CONCLUSION AND RECOMMENDATION

Conclusion

The coastal lands around the world have been facing with the problems of inadequate freshwater supply and inappropriate water quality, such as freshwater shortage crisis, saline water intrusion, and water pollution problem. The costal gate, which is a widespread structural measure, has been constructed to deal with such problems. However, it is found that the coastal gate operation is not simple task since it simultaneously concerns the management of several water parameters. Currently, the use of mathematical simulation model to determine the optimal gate opening by means of trial and error process is pervasive. Nevertheless, such method need the considerable experiences of the users, are also very time-consuming process, especially for the complex systems, and do not guarantee to obtain optimal solution.

This research presents the development of decision support modeling based on coupling simulation and optimization model, which is subsequently named CosatalGate model, to find optimal coastal gate operation scheduling. Although the coupling optimization and simulation model approach have been applied for solving numerous problems in the field of water resources engineering, the validity of the application of such model to the problem of controlling coastal gate has yet to be recognized. The coastal gate operation scheduling problem concurrently involves the management of several water parameters. In this research, one water quantity parameter (water level) and two water quantity parameters (salinity and dissolved oxygen) were considered. To solve multiple objective functions, the weighting method, conventional method in which multiple objectives are combined to form one objective, was selected for the model development. The use of weighting technique for solving multiple objectives like coastal gate operation problem, the operator is necessary to well understand regarding the behaviors of water flow and mass transport in coastal river region.

To development the CosatalGate model, the satisfaction function, which is the sum of satisfaction function of such three considered water parameters by means of the weighting method, was designed first, and the coupling simulation and optimization model was subsequently developed. The Differential Evolution (DE), which is an evolutionary optimization technique, and the River Operation Model (ROM), which is hydrodynamic and water quality modeling, were utilized herein.

To be able to apply the developed model in real situation, it is also necessary to consider the violation of physical bounds on gate operations since in practical gate cannot be operated in sharp change (i.e., sudden opening and closing). The way of dealing with this problem was to determine the possible upper and lower boundary of search space for the gate setting in the current run time step related to the gate setting in the previous run time step. During the model development, it was found that another topic that could be considered was the problem of the alternate optimal solutions. This problem usually occurs when the gate sill is higher than the levels of both the upstream and downstream water surfaces. It is called non-orifice flow condition. The method for solving this problem is to check if non-orifice flow condition or not. If a non-orifice flow situation occurs, the gate settings, which are guided by optimization model, have to be changed to be appropriate settings according to the current water surface elevations. On the contrary, if a non-orifice flow situation does not occur, the gate settings, which are guided by optimization, will be directly used for the calculation state vectors.

When using the CoastalGate model for planning coastal gate operation scheduling, it is required to provide the input information for hydrodynamic, water quality, and optimization models as follow. The input data file for hydrodynamic model contain details of geometry, gate operation, upstream boundary, downstream boundary, flow direction, and initial values of discharge and water level. The input data for salinity module consist of node type, boundary condition, initial condition, and calibrated salinity's diffusion coefficient. The input data for Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO) module comprise node type, boundary condition, initial condition, calibrated parameters of BOD and DO; namely:- diffusion coefficient, decaying rate (K_1), settling rate (K_3), sediment oxygen demand (SOD), reaeration rate (K_2), temperature, and dissolved oxygen saturation (DOS), and pollution load. Finally, the input data for optimization model consist of the DE's parameters, the general information about river network, the criteria for controlling speed of gate opening, required run time, observation point data, allowable gate opening, upper boundary and lateral discharge data, lower boundary data, point source information, file management information, desired criteria used for controlling water gate including the maximum and minimum values of water level, salinity concentration, and dissolved oxygen concentration at selected nodes, and the data of weighting factor and relative importance of interesting parameter.

The results obtained from the use of CoastalGate model to Pak Phanang coastal gate system showed the efficiency and capability of the model as a valuable decision support tool. It can help the gate operators for making a decision to operate coastal gate under overwhelming situation. In addition, it is more convenient than using mathematical simulation model, which use trial & error approach for determine the plan of control gate operations. It was found that coastal gate controlled by three full optimization scenarios outperformed a baseline scenario. When using the different weighting factor and relative importance of interesting parameter, the difference optimal control strategies are obtained. There is no the best strategy for controlling water gates, but it depends on the personal preference as well as experience of gate operators to decide to select which strategy is appropriate for current situation. Finally, it should be noted that the results obtained from running the developed model is only near optimal solution, not exactly solution.

