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SUMMARY OF DOCTORAL THESIS

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Title: A Data Driven Algorithm for Assessing and Constructing Artificial Intelligence River Basin Models

河川流域モデルの評価および人工知能モデルの構築のためのデータ操作アルゴリズム

Modeling of both groundwater and surface flow in a river catchment are among the most studied topics in hydrology, due to its essential application to water resources management. Recently, artificial intelligence has gained much popularity for calibrating the nonlinear relationships. However, although artificial intelligence methods such as neural networks and fuzzy logic have found wide acceptance in the water resources research community, a number of obstacles have to be overcome before they can be used routinely by the wider modeling community. Firstly, their success has to be demonstrated for a range of realistic applications, including their advantages over more conventional techniques. Secondly, their transparency needs to be increased, which can be achieved by gaining a better understanding of how they operate and behave. Thirdly, guidelines need to be developed that help users to choose an appropriate method from the ever-growing list of available options, and to implement the methods in an efficient manner. In order to overcome some of the obstacles mentioned above, this thesis addresses the utility of neural networks and fuzzy logic for a range of applications, particularly in relation to the management of both groundwater and surface water.

A series of studies were performed to: (a) examine the potential of fuzzy c-means algorithm for clustering the features similarity of irrigation pumps operating in the groundwater development area; (b) evaluate the potential of the neuro-fuzzy system as an alternative to the traditional statistical regression technique for the purpose of predicting flow from a local source in a river basin under uncertainty; (c) examine the advantage of the artificial neural networks and neuro-fuzzy system in continuous modeling of the daily and hourly behavior of runoff; (d) examine the advantage of the Takagi-Sugeno fuzzy system over the traditional models in the context of a one-step and multi-step water level estimations; (e) propose a new approach based on a Modified Adaptive Neuro-fuzzy Inference System (Mo-ANFIS) to modify the error correction rule of the Error Back Propagation (EBP method) used in the standard Adaptive Neuro-fuzzy Inference System (ANFIS) and applied to modeling of water level dynamics in a river basin.

Three different locations in Indonesia i.e. Madiun Regency, East-Java; Citarum river basin, West-Java; and Cilalawi river basin, West-Java were selected as the study areas.

The results indicate that fuzzy c-means clustering applied in the operation characteristics of groundwater pumps have reached encouraging results. The final result comprises of four groups; one group with low utilization and one group with high utilization of groundwater pumps for irrigation, whereas the remainder belonged to a less moderate utilization group and a moderate utilization group. Pumps operating in Region I was dominated by shallow groundwater pumps with low discharge. Region II and III were dominated by medium to deep groundwater pumps. Region IV was dominated by deep well pump and exploited more intensively than those in the other groups.

The simulation results to provide the uncertainty associated with the estimation of flow using a Monte Carlo simulation at 95% confidence intervals indicated that the neuro-fuzzy model was more accurate in predicting river flow dynamics. The neuro-fuzzy model was able to improve the RMSE and MAPE values of multiple linear regression forecasts of about 13.52% and 10.73% respectively. In addition, the inspection results of the comparative study of artificial neural networks and neuro-fuzzy system in continuous modeling of runoff indicated that although the model built on transformed data outperforms the model built on raw data, no significant differences were found between the forecast accuracies of the three examined models. Getting into more details, it is worth mentioning that the neuro-fuzzy predictor provided quite better results than those of the Levenberg-Marquardt-FFNN and the Bayesian regularization-FFNN.

From the numerical comparison results of the Takagi-Sugeno fuzzy modeling method with the results of the conventional linear regression model, it was found that the Takagi-Sugeno fuzzy approach was more accurate in predicting one-step and multi-step ahead of water level dynamics in a river basin than the conventional multiple linear regression approach. The Takagi-Sugeno fuzzy system was able to make a proper fuzzy rule from the training data set, which might be considered as one the main advantages of the Takagi-Sugeno fuzzy system.

The performance comparison between the proposed Mo-ANFIS and standard ANFIS models for predicting the water level dynamics confirms that the proposed model provides a more accurate estimation, and the training required to achieve acceptable accuracy was very fast compared to the standard ANFIS model. In order to enables users to process the data, a Mo-ANFIS graphic user interface (GUI) was also developed. The Mo-ANFIS based GUI was found to be useful due to its interactive nature, flexibility in approach and evolving graphical features and can be adopted for any similar situation to predict the river water level. The main data processing includes the gauging station selection, input generation, lead-time selection/generation, and period of prediction. The program code consists of a set of files, which can as well be modified to match other purposes.