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# An optimal design of wind turbine and ship structure based on neuro-response surface method

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**ABSTRACT**: *The geometry of engineering systems affects their performances. For this reason, the shape of engineering systems needs to be optimized in the initial design stage. However, engineering system design problems consist of multi-objective optimization and the performance analysis using commercial code or numerical analysis is generally time-consuming. To solve these problems, many engineers perform the optimization using the approximation model (response surface). The Response Surface Method (RSM) is generally used to predict the system performance in engineering research field, but RSM presents some prediction errors for highly nonlinear systems. The major objective of this research is to establish an optimal design method for multi-objective problems and confirm its applicability. The proposed process is composed of three parts: definition of geometry, generation of response surface, and optimization process. To reduce the time for performance analysis and minimize the prediction errors, the approximation model is generated using the Backpropagation Artificial Neural Network (BPANN) which is considered as Neuro-Response Surface Method (NRSM). The optimization is done for the generated response surface by non-dominated sorting genetic algorithm-II (NSGA-II). Through case studies of marine system and ship structure (substructure of floating offshore wind turbine considering hydrodynamics performances and bulk carrier bottom stiffened panels considering structure performance), we have confirmed the applicability of the proposed method for multi-objective side constraint optimization problems.*

***KEY WORDS:*** Multi-objective optimization; Back-propagation artificial neural network (BPANN); Neuro-response surface method (NRSM); Non-dominated sorting genetic algorithm-II (NSGA-II); Floating offshore wind turbine; Bulk carrier bottom stiffened panels.

## INTRODUCTION

The optimal engineering system design is built around the best of alternative design variables concerning system performances. Therefore, the performance evaluation is an essential process at the optimal design stage, but system performance analysis in particular is time-consuming. To solve this problem, many researchers are predicting the system performance using Response Surface Method (RSM) (Hong, 2000; Mayers and Montgomery, 1995). These RSM represent the relationship between inputs and outputs (Fig. 1). The RSM simplifies the configuration of the response surface and takes short time to generate it. In addition, it has the advantage of generating a stable response surface.

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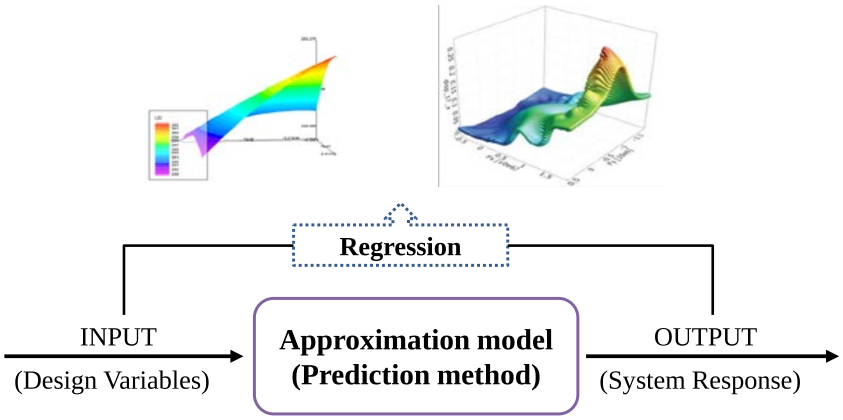


Fig. 1 Response surface method (RSM).

RSM is traditionally used to predict system performance in the engineering research field. Bucher and Bourgund employed RSM to solve structural reliability problems (Bucher and Bourgund, 1990). Kahraman developed a quadratic model for prediction and analysis of the relationship between the cutting parameters and surface roughness in the turning process of AISI 4140 steel (Kahraman, 2009), and Yu et al. (2009) studied the fatigue reliability of ship structures using RSM. However, this method produces errors in highly nonlinear problems. Marine system optimization design problems based on performance involve highly nonlinear elements, such as hydrodynamics problems (hull forms, propeller), and structural problems (superstructures, offshore structure). Therefore, many researchers have tried to increase prediction accuracy using various artificial intelligence methods. Shin employed the neuro-fuzzy algorithm to predict wake distribution (Shin, 2007), Han determined the satisfaction index of the noise using various evaluation parameters using the linear regression and back-propagation neural network algorithm (Han, 2012), and Lee et al. tried to predict the added resistance in waves using GP (Lee et al., 2014). Yang et al. (2015) studied reliability based design optimization of the tripod substructure of offshore wind turbines under dynamic constraints using the kriging method and Mandal et al. studied to predict the damage level for non-reshaped berm breakwater using ANN, SVM and ANFIS (Mandal, et al., 2012).

The application of optimization method, in NAOE optimal design problem, is time-consuming especially for performance analysis evaluation; performance prediction using approximation method can be used to reduce the evaluation time. Therefore, it is necessary to research the multi-objective optimal design framework in view of system performance in the initial design stage. In marine system optimal design problem, no research about optimization process including approximation method was found. The main objective in this study is to optimize a marine system while considering its performance, and to establish a design methodology for multi-objective optimization problems. For this purpose, we constructed a framework for optimal design based on the Neuro-Response Surface Method (NRSM) (Lee et al., 2013a). Through case study, we have confirmed the usefulness of the constructed framework in view of hydrodynamics and structural performance. The design alternatives for performance analysis are generated using an orthogonal array table (Ross, 1996), while commercial codes (AQWA, ANSYS APDL) are used for performance analysis. The framework was constructed using MATLAB code.

## OPTIMAL DESIGN FRAMEWORK BASED ON NEURO-RESPONSE SURFACE METHOD (NRSM)

The proposed multi-objective optimal design framework includes two principal phases (Lee et al., 2013b):

*(1$^{st}$ Phase)*

In order to predict the system performance, the response surface is generated using the Back-Propagation Artificial Neural Network (BPANN); this process is the Neuro-Response Surface Method (NRSM).

*(2$^{nd}$ Phase)*

Optimization of system geometry using NRSM.