Study on Forecasting the Berthing Time of the Ships in the Port

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Abstract: Forecasting the berthing time of the ships has a great significance to the operation management and
task arrangement in the port. The factors which influence the berthing time are proposed, the research ideas
are designed and the BP neural network, RBF neural network and linear neural network are constructed. A case
study which uses the data of Valencia port is analyzed. The outputs of the three neural networks are evaluated
and the best neural network is obtained. The simulation results show that the outputs of the neural networks
have the high accuracy and conform to the actual work needs.

Key words: Ship, berthing time, neural network, forecast

INTRODUCTION

The port management departments of different ports
have paid much attention to the berthing time of the ships
in the port and have taken a variety of measures to
shorten the berthing time of the ships, in order to improve
the utilization efficiency of the berths and improve the
operating efficiency of the port. The total berthing time
of the ships in the port is constituted by the productive
berthing time, unproductive berthing time and natural
factors and thus not only includes human factors but also
includes the impact of natural factors. How to forecast the
berthing time of the ships in the port correctly by using
the information that we have will have great significance
and important function to improve the operation
efficiency and increase port handling capacity.

Over the analysis of the research literatures about the
berthing time of the ships in the port in China and foreign
countries, we could find that most of the previous
researches are overview reports and qualitative studies
which only propose some advice and measures but lack of
quantitative researches (Xu and Wang, 2007; Chen, 1999). The quantitative researches will have a more
practical sense for the actual operation of the port and
provide a better reference for the orderly conduct of the
actual work. At the same time, because there are many
factors which influence the berthing time of the ships in
the port, we need to adopt advanced forecasting methods
in order to consider these factors comprehensively and
get the better forecasting results. The artificial neural
network is an advanced optimization method which could
simulate human thinking activities and find the internal
relations between different factors. Therefore, we adopt
the artificial neural network to forecast the berthing time
of the ships in the port.

THE FACTORS OF THE BERTHING TIME OF THE
SHIPS IN THE PORT

To study the berthing time of the ships in the port,
we need to use the statistics data which are existent.
There are many factors that influence the berthing time of
the ships in the port but because restrictions of the port
condition or some factors are not included in the
statistical works, we do not have these data. Therefore,
we will study on the berthing time of the ships in the port
by using the existing data.

According to the analysis of existing statistics data,
we pick out the four kinds of data as the factors which
includes regular line, ship type, berth and start month.

In the regular lines, the goods category is relatively
fixed and the tasks are relatively simple, however in the
non-fixed lines, there are more random factors and may
need more time to complete the tasks.

The different ship types will also affect the berthing
time of the ships in the port. The large ships require long
operating time and the loading and unloading process is
complex, thus there may be a longer berthing time.

The berth will influence the berthing time of the ships
in the port. The berths in different position will have
different conveniences for the short handling tasks and
use different time to complete the tasks.

The start month refers to the time that the ship enters
the port. In different start month, the port has different

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busy levels. Therefore the start month has a great impact on the tasks process and will affect the berthing time of the ships in the port.

Based on the above analysis, we select four factors: regular line, ship type, berth and start month as the input parameters of the neural networks.

**STRUCTURE OF THE ARTIFICIAL NEURAL NETWORKS**

The artificial neural network is a new subject which is quickly developed in the late 1980s. The artificial neural network is an abstraction and simulation of the biological neural structure and is a network structure which could repeat and reproduce the thought process of the humans and has the functions of learning, associating, memory and pattern recognition and a very wide range of application.

Towards the problem of forecasting the berthing time of the ships in the port in this paper, the artificial neural network could find the internal relations between the berthing time of the ships with the regular line, ship type, berth and start month, in order to ensure the forecast accuracy in the future. There are many types of neural network models and the different models have different adaptability, thus the difference between the results obtained may be relatively large. In order to guarantee the accuracy of the forecasting results, we use the BP neural network, RBF neural networks and linear neural network (You et al., 2004; Liu, 2012; Meng and Lv, 2012) to predict the berthing time of the ships in the port and pick out the most suitable model of the problem as the optimal network model, the research ideas of this paper is shown in Fig. 1.

Fig. 1: Research ideas of this paper

Fig. 2: The structure of the BP neural network

Back propagation neural network model. Back Propagation Neural Network has a powerful classification and forecasting capability and is able to approximate a nonlinear function and is a multi-layer feed forward neural network which is based on the back propagation algorithm. BP neural network generally has the topological structure of three layers or more and includes the input layer, hidden layer and output layer, where the hidden layer may be a multi-layer, the structure of the BP neural network is shown in Fig. 2.

