Toward a global retrieval of in-water optical properties using Deep Neural Network

*Salem Ibrahim Salem[1], Hiroto Higa[2], Kazuo Oki[1], Taikan Oki[1]

1. The University of Tokyo, 2. Yokohama National University

Reflected sunlight from water bodies, which records by ocean color sensors, contains information of optical properties of water bodies (e.g., chlorophyll-a concentrations, absorption and backscattering coefficients). During the last few decades, researches have been proposed many approaches for monitoring water bodies by retrieving their optical properties. These approaches include bands ratio, semi-analytical algorithms, and spectrum matching. However, there is no accurate continuous monitoring on a global scale, particularly over inland lakes and coastal regions. This is mainly due to the nonlinear complexity of water environment. In additions, there are a few studies that used the synthetic simulated reflectance to train artificial neural network (ANN) models to be applied on a global scale. However, the recent revaluation of these ANN models over the Japanese and European lakes revealed their limitation to provide accurate monitoring of these water bodies. These results could be attributed to two main reasons; (1) inappropriate ANN architecture with one hidden layer which could not be suitable to represent the complex situation of water bodies. (2) the limitation of the synthetic simulated reflectance that used to train these models. The deep neural network (DNN) with multiple hidden layers could provide a promising approach to overcome these complexities. Up to 2006, there is no way to accurately train a DNN due to a Vanishing gradient problem. the recent advances of DNN enable researchers to efficiently use the DNN models with low cost. During the current research, the performance of a DNN model with three-, five- and seven-hidden layers under different architecture conditions will be presented. These conditions include different activation functions (i.e., sigmoid, Relu and TanH), different optimization technique (i.e, Adam optimizer and stochastic gradient descent) and with/without applying dropout technique. The DNN model was designed to receive water leaving reflectance of several ocean color satellites (e.g., Global Change Observation Mission –Climate (GCOM-C)). Nine water quality parameters are generating from the DNN model. Two independent simulated datasets comprising 100,000 water leaving reflectance spectra each were generated for training and testing the DNN models. The two simulated datasets cover wide ranges of Chla (0.01–250 $mg \cdot m^{-3}$), NAP (0.01–250 $g \cdot m^{-3}$), and CDOM (0.001–10 m^{-1}) concentrations, representing the open ocean, coastal areas, and inland lakes. The proposed technique was also validated using in-situ datasets (e.g., NOMAD dataset, and many Japanese lakes and coastal bodies) that represent various trophic statuses. The results reveal the ability of proposed technique to provide accurate retrieval of in-water optical properties as will be discussed.

Keywords: deep neural network, water quality, optical properties, Lakes

Toward a global retrieval of in-water optical properties using Deep Neural Network

Salem Ibrahim Salem[1], Hiroto Higa[2], Kazuo Oki[1], Taikan Oki[1]
[1] Institute of Industrial Science, The University of Tokyo, Japan.
[2] Faculty of Urban Innovation, Yokohama National University, Japan.

Corresponding e-mail: salem@rainbow.iis.u-tokyo.ac.jp and eng.salemsalem@gmail.com

Reflected sunlight from water bodies, which records by ocean color sensors, contains information of optical properties of water bodies (e.g., chlorophyll-a concentrations, absorption and backscattering coefficients). During the last few decades, researches have been proposed many approaches for monitoring water bodies by retrieving their optical properties. These approaches include bands ratio, semi-analytical algorithms, and spectrum matching. However, there is no accurate continuous monitoring on a global scale, particularly over inland lakes and coastal regions. This is mainly due to the nonlinear complexity of water environment. In additions, there are a few studies that used the synthetic simulated reflectance to train artificial neural network (ANN) models to be applied on a global scale. However, the recent revaluation of these ANN models over the Japanese and European lakes revealed their limitation to provide accurate monitoring of these water bodies. These results could be attributed to two main reasons; (1) inappropriate ANN architecture with one hidden layer which could not be suitable to represent the complex situation of water bodies. (2) the limitation of the synthetic simulated reflectance that used to train these models. The deep neural network (DNN) with multiple hidden layers could provide a promising approach to overcome these complexities. Up to 2006, there is no way to accurately train a DNN due to a Vanishing gradient problem. the recent advances of DNN enable researchers to efficiently use the DNN models with low cost. During the current research, the performance of a DNN model with three-, five- and seven-hidden layers under different architecture conditions will be presented. These conditions include different activation functions (i.e., sigmoid, Relu and TanH), different optimization technique (i.e, Adam optimizer and stochastic gradient descent) and with/without applying dropout technique. The DNN model was designed to receive water leaving reflectance of several ocean color satellites (e.g., Global Change Observation Mission – Climate (GCOM-C)). Nine water quality parameters are generating from the DNN model. Two independent simulated datasets comprising 100,000 water leaving reflectance spectra each were generated for training and testing the DNN models. The two simulated datasets cover wide ranges of Chla (0.01–250 $mg \cdot m^{-3}$), NAP (0.01–250 $g \cdot m^{-3}$), and CDOM (0.001–10 m^{-1}) concentrations, representing the open ocean, coastal areas, and inland lakes. The proposed technique was also validated using in-situ datasets (e.g., NOMAD dataset, and many Japanese lakes and coastal bodies) that represent various trophic statuses. The results reveal the ability of proposed technique to provide accurate retrieval of in-water optical properties as will be discussed.

