,71899986	6.08.2007	8	WSW	251,7189941
24,88299942	131,4839935	21,97299957	270	1003,994019	2,108999968	12,65600014	6.08.2007	8	WSW	260,1560059
24,39500046	162,0700073	23,72999954	265,7810059	1005,16803	1,797000051	9,375	6.08.2007	8	WSW	262,9689941
24,68799973	205,3119965	21,09399986	265,7810059	1006,161987	1,797000051	10,07800007	6.08.2007	8	WSW	260,1560059
25,27300072	192,6560059	9,961000443	272,8120117	1006,974976	1,875	11,95300007	6.08.2007	8	WNW	275,625

Figure 2. Historical information of E1M3A float gathered from IFREMER

2.2. Properties of the proposed networks

Non-Linear Auto Regressive type (NARX) artificial neural network was used to process the data. The NARX-type artificial neural network takes the predicted values obtained at the output as input again and reduces the error to the minimum. The NARX type system is slower than other artificial neural network systems; this method is chosen because it is more accurate. The block diagram of the artificial neural network used is shown in Figure 3.

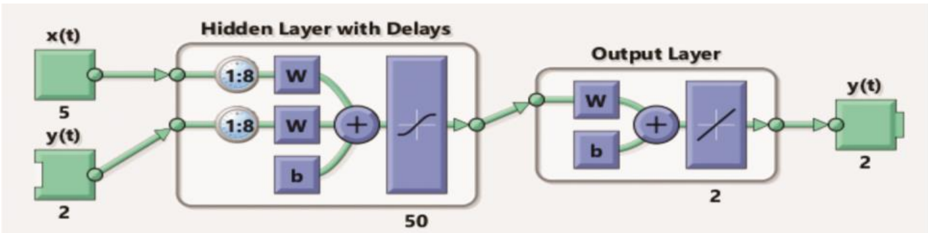

Figure 3. Block diagram of the proposed network

The proposed network is trained separately so that it can make three different estimates. Estimates were obtained in three different ways: direction and speed of current, wind direction and speed and wave direction and elevation. The input, output, number of neurons, latency, validation, testing and training parameters of the generated networks are as shown in Table 1.

Table 1. Parameters of networks

Parameters	System to predict wind direction and speed	System to predict current direction and speed	System to predict wave direction and height
Inputs	Temperature, pressure, month	Temperature, Pressure, month, wind speed, wind direction	Temperature, pressure, month, wind speed, wind direction
Neuron Number	50	50	50
Delay	8	8	8
Outputs	Wind direction, wind speed	Current direction, current speed	Wave direction, wave height
Validation	75%	75%	75%

Training	15%	15%	15%
Testing	15%	15%	15%

3. Results

3.1. Results of the system that predicts the current speed and direction

In order to examine the accuracy of the system estimating the current speed and direction, the data for January 2007 was taken and applied as an input to the system. Since the measurements are 3 hours apart, 8 measurements for 1 day and 240 measurements for 1 month are taken and the values that should be estimated with the system are measured and presented in Figure 4.

