

# Construction and verification of nonparameterized ship motion model based on deep neural network

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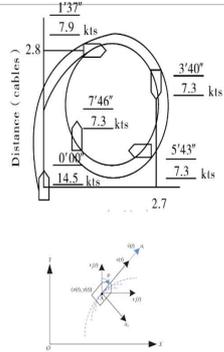
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**Abstract :** A ship’s maneuvering motion model is important in a computer simulation, especially under the trend of intelligent navigation. This model is usually constructed by the hydrodynamic parameters of the ship which are generated by the principles of hydrodynamics. Ship’s motion model is a nonlinear function. By using this function, ships’ motion elements can be calculated, then the ship’s trajectory can be predicted. Deeping neural networks can construct any linear or non-linear equation theoretically if there have enough and sufficient training data. This study constructs some kinds of deep Networks and trains this network by real ship motion data, and chooses the best one of the networks, uses real data to train it, then uses it to predict the ship’s trajectory, getting some conclusions and experiences.

**Keywords :** Ship’s maneuvering motion models, Deeping neural networks, Predicting ship’s trajectory

### 1. Background

Propose a method to predict the ship’s trajectory, and simulate them in the computer.

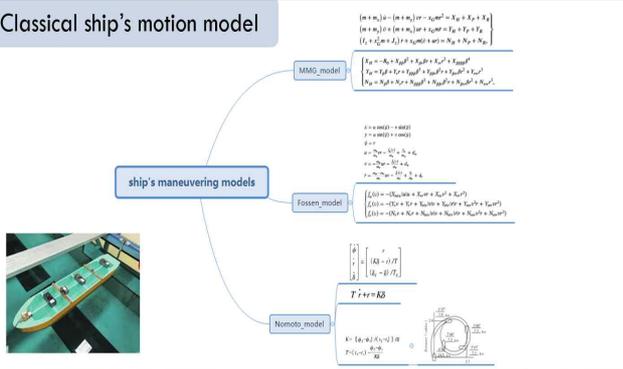



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### 1.1 Classical ship’s motion model

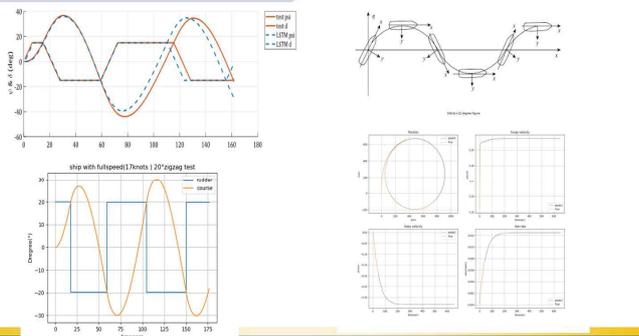
ship’s maneuvering models

- MMG model
- Fossen model
- Nomoto model



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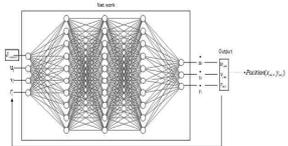
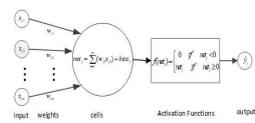
### 1.2 some result



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### 2. Deep Neural Network

#### 2.1 FNN: Full Connect Network

$$y_j = f(\text{net}_j) = f\left(\sum_i w_{ji} x_i + \theta_j\right)$$

$$\hat{y}_j = \sigma(y_j)$$

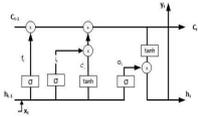
$$\text{error} = \frac{1}{n} \sum (\hat{y}_j - y_j)^2$$

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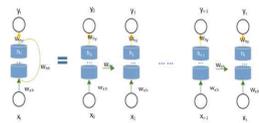
## 2. Deep Neural Network

