POLISH MARITIME RESEARCH Special Issue 2018 S3 (99) 2018 Vol. 25; pp. 99-110
10.2478/pomr-2018-0118

CALCULATION AND MEASUREMENT OF TIDE HEIGHT FOR THE NAVIGATION OF SHIP AT HIGH TIDE USING ARTIFICIAL NEURAL NETWORK

Li Qiang[1],
Yang Bing-Dong[2],
Hong Bi-Guang[1]
[1] Navigation College, Dalian Maritime University, Dalian, Liaoning, China
[2] Pilot Station of Huanghua Port, Huanghua, Hebei, China

ABSTRACT

Accurate tide height is crucial for the safe navigation of large deep-draft ships when they enter and leave the port. We have proposed an accurate forecasting method for the tide heights from the observation data and neural networks, which can easily calculate the tidal window period of large deep-draft ships' navigation through long channels at high tide. Moreover, an artificial neural network is established for the tide height from the observation of tide heights before their current time node. For an ideal forecast, the neural network was optimized for one year with the tide height data of Huanghua Port. In case of large ships, their tidal characteristics of channels for are complex. A new method is proposed for the observation of multiple stations and artificial neural networks of each observation station. When ships are navigating through the port, the tide height is predicted from the observed data and forecast tide heights of multiple observation stations. Thus, a valid tidal window period is secured when the ships enter the port. Comparative analysis of the ship's tidal window period with that of the measured one can lead us to conclude that the forecasted data has a strong correlation with the measurement. So, our proposed algorithm can accurately predict the tide height and calculate the node timing when the ship enters and depart the port. Finally, these results can be applied for the safe navigation of large deep-draft ships when the port is at high tide.

Keywords: Deep-draft ships, neural network, intelligent navigation, multi-observation stations

INTRODUCTION

The draught of large deep-draft ships has been continuously increasing due to their recent demand. The length and depth of the channels should high for the frequent entering and departure of the ships from the ports [1]. For instance, the channel length of the Comprehensive Port area of Huanghua Port [2] and Lanshan Port in Rizhao [3] reach 60.5 and 48.9 km, respectively. At certain ports, the tide timing for a ship can be obtained from the tide table. However, in case of a long channel with a high variation of tidal changes, tide table cannot calculate the tide timing when the ships enter or deport and under keel clearance. At the same time, it will also calculate the tide height during the high tide time period which meets the conditions of entering the river fail and the requirements of the ship's entering the port at high tide. This dramatically affects the efficiency of large-scale deep-draft ships when entering the port, reduces the passage capacity of the port channel, and affects the navigation safety of the ships.

To date, only theoretical research is conducted on the water level when the ships enter the port at high tide and other related plans. Furthermore, this topic has become one of the hot topics for researchers in the field. Tang et al.

investigated the adaptability of a 400 thousand dwt bulk cargo ships with the water depth when the ships enter Dongjiakou Port. They thoroughly investigated the node time of ships while entering the ports by the tide. Moreover, they also proposed methods for keel clearance of large ships from the observation of tidal records at Dongjiakou Port [4]. Zhang et al. proposed a method for the depth calculation of artificial long channel. Actually, they proposed this method from the tide forecast at a single station and the characteristics of channels in Lansshan Port District of Rizhao Port. However, their method cannot adequately differentiate in tide heights of different channel sections [3]. On the other hand, Huang et al. have proposed another method for the calculation of tide height at Yamen Channel in Jujiang. The value of tide height is required for the ships when they enter the port and the channels have high tide. This method can rarely be applied to those ports which have small differences in the tide period but large differences in the tide height [5]. In 2012, Xu et al. proposed a multi-station joint method for the calculation of tide height, especially, when the ships enter the port at high tide in the tidal estuary of the long channel [6]. It can be observed from the trial calculations that this method still needs to be optimized such as for the optimal process of entering the port at high tide and the optimal tide height for each tidal process. Furthermore, to get the tide height when the ships enter the port at high tide corresponding to different cumulative frequencies. So, the calculation process is realized by the program, but the results are not intuitive enough. On the other hand, this method can only be applied to those channels which have constant tide height, means cannot consider the different tide heights in different sections of the long channel.

The above analysis led us to conclude that for the safe navigation of large deep-draft ships and to clear the ports, accurate measurement of the tide height is required. The tide height is primarily related to the ship's navigation time while entering the port. Secondly, it is related to the mileage of the channel and the accuracy of the tide height forecast. In this paper, we are using the feedback neural network algorithm and the measured data of the tides in the port, to achieve the goals in the following two aspects: (1) using the measured tidal data to forecast the tide at the position of each station; (2) calculation of tidal window of the ships when entering the port.

MODEL FOR THE CALCULATION OF TIDAL WINDOW

Draughts of ships have been continuously increasing as the size of ships becomes larger and larger. The draught of 200 thousand dwt bulk cargo ship has reached 18.3 m. For a 300 thousand bulk cargo ship, its draught has reached to 21.5 m. In case of 400 thousand dwt ships, their draughts have reached 22 m. The high number of draught means, we need a deeper depth of channel for the safe navigation of ships. However, the depth of the channel cannot be increased unrestrictedly during the construction of channels for large ships due to the following three reasons.

1. High-depth channel requires high construction and maintenance cost;
2. There is enough time for large bulk cargo ships to wait for the tide raise as these ships have a longer sailing period. Moreover, there are more chances that they can enter the port at high tide;
3. A number of large ships that navigate through the port is limited. To deepen the depth of channel are waste of resources.

Therefore, the constructors are trying to employ those methods which can allow the ship's navigation through the channels at high tides to lower the depth of channels. When ships navigate through this type of channels, the tide height must reach a certain level to allow safe navigation through the port. In case of insufficient tide height, the short of under keel clearance will cause the risk of ships being stranded and also increase the difficulty of handling the ships. The time period for the appropriate tide height, where the ships can navigate through the port is called tidal window. Obviously, the tidal window is related to the draught and speed of ships, the tide height, and the under-keel clearance. Traditionally, the tidal window can be calculated from the typical tide curve method [7]. This method does not consider the effects of water level fluctuation, caused by meteorological factors, so, cannot be applied to those ports which have prominent water level fluctuation.