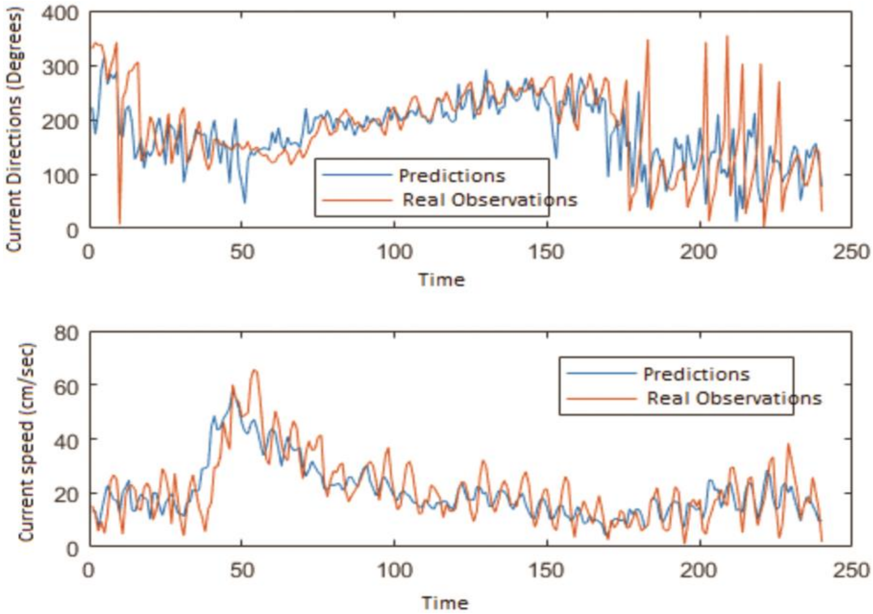

Figure 4. Results of the system that predicts wave direction and height

It was observed that the system was quite successful in estimating the speed of the current. When the direction of the current is predicted, it is observed that the error rate increases in the direction changes, but the recovery period is short. As seen from the figure, there was a sudden change in the direction after the 170th measurement, the system made erroneous predictions, but this process has survived the 190–200 measurements. The 200th measured income was again a change of direction, the system gave incorrect values but dropped the error to 240th measure. It has been seen that the system generally succeeds when there is no sudden change of direction.

3.2. Results of the system that predicts the wind speed and direction

As seen in Figure 5, it was observed that the system for predicting wind speed and direction was successful in predicting wind speed and direction. Errors in the prediction of the direction of flow have been observed to decrease in this system. The wind direction and speed were much related to temperature and pressure depending on the seasonal conditions, so the error did not occur at high rates.

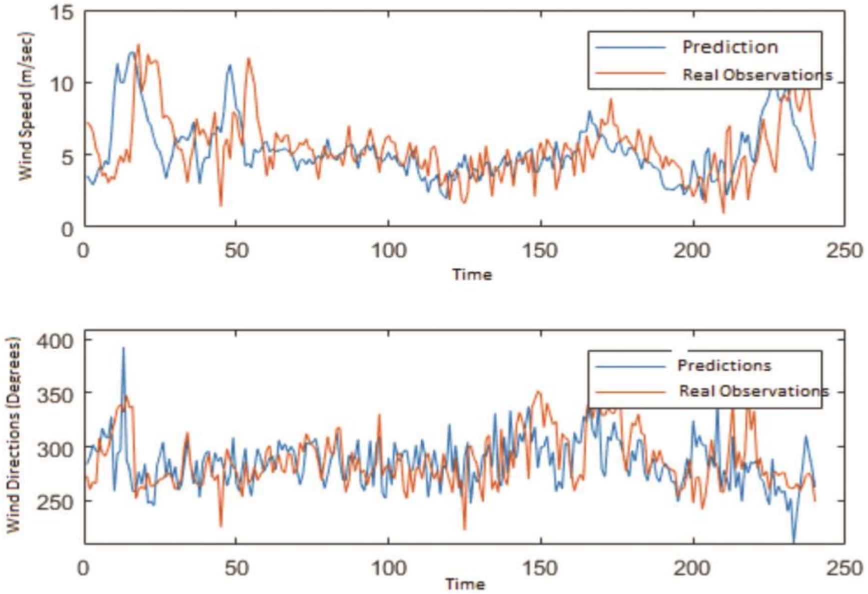

Figure 5. Results of the system that predicts wind direction and speed

3.3. Results of the system that predicts the wave speed and direction

When the results of the system estimating the wave direction and height are examined in Figure 6, it is observed that the system is successful in estimating the wave height. Although some errors were observed without guessing the wave direction, the system predicted the output as values above 360 in some measurements where the actual output value is close to 0, as can be seen at points called 1,2,3,4 and 5 on Figure 6, reflected as if there were high erroneous values.