There are some mathematical relationships between the different layers in BP neural network and the activation function in the BP neural network is generally sigmoid function. The activation function includes the logarithmic sigmoid function:

\[ f(x) = \frac{1}{1 + e^{-x}} \]

and tangent sigmoid function:

\[ f(x) = \frac{1 - e^{x}}{1 + e^{x}} \]

We adopt the logarithmic sigmoid function in this paper and the output is one-dimensional data. The output function of the BP neural network is given in Eq. 1:

\[ s = \frac{1}{1 + e^{\sum w_i y_i}} \]

where, \( s \) is the output of the BP neural network; \( H_i \) is the output of the hidden layer; \( w_i \) is the connection weights between the hidden layer and the output layer.
The structure of the linear neural network

Radial basis function neural network model. RBF neural network is a novel neural network which is proposed by Moody and Darken in 1989. RBF neural network is an efficient feed forward neural networks which is based on the function approximation theory and has the best approximation properties and the simple structure, so RBF neural network is widely used in many research areas.

The basic structure of the RBF neural network is similar to the BP neural network which is shown in Fig. 2 but the difference between the two neural networks is that the RBF neural network uses the radial basis function as the activation function in the hidden layer neurons.

The output function of the RBF neural network is given in Eq. 2:

\[
s = \sum_{j=1}^{n} w_j \phi_j(\|a - Z_j\|) = \sum_{j=1}^{n} w_j \exp\left(\frac{-\|a - Z_j\|^2}{2\delta_j^2}\right)
\]

where, \(\phi_j(x)\) is the activation function between the input layer and the hidden layer; \(a\) is the input vector; \(Z_j\) is the center of the radial basis function; \(\delta_j\) is the width of the radial basis function.

Linear neural network model. The linear neural network is a network with one or more neurons, including single-layer network and multi-layer network. The linear neural network is different from the perceptron network and each activation function of the neuron is a linear function, thus the output of the neural network can an arbitrary value. The single-layer linear neural network is used in this paper and its structure is shown in Fig. 3.

The linear neural network adopts the Widrow-Hoff learning rule which is also called LMS (Least Mean Square) algorithm to adjust the network weights and threshold. The output of the linear neural network is given in Eq. 3:

\[
s = \text{purelin}(Wx + P) = Wx + P
\]

where, purelin (●) is the transfer function of the linear neural network; \(x\) is the input vector of the neurons; \(W\) is the weight vector of the neurons; \(P\) is the threshold of the neurons.

Output errors of the three neural networks. In order to evaluate the performances of the proposed BP neural network, RBF neural network and linear neural network, we define the error function of the three neural networks as following, see Eq. 4:

\[
\text{mse} = \frac{1}{2} \sum (y - Q)^2
\]

where, mse is the output error of the neural network; \(Q\) is the expected output of the neural network; \(s\) is the actual output of the neural network.

FORECASTING THE BERTHING TIME OF THE SHIPS IN VALENCIA PORT

In this study, we take the Valencia port in Spain as the study object, analyze and calculate the data of the berthing time of the ships in Valencia port from the year of 2008 to 2011. We randomly select 500 sets of data as the training samples of the neural network and randomly select 50 sets of data as the testing samples.

We define the output of the neural network as showed in Table 1:

The part of the data of the training samples and the testing samples are shown in Table 2 and 3.

We study following the research ideas shown in Fig. 1 and use the Matlab software to program. We put the data of the completely training samples and testing samples input to the proposed neural network models and get the computed results which are shown in Fig. 4-6.
By comparing the outputs of the three neural networks, we can see that the BP neural network reaches the mean squared error of $10^{-4}$ in 61 epochs, the RBF neural network reaches the mean squared error of $10^{-5}$ in 45 epochs, while the linear neural network reaches the mean squared error of $10^{-2}$ in 20000 epochs which is the maximum number of calculation. Therefore, the RBF neural network achieves the accuracy requirement in a minimum number of calculated times and we choose the proposed RBF neural network as the optimal neural network.

We adopt the proposed RBF neural network to simulate 50 testing samples and we obtain the results which are shown in Fig. 7.

We can see from Fig. 7 that the RBF neural network has high computing accuracy and has the good fitting results with the 50 testing samples, so the RBF neural network can be used as the neural network that forecasting the future berthing time of the ships in the port.
CONCLUSION

This study analyzes the importance of forecasting the berthing time of the ships in the port and proposes four factors which affect the berthing time of the ships and are used as the input parameters of the neural networks. We build three neural network models which include the BP neural network, RBF neural network and linear neural network and analyze a case study which uses the berthing time of the ships data in Valencia port from the year of 2008 to 2011. We get the outputs of the three neural networks and through the comparative analysis, we find that the RBF neural network achieves the accuracy of the demand in a minimum number of calculations and thus we choose the RBF neural network as the best neural network in our research. We can use the proposed RBF neural network to forecast the future berthing time of the ships in the port. The constructed neural network model has a good portability and could also be applied to the other ports in the forecasting work of the berthing time of the ships in the port and provide the support for the orderly conduct of the port operation.

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REFERENCES