When a ship navigates, then its velocity depends on the following factors such as depth of water, navigation obstacles, and the distance from the port. Thus, the velocity tends to be not a fixed value [8, 9]. In this study, the velocity of the ship at time t is presented by function V (t) ($t \subset [t_0,\ t_1]$), t0 and t1 are the nodes time while navigating through the port at high tide at the beginning and end, respectively. The location of the ship in the channel can be expressed by the following equation:

$$M(t) = \int_{t_0}^{t} V(t)\ dt \tag{1}$$

When the ships navigate in the port, they produce water pressure which led to ship squat. The higher the velocity, the higher the amount of the ship squat . In addition, other factors such as tidal current, waves, the heel and trim of the ship are also responsible for the ship squat. To avoid ships from stranded and touching the bottom of the sea, a certain amount of abundant depth between the keel of the ship and the bottom of the sea is required. This extra depth is called under-keel clearance.

When the ships navigate through the channel, the water depth is required for the draught of the ship and the under-keel clearance. The following conditions are required for the safe navigation of ships through the port.

$$\begin{cases} D_T \geq d + UKC \\ D_T = D_0 + T \end{cases} \quad (2)$$

where D_t is the actual water depth; D_0 is the deigned depth; T is the tide height at high tide; d is the draught of the ship; UKC is the under-keel clearance.

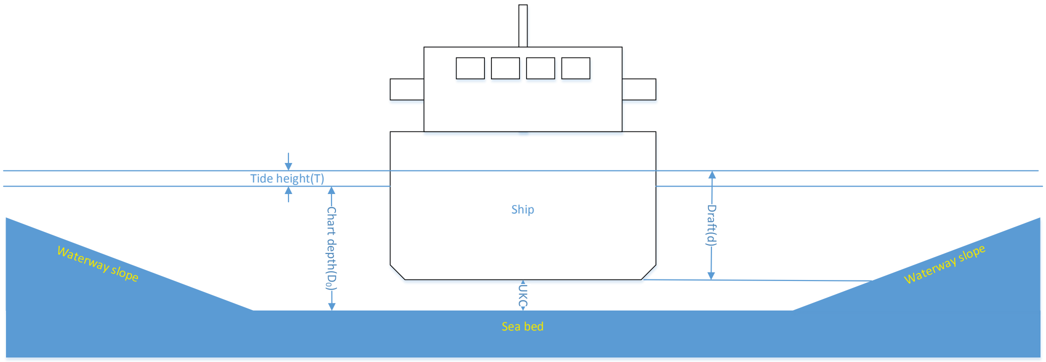


Fig. 1. The UKC during the ship's traversing the channel

Figure 1 shows the relation between water depth, tide height, draught, and under-keel clearance when the ships navigate through the channel. From Figure 1, we can see that the tide height, required for the ships' navigation, has a direct relation with the draught, the under-keel clearance, and the actual water depth of the channel. The time period of tide height in which large deep-draft ships can enter the port is called tidal window. So, the actual tide height for the ship's location should meet the following requirements as specified in Equation 2.

Under-keel clearance is a vital factor which affects the safe navigation of the ships through the port. The calculation method for the UKC, has already been reported [10]. Once UKC is fixed, then the tide height can determine and ensure the safe navigation through the channel of ships. For the tidal window, the tide height in the port should be precisely calculated when the ship navigates through the channel at high tide. In case of the small area of the port, the tide heights remain the same through the whole channel area and the ships can navigate through it at high tide. On the other hand, the larger port has highly fluctuated tide heights at different locations for the ships' navigation through at high tide. In this study, we propose a method for the prediction of tide height which is based on the measurement of tide height combined with neural network and calculate the length of the tidal window when the ship navigates through the port at high tide.

TIDE HEIGHT MEASURING SYSTEM

STRUCTURE AND LOCATION OF OBSERVATION STATIONS

We have selected the Huanghua Port for this research project. Observation stations were located at different positions of the channel of Huanghua Port to record tidal data and calculation of forecasting the tidal window period. The tide consists of astronomical tide and water level fluctuation, caused by meteorological factors. The structure of the tide height measuring system is shown in Figure 2. This structure consists of a database center, observation stations, and transmission system.

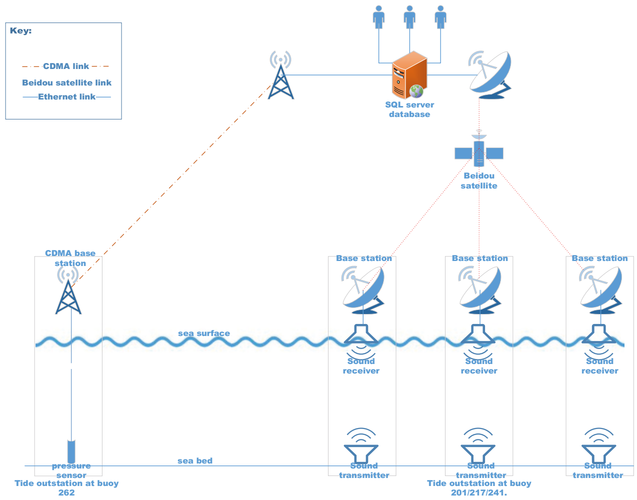


Fig. 2. Structure of the tide height measuring system

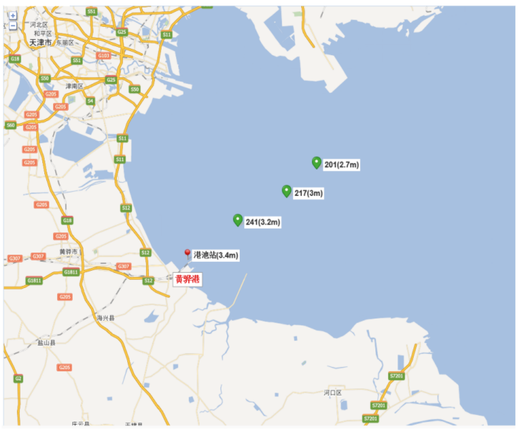


Fig. 3. Locations of observation stations

Each observation station is made up of one onshore tide height and three offshore buoy observation stations. The location of each observation station is presented in Figure 3. Shore-based tide height observation station is adapted to set up the onshore tide height observation station. Pressure-based tide gauges are used to detect the tide height, and the real-time transmission via the cellular network.

Offshore observation stations are located at channel mileage 22+000 (Buoy 241#), 44+000 (Buoy 217) and 60+000 (Buoy 201). In this work, we have employed the Beidou satellite communication technology to realize the real-time online data transmission.

The onshore tide height observation station uses a water level recorder which is equipped with a CDMA mobile data communication device and a solar power supply system. This is used to get the real-time observation and telemetry of tide height data, and uninterrupted 24 h recording and real-time telemetry of water level data.

On the other hand, the offshore buoy observation station uses an acoustic communication device which is part of a pressure-based tide gauge, mounted at the bottom of the sea and transport the monitoring data of real-time pressure to the buoy. All observation data can be collected at the buoy and subsequently transmitted to the onshore data (receiving center) via the Beidou Satellite Communication Method.

