# Digital Twins Modeling of Maritime Autonomous Surface Ships Based on Deep Neural Predictor

1st Lingfeng Li
*School of Marine Electrical Engineering*
*Dalian Maritime University*
Dalian, China
lilingfeng0207@dlmu.edu.cn

2nd Zhouhua Peng
*School of Marine Electrical Engineering*
*Dalian Maritime University*
Dalian, China
zhpeng@dlmu.edu.cn

3rd Anqing Wang
*School of Marine Electrical Engineering*
*Dalian Maritime University*
Dalian, China
anqingwang@dlmu.edu.cn

4th Dan Wang
*School of Marine Electrical Engineering*
*Dalian Maritime University*
Dalian, China
dwangdl@gmail.com

***Abstract*—Maritime autonomous surface ships (MASSs), as a class of typical cyber-physical system, mainly applied in the field of waterborne transportation. According to the International Maritime Organization (IMO), MASSs are expected to be the main means of maritime transport in the future due to the low seafarers cost, high degree of efficiency and safety. The system modeling methods of MASSs, as an approach to evaluate the behavior of MASSs system for different working conditions, has also received widespread attention over the past decades.**

**Digital Twins (DT) is a software platform aiming at mirroring the dynamics of the actual system, which mainly consists of three components: 1). a model; 2). a bi-directional data flow between the DT system and the actual system; 3). real-time synchronization between the DT system and the actual system. Based on these characteristics, Deep Neural Predictor (DNP) is designed for modeling the DT system of MASSs and estimating the internal uncertainties and external disturbances. As a dual time-scale architecture, the entire DNP algorithm divides Deep Neural Networks (DNNs) into two parts: the inner loop and the outer loop. The slower back propagation process of neural networks, as the inner loop of the DNP algorithm, is mainly responsible for providing DL-learned basis functions with different feature knowledge to the predictor in the outer loop. The outer loop is mainly responsible for fast learning of unknown system dynamics with the last layer weights estimated by the predictor and the learned basis functions. With the learned dynamics, an DT system of an MASS is thus constructed, and the real-time synchronization between the DT system and the actual system is realized.**

**Simulation results demonstrate the effectiveness and reliability of the proposed DT modeling method.**

***Index Terms*—Maritime autonomous surface ships, Digital twins modeling, Deep neural predictor**