### 2.2 LSTM



$$\left. \begin{aligned}
 i_t &= \sigma(x_t U^i + h_{t-1} v^i) \\
 f_t &= \sigma(x_t U^f + h_{t-1} v^f) \\
 o_t &= \sigma(x_t U^o + h_{t-1} v^o) \\
 \tilde{C}_t &= \tanh(x_t U^c + h_{t-1} v^c) \\
 C_t &= \sigma(f_t * C_{t-1} + i_t * \tilde{C}_t) \\
 h_t &= \tanh(C_t) * o_t
 \end{aligned} \right\} (1)$$

### 2.3 RNN



$$\left. \begin{aligned}
 y_t &= \text{soft max}(h_t w_{ly} + b_t) \\
 h_t &= \tanh(x_t w_{lh} + h_{t-1} w_{hh} + b_{h,t})
 \end{aligned} \right\} (2)$$

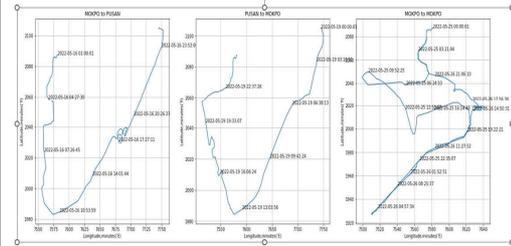
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## 3. The DNN of the ship motion model

### 3.1 Our training data

Our data is based on a training ship which is belonged to Mokpo national maritime university.



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## 3. The DNN of the ship motion model

### 3.2 Our networks

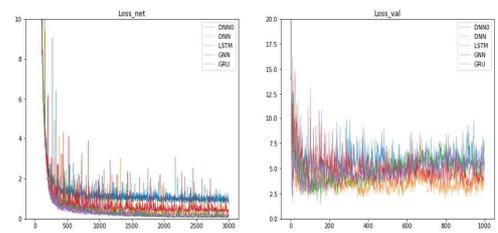
model	Input equation	Layer0 (Normalization)	Layer1 (Numbers, Activation)	Flatten	Dropout	Layer3 (Numbers, Activation)	Layer4 (Numbers, Activation)	Layer5 (Numbers, Activation)	Layer6(Out) (Numbers, Activation)
DNN0	(5)	Yes	Dense 128/ReLU	Yes	0.001	Dense 256/ReLU	Dense 128/ReLU	Dense 32/ReLU	Dense 3/None
DNN1	(10)	Yes	Dense 128/ReLU	Yes	0.001	Dense 256/ReLU	Dense 128/ReLU	Dense 32/ReLU	Dense 3/None
LSTM	(10)	Yes	LSTM 128/ReLU	NA	0.001	LSTM 128/Tanh	LSTM 64/Tanh	LSTM 32/Tanh	Dense 3/None
RNN	(10)	Yes	RNN 128/ReLU	NA	0.001	RNN 128/ReLU	RNN 64/ReLU	RNN 32/ReLU	Dense 3/None
GRU	(10)	Yes	GRU 128/ReLU	NA	0.001	GRU 128/ReLU	GRU 64/ReLU	GRU 32/ReLU	Dense 3/None

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## 4. The DNN of the ship motion model Result

### 4.1 The learning rate of five networks after training

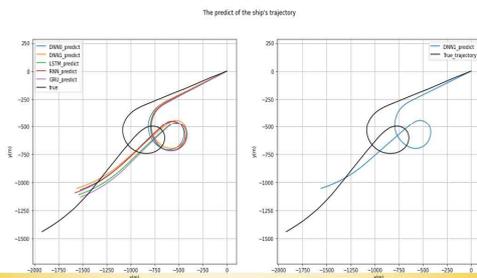


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## 4. The DNN of the ship motion model Result

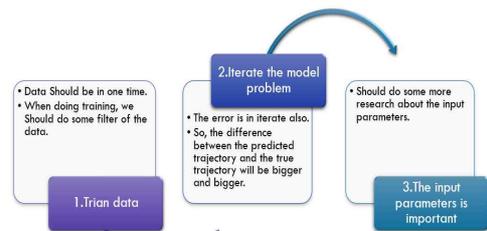
### 4.3 The predict trajectory of five networks after training



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## 5. Conclusions



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