The onshore data receiving server automatically receives the transmitted data and forward to each user (client) via broadband network or mobile cellular network.

DATABASE CENTER AND USER INTERFACE

In this work, the MySQL Database is used to manage and store all the data. The data was processed by decryption, analysis, format conversion, screening, filtering, and other online processes. The results generated from these processes were then transferred to the database.

The data management program mainly triggered the instruction of looping at a time interval or by releasing the port data in a background execution mode. The environment management program of the observation station is designed to realize the browsing, management and analysis of the corresponding environment of the onshore tide height observation station. The program is constructed in B/S architecture to display the real-time in the map, station parameters configuration, graphics displaying, and tabular displaying of the station and environment data. Moreover, it is a convenient source for the users to get information from the observation stations at any time.

The online data sharing system is named as "Huanghua Port Channel Hydrology Online". Function modules of the display system, user login at the welcome page, the observation station, and displaying a map of tide height at the homepage, tide height data, and displaying of tidal current data have been observed. The online data sharing system consists of functions or sections of the welcome page, functions of the homepage, user management, tidal data display, and tidal current data display. The user interface is presented in Figure 4.

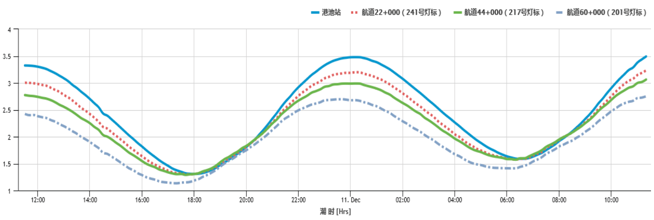


Fig. 4. Interface of database center client

A THEORETICAL MODEL FOR WINDOW PERIOD, BASED ON FEEDBACK NEURAL NETWORK

Recently, with the development of artificial intelligence, many researchers have reported the forecasting of the tide at the ports, using the artificial neural network. In Reference [11], a tide height prediction model is established from the proposed algorithm for the improved and practical genetic neural network tide height prediction. Reference [12] explains the tide height prediction model, using the artificial neural network. A neural network forecast model for storm surge elevation is established, based on high and low tide [13]. Moreover, the tide height is considered for the measuring process under abnormal weather conditions as a research object [14]. Artificial neural network BP algorithm is used as a forecasting tool due to the non-stationary time series of the tide height under these conditions. An artificial neural network model is established from the meteorological data database to predict the water level fluctuation phenomenon in the tidal process. Previously, neural networks have been used to predict the tide on a weekly basis [15]. Recently, a backward-propagation neural network application has been proposed for long-term tide prediction [16]. Moreover, artificial neural networks have also been used for the improved forecasting of ocean tide [17]. So, these studies focus on the long-term forecast of tides at a port, however, the accuracy of the forecast is limited due to the long forecast time. For the long artificial channel, the tidal change within the length of the channel is more notable. An accurate short-term tide forecasting method which involves multi-observation stations is required, to forecast tidal window period for the safe navigation of ships through ports at high tide [18].

COMPUTING ARCHITECTURE FOR TIDAL WINDOW PERIOD BASED ON ARTIFICIAL NEURAL NETWORK

In order to study the ship tidal window forecasting system, having four observation stations, it is necessary to use the tide height signals (measured by the sensors of each observation) for the establishment of a neural network. In this study, we used an artificial long channel which requires four independent observation stations. There is some minor relevance among the tide height information, collected by each observation station [19]. During the prediction process of tide height, four artificial neural network architectures are established for the corresponding tide height prediction of four observation stations. Finally, this paper establishes a calculation system for tidal window period when the ships navigate through the port at a high time (see Figure 5). This system consists of a sensor, database, neural network prediction system, and a tidal window calculation processor.

There are four sensors which are located in Buoy 201, Buoy 217, Buoy 241, and Buoy 262, as shown in Figure 5. The recorded data of these sensors are transmitted to the data processing center, namely the database, via CDMA or Beidou Satellites Communication Method. Artificial neural networks ANN1-ANN4 were deployed in the above four observation stations to predict the tide heights [20]. Predicted results combined with the location information of four observation stations were transferred to the tidal window calculation processer for the calculation of tidal window (when the ships navigate through the ports).

for the network. This process does not terminate until the error output of the network reduced to an acceptable level, or the learning time period or the time of learning practice reached the pre-set level.

In this work, we used the forecast process and input data were collected from 00:00 to 16:00 each day, while the tide height data which is collected from 17:00 to 24:00 is used as the output data. The number of hidden layers is set to 1, the number of hidden layer nodes 25, the learning rate of 0.1, and the target value is set to 0.001. The activation function of the hidden layers is a bipolar Sigmoid type function while the transfer function of the output layer is a linear function [23]. The observed data of the Huanghua Port is collected from 1st May 2017 to 30th April 2018, so, a total of 365 groups data was processed. The first 300 groups were used as training data, and the remaining 65 groups were used as verification data. The forecast results for the verification data is shown in Figure 6.

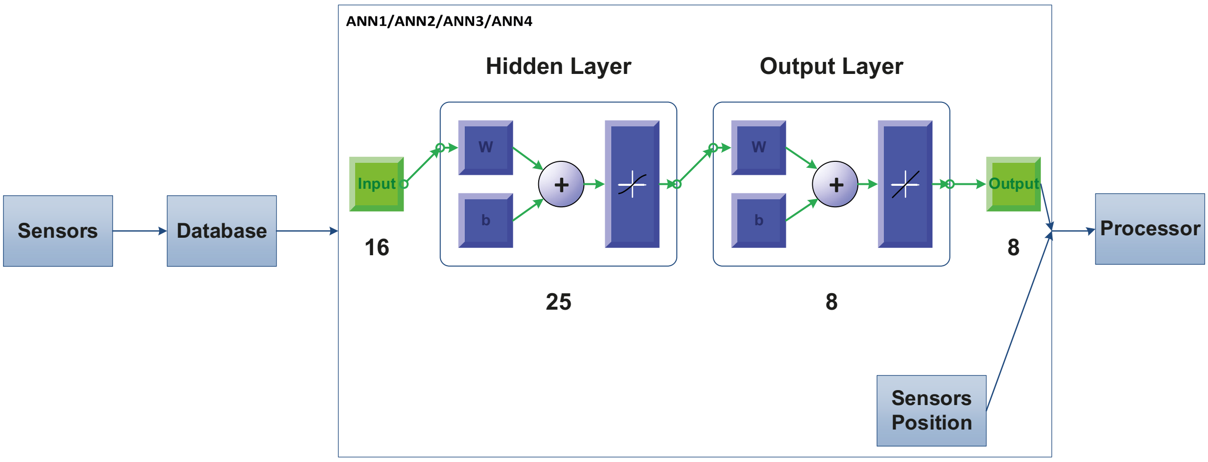


Fig. 5. Architecture for window period calculation model based on the feedback of neural network

