# **Ocean Color Inverse Problem**

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This article discusses about identifying the active constituents of sea water by studying the output of sensors which measure the sunlight reflected off of the sea water. This is to determine the optically active constituents of the sea water as there is a strong relation between the light reflected to the constituents of the water. The authors discuss the solution to solve the problem using evolutionary multi-objective algorithm which uses the Takagi-Sugeno (TS-type) Fuzzy model. TS-type Fuzzy rule based system (FRBS) is used an artificial neural network. This neural network is trained and the parameters of the Fuzzy models are adjusted which leads to identification of the structure of the fuzzy model and also tuning the neural network parameters. This TS-type FRBS is embedded in a Adaptive –Network Based Fuzzy interference System (ANFIS).

**Takagi-Sugeno Fuzzy Model**

Cococcioni et al. initially have used the Takagi-Sugeno (TS)-type fuzzy rule to solve the ocean color inverse problem where the inverse relation between the reflectance and optically active constituents in the water is modeled. The rules for the fuzzy model are generated where the antecedents of these rules are derived using the fuzzy clustering algorithm and then the resulting clusters are projected onto each input variables. The parameters for the model are calculated by Least Square estimates and finally the fuzzy model is optimized using a genetic algorithm. The results of the TS-type fuzzy model were better than the previously proposed MLP (Multi-Layer Perceptron) and RBF (Radial Basis Function). However for the TS-type fuzzy model requires to determine a-priori the number of rules based on the distribution data rather than the accuracy which can limit the performance of the model. In order to overcome the limitations of the classic TS-type model, the author has used a hybrid approach of using the TS-Type Fuzzy rule based system along with the Adaptive network Based Fuzzy inference system (ANFIS). This approach allows the TS-type model to adapt based on the learnings of the ANFIS. The TS-Type FRBS (along with (2+2)M-PAES to evolve the antecedent used) in this approach generates Fuzzy sets that are a tradeoff between Complexities and Accuracies. Thus, the authors are able to choose the sets with more accuracy and less complexity and better MSE than the MLP and RBF methods.

**ANFIS**

As mentioned earlier the authors use the TS-Type model is used along with the Adaptive Network Based Fuzzy Inference system (ANFIS) to build the mapping to relate the input and output of the FIS. The ANFIS integrates both the neural networks and fuzzy logic principle and it’s inference system corresponds to set of fuzzy IF-THEN rules that have learning capability to approximate Non-Linear function. The author uses this learning capability so that the embedded TS-type model can adapt constantly to the input data. With increased number of inputs to the ANFIS can become a problem generating rules. In order to avoid this limitation, MOEA (Multi-objective Evolutionary Algorithm) is used to determine the parameters. The authors use two generalization of classical ANFIS here, the first generalization states that the rules expresses assumes that all input variables are used to determine the region of input space determined by the antecedent and ignoring the input variables that are irrelevant. With increase in the input variables the number of rules that doesn’t contribute to the cause grows exponentially and hence the second generalization helps to mitigate this, which is pre-setting the total number of rules used. This leads to generating ANFIS that has low number of parameters (feature selection) and hence better accuracy keeping the complexity (as it depends on the number of parameters that need to be learned and they are limited) low. The ANFIS tunes the overall model by calculating the antecedent parameters by gradient descent method and the corresponding consequent parameters are determined by the recursive least square method.

**Conclusion**

The authors used the ANFIS embedded with the TS-type model to solve the ocean color inverse problem. They had to use additional algorithms to improve the feature selection and avoiding the parameters and hence the rules that doesn’t contribute to the problem. They were able to show case that their approach (with a trade-off between Complexity and Accuracy) performed better than the MLP and RBF algorithm. Using the generalization of the classical ANFIS for the problem also helped in having control over the Rules generated and hence improving the overall Accuracy of the model.

# **References**

Cococcioni, M., Corsini, G., Lazzerini, B., & Marcelloni, F. (2009). Solving the ocean color inverse problem by using evolutionary multi-objective optimization of neuro-Fuzzy Systems. *International Journal of Knowledge-Based and Intelligent Engineering Systems*, *12*(5-6), 339–355. https://doi.org/10.3233/kes-2008-125-604