In addition, this research proposed the development of coastal gate operating rules through neural network controller. Despite the fact that most researchers in recent years have utilized ANNs for controlling water level, yet it has never been applied to the problem concerning the control of several water parameters simultaneously like coastal gate operation scheduling. For this study, the hypothetical coastal gate system that relates to Uthokawiphatprasit water gate was considered. There are two steps for development of ANN controller. Firstly, the CoastalGate model was used as reference model was used for providing several pair data sets between influencing water parameters and the optimal gate setting under a wide range of exogenous input of coastal river system. Secondly, these optimization results were used as input for the ANN learning process.

In training and testing process, the data sets provided by CoastalGate model were randomly divided into two parts: 70% of the records for training and using the remainder, 30% of the record, for testing. Seven input patterns and two types of supervised neural networks such as back propagation (BP) and general regression neural network (GRNN) were carried out to determine the best structure. It was found that the suitable type of neural network and input pattern for this study case was GRNN and the third input pattern, respectively. Such ANN structure gave AAE value of 0.0014 and 0.1700 for training and testing process, respectively and R^2 value of 0.992 and 0.7140 for training and testing process, respectively.

To validate the performance of the developed coastal gate operating rules, moreover, the coupling trained neural network and mathematical simulation model (or NGO-ROM model) was developed. It was found that although state variables (e.g. water level, salinity concentration, dissolved oxygen concentration) may encounter phase shift, the minimum, maximum, and average values of such state variables reached are very similar.

Recommendation

As the first time of developing decision support modeling for optimal coastal gate operations, there are still areas of study that can be improved in future research as follows.

1) In addition to three water parameters considered in this study, e.g. water level, salinity concentration, and dissolved oxygen concentration, other water quality parameters, e.g. pH, and BOD should be considered for coastal gate operations as well. However, it should be reminded that the more water parameters being considered, the more computer time is required.

2) Presently, the Differential Evolution based on weighting technique is used for solving the multiple-objective problem of coastal gate operations. It is still difficult to determine the optimal weighting factor and their relative importance. The user could test several different parameter combinations for a specific event and also for general events to get the experience for the determination of suitable weighting factor and relative importance corresponding to desired control. There are other multiple-objective optimization techniques such as Differential Evolution for Multi-objective Optimization (DEMO), Pareto Differential Evolution (PDE) algorithm, and Vector Evaluated Differential Evolution (VEDE) available for solving this problem. These techniques can find multiple Pareto-optimal solutions simultaneously so that decision makers may be able to choose the most appropriate solution for the current situation. Therefore, these techniques should be investigated for their application in comparison to what proposed in this study. However, it should realize that such methods requires more computer time than the use of weighting technique for each run.

3) In present research, only DE/rand/1/bin strategy was selected. Hence, it should investigate the other nine DE's strategies such as DE/best/1/bin, DE/best/2/bin, DE/rand/2/bin, DE/randtobest/1/bin, DE/rand/1/exp, DE/best/1/exp, DE/best/2/exp,

DE/rand/2/exp, DE/randtobest/1/exp for determining optimal coastal gate operations to compare their performances.

4) Since the Different Evolution needs four parameters: (1) maximum number of generations; (2) population size within each generation (NP); (3) weighting factor (F); (4) crossover constant (CR), it is necessary to always make a new experiment to determine the suitable DE's parameters when changing location. Therefore, the DE's parameters should be studied for numerous cases to be the guideline for determining such parameters.

5) In this research, the weighting factor and the relative importance of each parameter are assumed to be constant throughout control horizon, although these values are easily changed following the priority level of each relevant water parameter according to location and time of day. Therefore, the method that can automatically adjust these parameters corresponding to the change of environmental conditions should be developed.

6) To properly manage coastal gate operations corresponding to several water use activities, the gate control criteria should be precisely studied. It should be obtained from the agreement between the stakeholders and the government agencies.

7) The ANNs controller performs well for present case study, which rather limits the diversity of exogenous input, especially upstream discharge, waste load, initial condition of salinity and dissolved oxygen parameters. Future work should focus on enriching the training data sets by collecting necessary field data as much as possible. However, when training ANNs with the diversity of exogenous input, it is better to segregate the numerous data sets into the several smaller data set groups depending on time period or properties of relevant water parameters.

8) Presently, ANNs were used for deriving one coastal gate operating rules. Further, it is possible to test the ability of ANNs for deriving multiple coastal gate operating rules.

9) Other offline training techniques such as fuzzy logic, support vector machine as well as online training technique (i.e. genetic based machine learning) should be investigated and compared their control performance in generating coastal gate operating rules.

10) Since NeuroGenetic Optimizer software package cannot generate computer code itself, it is not convenient for developing the coupling trained neural network and River Operation models and require more computer time for calculations. Therefore, it is recommended to select other ANNs software like NeuroShell 2.0 to solve this problem.