TIDE HEIGHT FORECAST

The algorithm of feedback neural network is consisting of forwarding propagation of signal and backward propagation of error. In the forward propagation, the input samples are imported from the input layer which is processed by the hidden layers (layer-by-layer) before being exported to the output layer. If the real output of the output layer is not equal to the expected output, then the propagation process will switch to the backward propagation process [21]. In the backward propagation of error, the output error propagates backwardly through hidden layers (layer-by-layer) in a certain manner. Moreover, this error can be assigned to all the neurons of every single layer which generate the error signal of each layer. From this error signal, we can correct the weight of each neuron. This adjustment of weight in each layer occurs repeatedly, during the forward propagation of signal and backward propagation of error [22]. The continuous adjustment of weight is also a learning and training process

DATA NORMALIZATION AND CRITERIA FOR THE ANNS PERFORMANCE

All data of the input layer are normalized to a range from 0 to 1 by the function:

$$\bar{y}_i = \frac{y_i - y_{\min}}{y_{\max} - y_{\min}} \quad (4)$$

Where $\bar{\ }$ is the value of data after normalization, y_i is the value of data before normalization, $y_{\max}$ is the maximum and $y_{\min}$ is the minimum of all the hourly tide height respectively.

The ANNs performance is assessed in terms of the root mean square error(RMSE), the correlation coefficient R and mean absolute error(MAE).

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(y_i - y_i^0)^2}{n}} \quad (5)$$

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|y_i - y_i^0\right| \quad (6)$$

$$\mathrm{R} = \frac{\sum_{i=1}^{n}(y_i^0 - \overline{y}^0)(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(y_i^0 - \overline{y}^0)^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}} \quad (7)$$

Where y_i^0, y_i are observed and predicted tide height. $\overline{y}^0$, $\overline{y}$ are mean values of tide height observed and predicted respectively.

Figure 6 shows the forecasted tide height and the observed tide height data of four observation stations, respectively. The forecasted tide height data measures the tide heights from 17:00 to 24:00 each day. The bigger picture in Figure 6 shows the tide heights per hour from 25th February to 30th April (1560 h in total) while the smaller picture represents the observed and forecasted tide height data per hour from 25th-28th February (72 h in total). The input and forecasted data are recorded every day from 0:00 to 16:00 and 17.00 to 24.00, respectively.

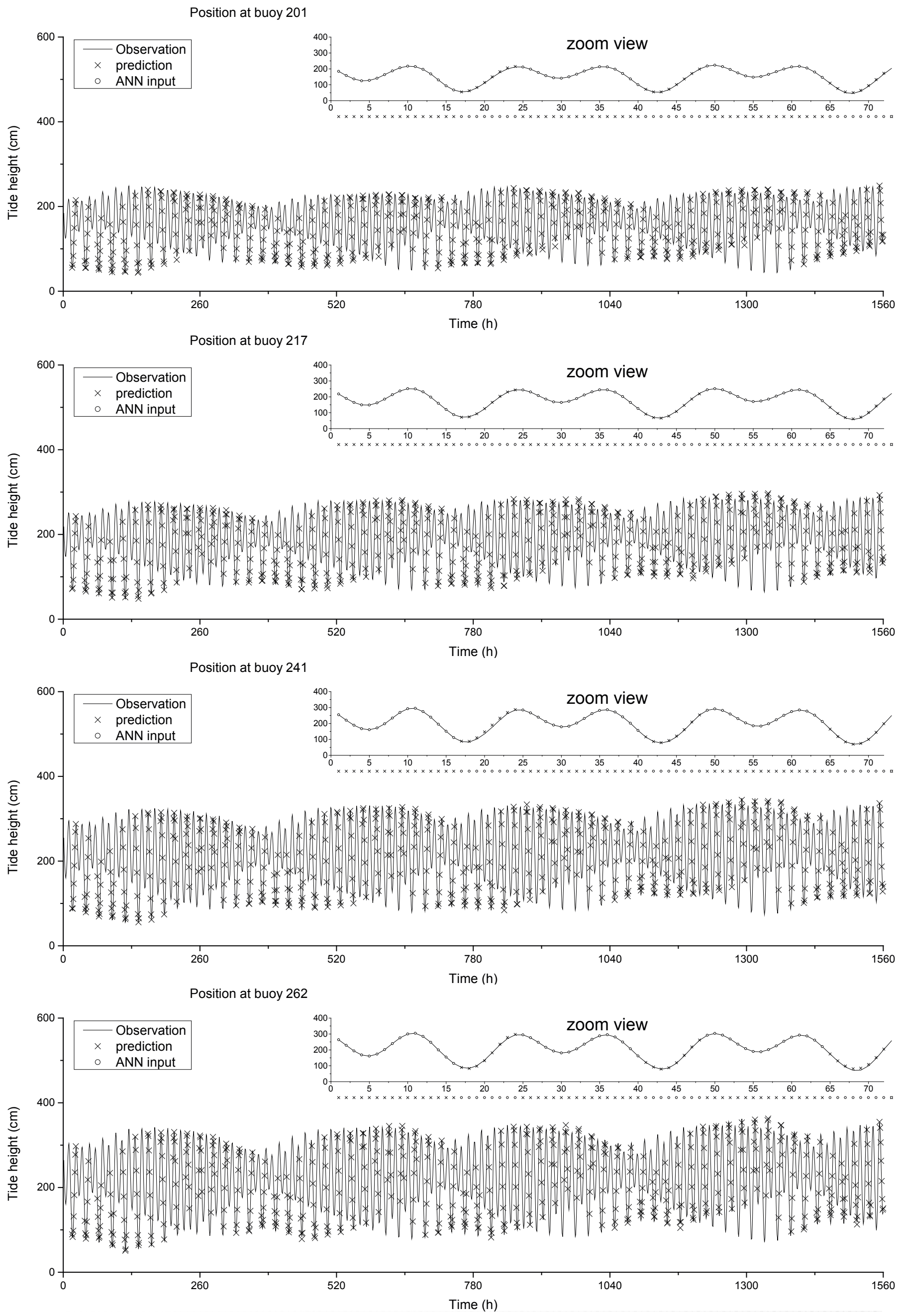
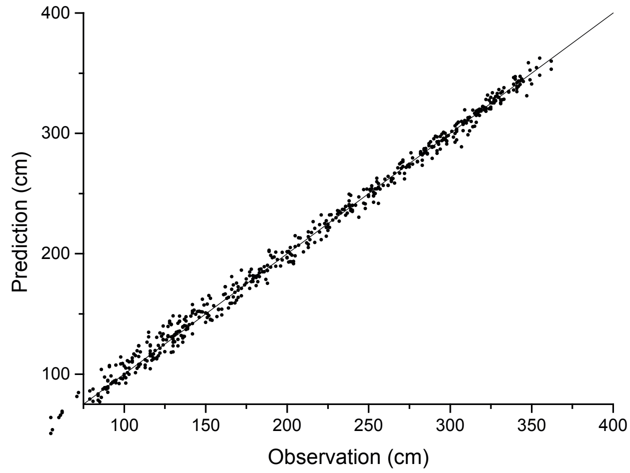
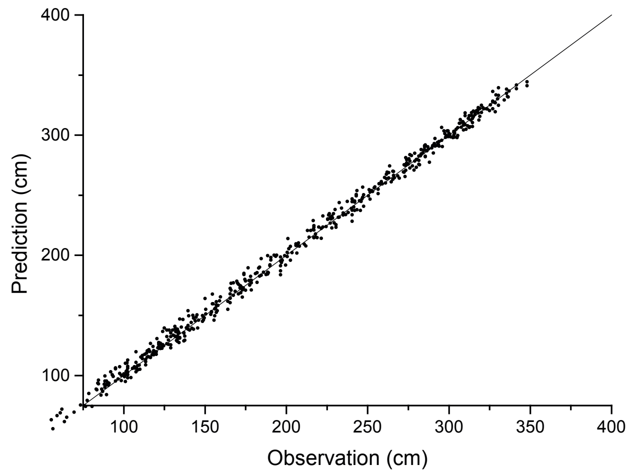
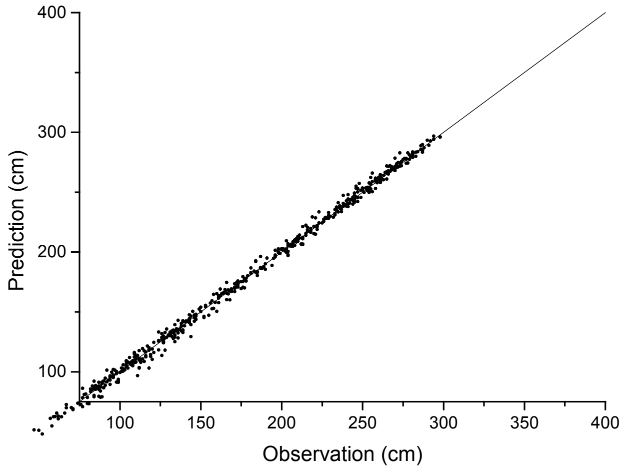


