한국환경과학회 봄 학술발표회지 제16권(제1호). 218~222. 2007
Proceedings of the Korean Environmental Sciences Society Conference, May, 18~19, 2007

OE9)

Modeling of the Nonlinear Time Series

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1. Introduction

Evaporation and evapotranspiration are an indicative change of moisture efficiency for the study basin and their quantities can be used to estimate streamflow discharge in the river. Evaporation is an element of hydrologic cycle, which can be generally estimated by the indirect methods such as mass transfer, energy budget, and water budget methods. Many researchers have tried to estimate the evaporation by the methods using meteorological variables, but most of these techniques require the data which can not be easily obtained (Burman, 1976; Christiansen, 1966). The estimation of evapotranspiration from plant surface can be regarded as the basic element in the computation of water budget and in the estimation of demand and supply of water. The empirical approach based on climatic variables is generally used toestimate evapotranspiration (Allen et al., 1989; Penman, 1948). Jensen et al. (1990) measured the evapotranspirations by lysimeter at the 11 stationslocated in the different climatic zones of each region over the world and compared the results with 20 different empirical equations and methodologies for the measurements. As a result, the Penman-Monteith (PM) method showed the optimal results over all the climatic zones. Therefore, if the observed data of evapotranspiration does not exist, PM method can be considered as a reference methodology for comparing other equations (FAO, 1990).

The purpose of this study is to develop and apply the generalized regression neural networks model (GRNNM) embedding the genetic algorithm (GA) for the estimation and calculation of the pan evaporation (PE) which is missedor ungauged and the alfalfa reference evapotranspiration (ETr) which is not measured in South Korea. Actually, the alfalfa reference evapotranspiration should be measured by lysimeterbut we do not have the measured data. In the case there is no measured alfalfa reference evapotranspiration data, the American Society of Civil Engineers (ASCE) recommended that PM method can be used as a standard one for the estimation of reference evapotranspiration data. Therefore, this study assumes that the estimated data by PM method can be considered as the alfalfa reference evapotranspiration and develops the reasonable GRNNM-GA algorithm for the estimation of the pan evaporation and the alfalfa reference evapotranspiration.

2. Neural networks model and genetic algorithm

2.1. Concept of generalized regression neural networks model

The generalized regression neural networks model (GRNNM), which is applied to this study, is the modified forms of radial basis function neural networks model (RBFNNM). GRNNM iscomposed of four layers, that is, input layer, hidden layer, summation layer, and output layer. And GRNNM is the neural networks model based on the nonlinear regression theory. Input layer, hidden layer, and summation layer nodes are connected completely,whereas output layer node is connected with only some of summation layer nodes. Summation layer is composed of two kinds of nodes including several summation nodes and one division node. The number of summation nodes is equal to that of output layer nodes. Division nodes do not use transfer function, but equals adding up the weighted transfer values of hidden layer nodes. Each output layer node is connected with the summation node and division node of summation layer, and the connection weight is not composed between summation layer and output layer(Kim et al., 2001; Specht, 1991; Tsoukalas and Uhrig, 1997; Wasserman, 1993).

2.2. Genetic algorithm

Holland(1975) presented the use of the genetic algorithm as the searching method in the mixed optimization for the first time. The genetic algorithm, which is different from many kinds of traditional searching method, is operated as not a single but the population of solutions. Each chromosome of the population is the perfect specification forthe selected decision variables of the problem. Chromosomes experience the process of recombination through the cycle called evaluation, selection, and generation. Chromosomes can survive through many generations or can experience crossover in the next generation through the policy of generation gap by the designer of genetic algorithm. The genetic algorithm evolves the population of chromosomes for many generations until it reaches the final threshold. So, the genetic algorithm is used to examine the fitness to determine the objective in population's survival of the fittest and reproduction.