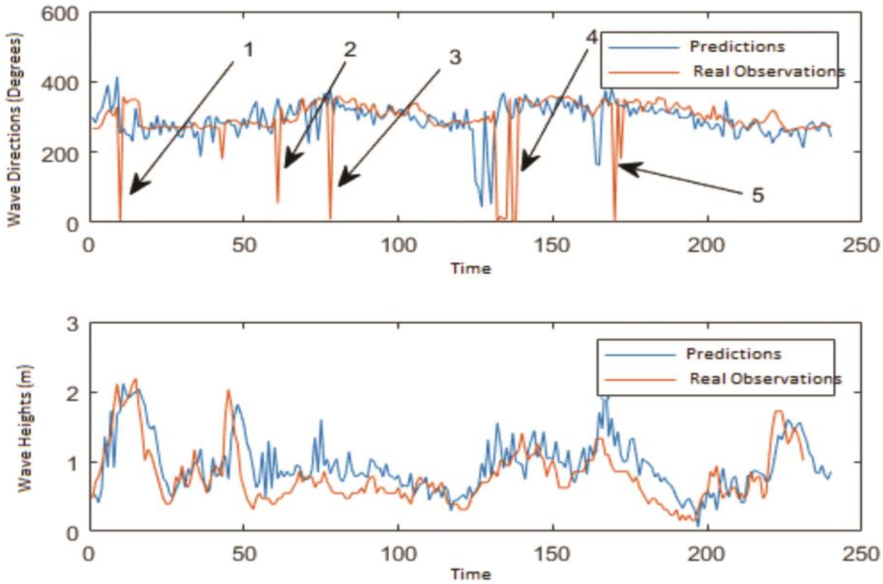

Figure 6. Results of the system that predicts wave direction and speed

However, the estimates at the measurement points in Figure 6 and the required output values are as in Table 2.

Table 2. Examination of the error values of the system that predicts wave direction and height

Observation no.	Prediction	Real observation	Actual error
1	414°	5°	49°
2	353°	27°	34°
3	377°	9°	8°
4	368°	8°	0°
5	380°	1°	19°

4. Discussion

When the performance of the three systems is evaluated in general, it is seen that the system that predicts the wind direction and speed and the wave direction and height estimation systems are successful. It is explained why the values that seem to be errors in direction estimation are obtained. In the current direction and speed prediction system, it is thought that the cause of the high error in some areas of the prediction depends on the sudden change in the direction of the current. The sudden change of direction of current is thought to be caused by the transition of the regional and small currents on the sea surface when a decline in the speed of the wind that directs the current. The information in Figure 4 confirms this. When Figure 4 is examined, it is seen that the wind speed decreases after the 170th measurement and accordingly the sudden changes in the direction of the current occurs.

The general performance of the prediction systems are calculated by means of mean squared error (mse), and regression coefficient (R) using equation 1 and 2.

$$mse = \frac{\sum_{t=1}^{n}\left(e_t - o_t\right)^2}{n} \tag{1}$$

$$R = \frac{\sum_{t=1}^{n}\left(e_t - \bar{e}_t\right)\left(o_t - \bar{o}_t\right)}{\sqrt{\sum_{t=1}^{n}\left(e_t - \bar{e}_t\right)}\sqrt{\sum_{t=1}^{n}\left(o_t - \bar{o}_t\right)}} \tag{2}$$

The mean squared error and regression values of the proposed systems can be seen in Table 3.

Table 3. Accuracy of proposed networks

System	Mean squared error	Regression
Current direction and speed prediction	7.82	0.91853
Wind direction and speed prediction	7.02	0.94828
Wave direction and height prediction	7.82	0.91853

5. Conclusions

Three forecasting systems for estimating weather and marine conditions for ships were carried out using artificial neural networks.

The success achieved in artificial neural network studies related to wind speed and wave height was also obtained in this study. Although the direction estimation part of our study seems to have a high error because it yields degrees, when the result obtained from the artificial neural network exceeds 360 degrees, 360 is actually subtracted from the value. Detailed information related to this situation is given in the findings section.

In general, in this study, artificial neural networks that learn and predict by using historical information were constructed to predict important parameters in terms of ship navigation and the results obtained by the system were satisfactory.

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