Fig. 6. Observed tide height and forecasted tide height results, obtained from the verification data in 65 days

The forecasted tide height results of four locations in Huanghua Port from 17:00 to 24:00 using four artificial neural networks with identical architecture are shown in Figure 6. Analysis of this Figure led us to conclude that all four neural networks can forecast the tide height well. However, the shorter the distance of the observation station to the port, the higher the difference between the tide heights at high tide and low tide. The scatter plots of the four neural networks are shown in Figure 7. The error of the forecasted results is listed in Table 1. In Table 1, the linear correlations of forecasted results for the next hour, based on the analysis of data recorded in the past 16 h are 0.9999, 0.9999, 0.9998, and 0.9997, respectively. This indicates that the forecast results for the next hour, generated from the four neural networks are very ideal. Moreover, the location which has the higher difference between the tide heights at high tide and low tide is also recorded, which has a lower linear correlation between the measured and the verification results. The linear correlations of the forecasted results for the next 4 h are 0.9993, 0.9993, 0.9987, and 0.9977, respectively, which are slightly lower than that of the linear correlations in the next hour. The linear correlations of the forecasted results for the next 8 h are 0.9982, 0.9984, 0.9981, and 0.9973, respectively, which are again lower than that of the linear correlations of the forecasted results for the next 4 h. This indicates that the accuracy of the forecasted results decreases with the increase of forecast time, but still maintains a satisfactory level.







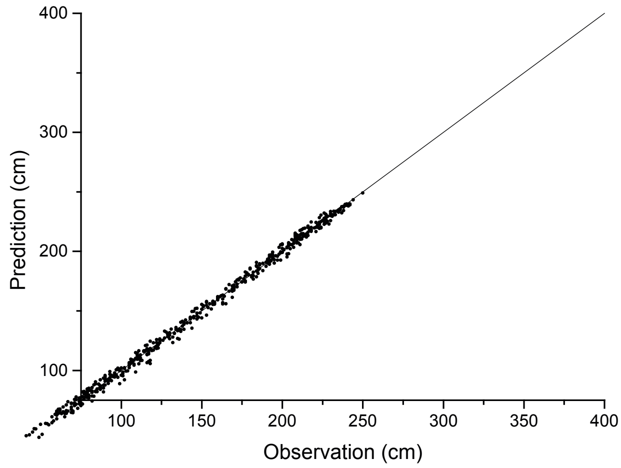


Fig. 7. Scatter plots of observed data

The root-mean-square error significantly increases with the increase of forecast time. The position error of Buoy 201 increases from 1.2 to 3.4 cm; the position error of Buoy 217 increases from 1.0 to 3.8 cm; the error for the position of Buoy 341 increases from 1.6 to 5.0 cm; and the error for the position of Buoy 262 increases from 2.2 to 6.2 cm. Similarly, mean errors for the four places change in the same manner. Our results and discussion led us to conclude that the prediction accuracy of the neural network with the channel of the port is smaller than that of the outside of the port due to the large difference between the tide heights at high tide and low tide. There may be other factors as well such as damming caused by the breakwater.