3. Research scope and data

This study selected the meteorological stations, which can represent the whole land of our country, among the 71 meteorological stations including Jeju-do under the control of Korea Meteorological Administration (KMA). The selected meteorological stations should be first distributed over the whole country, and so should represent each region, and then should possess the meteorological data of at least more than 30 years. And, because the important meaning of pan evaporation data decreased owing to rapid urban development, the station, which is appropriate for this study, should have stopped the measurement of small pan evaporation since 1990. Thus, the meteorological stations, which are appropriate for these conditions, are the total of 14 meteorological stations, including Gwangju, Gunsan, Daegu, Buyeo, Seoul, Seongsanpo, Ulsan, Wonju, Inje, Jeonju, Cheongju, Tongyoung, Pohang, and Haenam meteorological stations.

4. Application of the GRNNM-GA

4.1. Training performance

This study set up, as the training data of GRNNM-GA, the 5-year data from 1985 to 1989 among the daily meteorological data from 1985 to 1992 in 14 meteorological stations. So, the total number of the data used for the training is composed of 1,826 data time series. The statistical index for examining the performance of GRNNM-GA in this study is correlation coefficient (CC), root mean square error (RMSE), and modeling bias (MB).

4.2. Testing performance

This study set up, as the testing data of GRNNM-GA, the 1-year data of 1990 among the daily meteorological data from 1985 to 1992 in 14 meteorological stations. The testing performanceapplied the cross-validation method in order to overcome the over-fitting problem of GRNNM-GA. The cross-validation method is not to train all the training data until GRNNM-GA reaches the minimum RMSE, but is to cross-validate with the testing data at the end of each training stage. Generally, the maximum 40% of the total training data are used as the testing data, and this study used, as the testing data, the 1-year data equivalent to 20% of the total training data, which are composed of 365 data time series in 1990. If the over-fitting problem occurs, the convergence process over the mean square error of testing data will not decrease but will increase as the training data are still trained (Bishop, 1994; Kim, 2005).

4.3. Reproduction performance

This study executed the reproduction performancein order to complement and expand the missing data in 14 meteorological stations, which had stopped observing the pan evaporation since 1990. According to the results of training and testing performance, the statistical results of COMBINE-GRNNM-GA (Type-1), which used both the extreme and average values of climatic variables, were better than those of EXTREME-, and AVERAGE-GRNNM-GA, which used only the extreme or average values of climatic variables. So, this study reproduced the missing pan evaporation time series by using the optimal parameter estimated from the training and testing results of COMBINE-GRNNM-GA (Type-1). And, this study examined the reliability of PM method by comparing the reproductive alfalfa reference evapotranspiration with the data estimated by PM method.

5. Conclusion and future research tasks

This study developed and applied the GRNNM-GA in order to expand the pan evaporation and estimate the alfalfa reference evapotranspiration in 14 major meteorological stations, which had stopped observing the pan evaporation owing to the rapid economic growth and urbanization in South Korea. The applied GRNNM-GA was composed of COMBINE-GRNNM-GA (Type-1), EXTREME-GRNNM-GA (Type-2), and AVERAGE-GRNNM-GA (Type-3) according to the kinds of climatic variables forming the input layer node. The output layer node for each model was composed of the pan evaporation and the alfalfa reference evapotranspiration. According to the results of the training, testing, and reproduction performances, The results of COMBINE-GRNNM-GA (Type-1) were better than those of EXTREME-GRNNM-GA (Type-2), and AVERAGE-GRNNM-GA (Type-3), and the results of the alfalfa reference evapotranspiration were better than those of the pan evaporation. so the more the number of available meteorological data was, the better the results were. Also, further continuous studies needs to analyze the uncertainty for the input layer node of COMBINE-GRNNM-GA (Type-1), which induced the reasonable results in this study, and so recompose the optimal COMBINE-GRNNM-GA (Type-1), and induce the correlation relationship between the pan evaporation and the alfalfa reference evapotranspiration, and then construct the map of annual pan evaporation and alfalfa reference evapotranspiration in South Korea.

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