Tab. 1. RMSE, MAE and R for different position and different time using ANN

		1hr	2hr	3hr	4hr	5hr	6hr	7hr	8hr
Buoy 201	RMSE	1.2	1.8	2.3	2.6	2.8	3.1	3.3	3.4
	MAE	0.9	1.4	1.7	2.0	2.2	2.4	2.5	2.6
	R	0.9999	0.9997	0.9995	0.9993	0.9990	0.9987	0.9985	0.9982
Buoy217	RMSE	1.0	1.6	2.1	2.7	3.1	3.5	3.7	3.8
	MAE	0.8	1.2	1.6	2.0	2.3	2.6	2.8	2.8
	R	0.9999	0.9998	0.9996	0.9993	0.9990	0.9987	0.9985	0.9984
Buoy 241	RMSE	1.6	2.6	3.6	4.4	4.8	5.0	5.1	5.0
	MAE	1.4	2.1	2.8	3.4	3.7	3.9	3.9	3.9
	R	0.9998	0.9995	0.9991	0.9987	0.9985	0.9984	0.9982	0.9981
Buoy 262	RMSE	2.2	3.5	4.8	5.8	6.3	6.4	6.4	6.2
	MAE	1.7	2.6	3.5	4.3	4.8	4.9	4.9	4.8
	R	0.9997	0.9992	0.9984	0.9977	0.9973	0.9972	0.9972	0.9973

CALCULATION OF TIDAL WINDOW PERIOD

In this paper, we have verified the accuracy of the tidal window for the ships. So, the actual tidal window periods for the ships with a draught of about 18 m were observed by the observation system from 20-27th May 2017. The earliest node time and the latest tide time node of each ship, which navigates through the port at high tide were recorded. The tidal window periods were calculated with the help of neural networks. The forecasted and measured results were compared to verify the accuracy of the model.

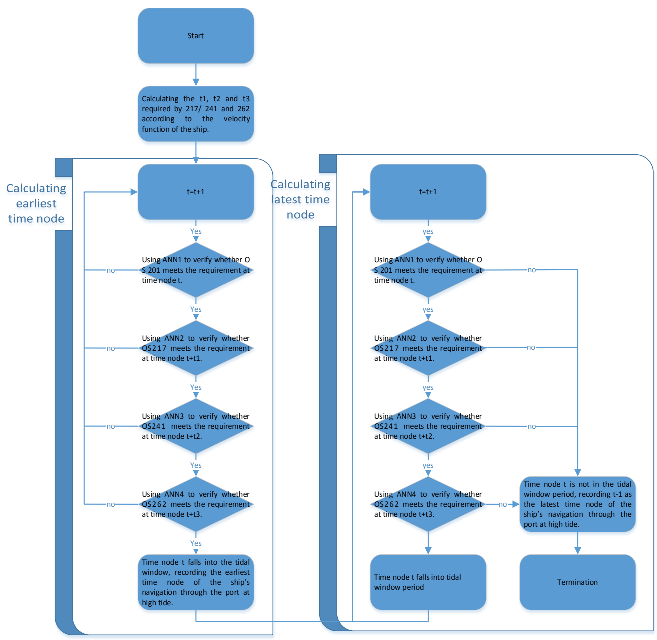


Fig. 8. Computing diagram for the tidal window period

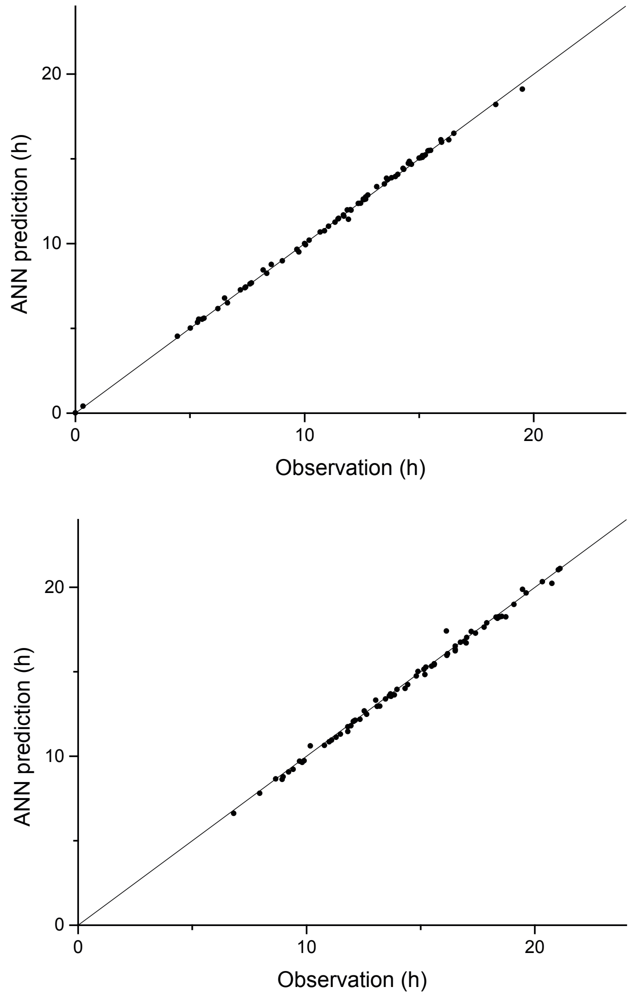


Fig. 9. Scatter plots of measured data

The calculated and observed data of the earliest and latest time nodes during 74 ships, when approaching the port at high tide was compared. The compared scatter plots are shown in Figure 9. When the ships navigate through the port, then the root-mean-square and the mean errors of the earliest time node at high tide are 0.13 and 0.08 h, respectively, while the linear correlation coefficient is 0.9995. Similarly, the root-mean-square and the mean errors of the latest time node at high tide are 0.24 and 0.17 h, respectively, with a linear correlation coefficient of 0.9980. The linear correlation coefficient of the latest time node is lower than that of the earliest time node. The reason behind this is, latest time node is later than the former which makes longer the forecast time of the required neural network. The mean error is 0.17 h, which is approximately 10 minutes. So, it fulfills the requirements of ships for entering and exiting the port. The results and discussion of this work led us to conclude that our proposed method (based on the measured results combined with neural network forecasting method) can accurately forecast the navigation of ships through the port at high tide. In addition, our simulations satisfy the safety requirements for the ship's navigation through the port. Parameters of each ship and the forecasted and measured values of its tidal window period are listed in Table 3.

Tab. 2. RMSE, MAE and R for the earliest time node and latest time node, using ANN.

	the earliest time node	the latest time node
RMSE	0.13	0.24
MAE	0.08	0.17
R	0.9995	0.9980

Tab. 3. Parameters of each ship and the forecasted and measured values of its tidal window period

Ship' name	LOA	Draft	Date	Measured value	Calculated value using ANN
FPMC B KINGDOM	299.7	18.21	2017-5-27	15:13-17:00	15:11-16:42
HEBEI CHALLENGER	295	18.31	2017-5-30	18:21-19:05	18:12-18:59
ARIADNE	299.97	18.31	2017-5-31	19:30-19:37	19:07-19:40
LAVENDER	292	18.14	2017-6-26	15:23-18:18	15:28-18:14
MOUNT AUSTIN	292	18.04	2017-7-1	04:27-09:25	04:32-09:13
RINI	292	18.32	2017-7-4	10:12-12:03	10:12-12:03
COTSWOLD	292	18.3	2017-7-7	12:36-16:31	12:36-16:31
LOWLANDS SUNRISE	291.98	18.23	2017-7-12	15:00-19:28	15:03-19:53
LEOPOLD OLDENDORFF	299.97	18.11	2017-7-13	15:09-20:20	15:05-20:20
AM GIJON	292	18.04	2017-7-14	15:30-21:02	15:30-21:02
PERCIVAL	291.8	18.28	2017-7-20	10:00-13:41	10:00-13:41
MINERAL BELGIUM	289	18.1	2017-7-22	11:28-17:54	11:28-17:54
STAR MARISA	299.88	18.3	2017-7-22	12:00-16:45	12:00-16:45
CSK FORTUNE	289	18.1	2017-7-27	15:04-20:45	15:04-20:14
PHILIPPOS A	291.8	18.04	2017-7-29	15:59-21:06	15:59-21:07
NAVIOS FANTASTIKS	288.93	18.15	2017-8-23	13:35-18:44	13:51-18:15
NAVIOS AZIMUTH	292	18.3	2017-8-24	14:32-18:22	14:44-18:10
PACIFIC VISTA	295	18.12	2017-8-29	16:31-21:15	16:30-21:20
MINERAL EDO	299.94	18.26	2017-9-4	12:21-16:08	12:22-17:25
KSL SALVADOR	292	18.3	2017-9-6	13:29-17:01	13:31-17:02
CAPE AUSTRALIA	299.88	18.08	2017-9-24	14:20-18:28	14:23-18:15
FPMC B IMAGE	299.7	18.2	2017-9-25	15:16-18:33	15:14-18:17
CLEAR HORIZON	300	18.26	2017-9-29	07:41-09:42	07:41-09:42
ARIADNE	292	18.22	2017-10-6	13:09-16:11	13:22-16:04
FRONTIER BONANZA	291.97	18.22	2017-10-7	13:37-16:31	13:46-16:14
EDWIN	291.8	18.3	2017-10-11	16:18-18:24	16:07-18:15
ANANGEL VOYAGER	292	18.22	2017-10-12	05:32-09:13	05:32-09:04
MARLENE OLDENDORFF	299.88	18.12	2017-10-14	07:37-12:05	07:37-12:05
EHIME QUEEN	291.98	18.3	2017-10-19	12:46-15:11	12:52-14:50

Ship' name	LOA	Draft	Date	Measured value	Calculated value using ANN
OU MAY	295	18.06	2017-10-24	14:18-17:47	14:26-17:38
IMPERIUS	292	18.3	2017-10-28	07:26-08:39	07:26-08:39
PROSPER SUNWAITO	299.7	18.27	2017-10-31	10:41-12:08	10:41-12:08
RAIATEA	292.00	18.3	2017-11-1	11:28-13:06	11:28-12:57
GIANT ACE	291.97	18.3	2017-11-8	15:25-16:55	15:29-16:48
AFALES	292	18.23	2017-11-18	12:40-14:49	12:45-14:45
OCEAN COMMANDER	289	18.08	2017-11-19	12:34-15:36	12:37-15:27
ANTONIS ANGELICOUSSIS	292	18.05	2017-11-27	06:38-10:10	06:30-10:37
GUANG LI HAI	299.88	18	2017-11-28	07:24-11:18	07:24-11:07
ANDAMA	292	18.27	2017-12-1	11:03-12:38	11:01-12:29
LAKE DESPINA	291.98	18.23	2017-12-4	12:37-14:26	12:37-14:14
SEALINK	292.1	18.08	2017-12-19	12:40-15:29	12:37-15:20
STELLA CHARLENE	292	18.3	2017-12-20	14:40-15:09	14:41-15:09
SILVER ROAD	290	18	2017-12-25	05:01-08:56	05:01-08:38
BERGE ATLAS	288.93	18.16	2017-12-30	09:40-11:49	09:40-11:28
MINERAL HOKKAIDO	288.93	18.15	2018-1-2	11:43-13:58	11:37-13:57
KN AMETHYST	300	18.3	2018-1-2	12:27-13:42	12:23-13:33
CAPE INDIA	299.88	18.1	2018-1-5	13:58-16:31	13:57-16:19
FEG SUCCESS	292	18.19	2018-1-12	09:02-11:06	08:59-10:57
DAWN HORIZON	295	18.19	2018-1-15	11:42-13:28	11:41-13:23
SOUTHERN CROSS DREAM	292	18.11	2018-1-16	11:55-14:19	11:26-14:01
TAURUS	292	18.32	2018-1-18	14:34-14:53	14:51-15:01
LONDON COURAGE	299.94	18.1	2018-1-24	05:23-07:57	05:32-07:48
PAN DREAM	291.8	18.25	2018-1-27	08:21- 09:49	08:15-09:38
CAPE ISLAND	288.88	17.85	2018-1-27	06:31-10:47	06:47-10:38
MOUNT HERMON	292	18.15	2018-1-29	09:40-11:57	09:39-11:48
HEBEI TRIUMPH	295	18.27	2018-1-31	12:02-13:38	11:58-13:34
CSK GENERATION	292	17.7	2018-2-1	00:20-15:36	00:25-15:25
K VICTORY	292	18.15	2018-2-4	15:09-17:24	15:11-17:17
GOLDEN HORIZON	299.7	18.01	2018-2-8	05:37-08:59	05:36-08:47
CHINA HARMONY	295	18.09	2018-2-11	08:33-11:29	08:46-11:18
C H S SPLENDOR	289.00	17.55	2018-2-11	00:00-13:13	00:01-12:58
GREAT DYNASTY	295	18.28	2018-2-22	05:20-06:49	05:21-06:37
CAPE MARS	289.00	18	2018-2-26	07:12-11:00	07:16-10:51
SHIBUMI	292	18.25	2018-3-1	11:52-13:51	11:59-13:38
CAPE VICTORY	292	18.32	2018-3-3	13:48-15:36	13:53-15:28
LONDON COURAGE	299.94	18.04	2018-3-11	06:13-9:54	06:10-09:44
ALPHA MILLENNIUM	289	17.98	2018-3-13	08:12-12:21	08:27-12:11
TIAN LU HAI	289	18.2	2018-3-14	11:20-12:32	11:16-12:41
JABAL NAFUSA	290.49	17.82	2018-3-17	11:29-16:09	11:29-15:58
CAPTAIN PETROS H	289.98	17.68	2018-3-30	09:45-15:14	09:30-15:16
OCEAN ROAD	291.91	18.19	2018-4-26	10:03-11:49	09:56-11:45
LOWLANDS PROSPERITY	292	18.17	2018-5-1	14:04-17:13	14:05-17:23
THEODOROS P	292	18.3	2018-5-3	15:57-18:20	16:07-18:12
GREAT SUI	291.97	18.1	2018-5-12	10:52-13:02	10:45-13:19

CONCLUSIONS

An accurate calculation method for the tide height is required for the safe navigation of ships and efficiency of the port during long length channels having complicated tidal. In this work, we have proposed an accurate method from the measured results combined with neural networks for artificial long channels to forecast the tide height. An intelligent calculation model for the ship's navigation through the port at high tide is subsequently proposed. The tidal data observed for 300 days is used as the training data to train the network, and the data observed during the following 65 days is used for the verification of the proposed method. The minimum linear correlation coefficient was 0.9973, which is at an ideal level. In addition, the tidal window periods for the ships with a draught of about 18 meters, arrived at the port in one year are calculated and observed. Moreover, the linear correlation coefficient of 0.9980 indicates that our proposed method in a high tide can accurately and intelligently navigate the large deep-draft ships at the port. Finally, this research can be employed for the navigation of large ships through the port at high tide and port management.

REFERENCES

1. Bao-chun, L., Da-qi, Z.: Analysis of Safety Measures for the Entry of Large Deep Draught Ships Under the Same Tide. *China Water Transport,* 2016, 9(1), Pp. 34-35.

2. Jin-zhong, Z., Song-shan, Y.: Analysis of Design Water Level for Huanghua Port 200 000 DWT Channel. *Port Engineering Technology*, 2016, 53(6), Pp.14-16.

3. Ning, Z., Tie-zheng, S.: Analysis of Method of Calculating the Depth of Waterway by Segmented Artificial Long Channel. *China Water Transport,* 2017, 17(7), Pp.190-194.

4. Cun-bao, T., Liang, Z., Jing-xian, L.: Water Depth Investigation for Dongjiakou Port Receiving 400 000t Carrier by Tide. *Navigation of China,* 2017, 40 (2), Pp. 60-64.

5. Zhi-yang, H., Yuan, X.: Research and application of a new method for the calculation of ridable high tide level. *The Ocean Engineering,* 2017, 35(2), 2017, Pp. 83-88.

6. Yuan, X., Zhi-yang, H., Hong-feng, G.: On riding high tide level in a long waterway at a tidal estuary. *Port & Waterway Engineering,* 2011, 6(5), Pp.1-6.

7. Zhi-yang, H., Jian-feng, Z.: Research and application of ridable tide level considering the effect of tide current. *The Ocean Engineering*, 2018, 36(3), Pp.104-109.

8. Feng, M., Hong-bo, C.: An analysis for entering a port considering tide based on high-precise instantaneous depth model. *Science of Surveying and Mapping,* 2012, 37(4), Pp. 40-42.

9. Ning, M., Yan, C., Jun, W.: Design throughput capacity simulation for multi-shallow waterway. *Journal of Dalian Maritime University*, 2011, 37(1), Pp. 63-67.

10. Qing-long, H., Zu-xu, G., Peng-fei, Z.: Research on the Under-Keel Clearance and Ship Squat for VLCC Navigating within Port Area. *Marine Technology*, 2013, 17(5), Pp.2-5

11. Yi, L., Yang, Y.: A Tidal Forecasting Algorithm Based on Genetic Neural Network. *Electric Power Science and Engineering*, 2015, 31(8), Pp.1-7

12. Ze, G., Zhi-gang, L., Yan, Z.: Tide Prediction in Tidal Power Generation by Harmonic Analysis and Artificial Neural Network. *Journal of Hebei United University (Natural Science Edition)*, 2014, 36(1), Pp. 84-87.

13. Ru-yun, W., Lei, L., Fei, Z.: Neural network forecast model of storm surge elevation based on high tide and low tide. *Marine Forecasts*, 2014, 31(6), Pp. 23-27.

14. Ming-chang, L., Shu-xiu, L., Zhao-chen, S.: Research on tide supplemental prediction using ANN methods under unusual weather. *Chinese Journal of Computational Mechanics,* 2008, 25(3), Pp. 368-372.

15. Salim, A.M., Dwarakish, G.S., Liju, K.V.: Weekly Prediction of Tides Using Neural Networks. *Procedia Engineering*, 2015, 116(1), Pp.678-682.

16. Lee, T.L.: Back-propagation neural network for long-term tidal predictions. *Ocean Engineering*, 2004, 31(2), Pp. 225-238.

17. Alessandro, F., Torres, R., Kjerfve, A.: Application of Artificial Neural Network (ANN) to improve forecasting of sea level. *Ocean and Coastal Management*, 2012, 55, Pp.101-110.

18. He, Z.G., Gu, X.A., Sun, X.Y., Liu, J., Wang, B.S.: A coupled immersed boundary method for simulating multiphase flows. *Acta Electronica Malaysia*, 2017, 1(1), Pp. 05-08.

19. Ibrahim, M.S., Kasim, S., Hassan, R., Mahdin, H., Ramli, A.A., Md Fudzee, M.F., Salamat, M.A.: Information Technology Club Management System. *Acta Electronica Malaysia*, 2018, 2(2), Pp. 01-05.

20. He, Z.G., Gu, X.N., Sun, X.Y., Liu, J., Wang, B.S.: An efficient pseudo-potential multiphase lattice Boltzmann simulation model for three-dimensional multiphase flows. *Acta Mechanica Malaysia*, 2017, 1(1), Pp. 08-10.

21. Luo, X.: Research on Anti-Overturning Perfomance Of Multi-Span Curved Girder Bridge with Small Radius. *Acta Mechanica Malaysia*, 2(1), Pp. 04-07.

22. Halim, H., Abdullah, R., Mohd Nor, M.J., Abdul Aziz, H., Abd Rahman, N.: Comparison Between Measured Traffic Noise in Klang Valley, Malaysia And Existing Prediction Models. *Engineering Heritage Journal*, 2017, 1(2), Pp. 10–14.

23. Hassan, M.A., Mohd Ismail, M.A.: Literature Review for The Development of Dikes's Breach Channel Mechanism Caused by Erosion Processes During Overtopping Failure. *Engineering Heritage Journal*, 2017, 1(2), Pp. 23-30.

CONTACT WITH THE AUTHORS

LI Qiang, Lecturer
e-mail: manumail@dlmu.edu.cn

Navigation College
Dalian Maritime University
116026 Dalian, Liaoning
China