UNIVERSITI PUTRA MALAYSIA

ANT COLONY OPTIMIZATION AND GENETIC ALGORITHM MODELS FOR SUSPENDED SEDIMENT DISCHARGE ESTIMATION FOR GORGAN- RIVER, IRAN

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By

OMOLBANI MOHAMMAD REZA POUR

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

March 2011

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DEDICATION

Dedicated to my parents “mother and father” and to my lovely son “Ahoura”

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Abstract of thesis presented to the Senate of University Putra Malaysia in fulfilment of the requirement of the degree of Doctor of Philosophy

ANT COLONY OPTIMIZATION AND GENETIC ALGORITHM MODELS FOR SUSPENDED SEDIMENT DISCHARGE ESTIMATION FOR GORGAN - RIVER, IRAN

By

OMOLBANI MOHAMMAD REZA POUR

March 2011

Chairman: Prof. Dr. Lee Teang Shui

Faculty: Engineering

ABSTRACT

Suspended sediment transport by rivers is an important phenomenon in the science of sedimentation in river engineering. Empirical relations, such as sediment rating curves, are often applied to determine the average relationship between discharge and suspended sediment loads. These types of model generally underestimate or overestimate the amount of sediment. Notably, the direct measurement of sediment loads is very expensive to implement. Various models have been developed so far to identify the relationship between discharge and sediment loads. Most of the models, based on the regression method, have some restrictive assumptions. In recent years, some black box models based on artificial neural networks have been developed to overcome this problem. Therefore, it is still necessary to develop the model for the discharge-sediment relationship. New models based on artificial intelligence models, namely; Ant Colony Optimization (ACO) and Genetic Algorithm (GA) are now

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being used more frequently to solve optimization problems. Hence, the main purpose of this study was to apply ACO and GA in order to identify the relationship between stream flow discharge and suspended sediment discharge for estimation of sediment loads for the Nodeh Station at the Gorgan River in Iran. In this study, to identify the relationship between the suspended sediment discharge and flow discharge for each model, data from around 600 samples of suspended sediment discharge and flow discharge at Nodeh Station on the Gorgan River in Iran were used. Also, the daily flow discharge was used for the estimation of suspended sediment load for Nodeh station. After testing each model, the best relationship between suspended sediment discharge and flow discharge for all methods were found, and the suspended sediment load was estimated for Nodeh station from 1978-2008. The training and testing data sets were chosen based on the K-fold method of cross validation to find the optimal classifier. In the first part of this study, the sample data, which included suspended sediment discharge and flow discharge, were used as the inputs to the ant colony optimization and genetic algorithm models to identify the relationship between the suspended sediment discharge and flow discharge. Three methods based on the dividing of used data into monthly, seasonally and annually time bases were used by each model to identify the relationship between suspended sediment discharge and flow discharge for estimate the suspended sediment. Different input combinations of ACO and GA models (i.e. ACO1 and GA1: the suspended sediment estimation based on current discharge; ACO2 and GA2: the estimation of suspended sediment based on current and one day of previous discharges; and ACO3 and GA3: the suspended sediment estimation based on current, one and two-day of previous discharges) were chosen based on similar meteorological requirements to those of the suspended sediment equations included in this study. The accuracy of the ACO and

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GA models was also compared with the empirical model of the sediment rating curve (SRC) technique. The models were compared based on statistical criteria, namely; the Regression Coefficient (R^2) and the Root Mean Square Error (RMSE). The results of the monthly method indicated that ACO model with inputs of current discharge (ACO1) model provided better performance as compared to the other ACO models. As seen from results for majority of related months (about 10 month) the ACO1 had the lowest RMSE and the highest R^2. In this case, for example, in May, the RMSE and R^2 values for the ACO1 model were 28.98 and 0.37, respectively. On the other hand, the RMSE and R^2 for the ACO2 model were 50.48 and 0.38, respectively, and 31.80 and 0.11, accordingly for the ACO3 model. Also, the GA2 model was more accurate than the GA1 and GA3 models because from results for majority of related months (about 8 month) the GA2 had the lowest RMSE and the highest R^2. For example in Aril, the RMSE and R^2 values for the GA1 model were 117.83 and 0.68, respectively. On the other hand, the RMSE and R^2 values for the GA2 model were 86.93 and 0.74, and as for the GA3 model, they were 130.2 and 0.63, correspondingly. The findings in this study showed that the performance of the GA model was inferior than the ACO and SRC techniques when the inputs of the GA, ACO and rating curve models comprised only the current discharge. As seen from the results, the ACO1 model approximated the corresponding of the observed suspended sediment values better than the rating curve and GA2 techniques. The GA2 also performed better than the SRC model. It was seen from the results that both the low and high sediment values and in general the overall shape of the sediment time series were closely approximated by the ACO1 for the monthly method. The ACO1, GA1 and SRC models were applied to identify the relationship between the suspended sediment discharge and flow discharge for annually and

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seasonally methods. For the annually method the result showed that the GA1 has good performance than sediment rating curve and ACO1 techniques. In this case the RMSE and R^2 values for the ACO1 model were 14.06 and 0.79, respectively. On the other hand, the RMSE and R^2 for the GA1 model were 10.47 and 0.79, respectively, and 16.59 and 0.73, accordingly for the SRC model. In addition, as for the seasonal suspended sediment estimation, it can be obviously seen from this result that the ACO1 model performed much better than the rating curve techniques for spring and winter. Conversely, the SRC model for summer and autumn is much better than ACO. Furthermore, it can be observed from Table 4.27 that the performance of the ACO1 model was much better than the GA1 techniques in summer and winter, while the GA1 was much better in spring and autumn. The comparison between the GA1 and SRC models showed that the GA1 model for spring had more accuracy than the SRC model. Conversely, the accuracy of the SRC model in summer, autumn and winter were much better than GA1. Comparison between the ACO1 model and SRC showed that the ACO1 model had more accuracy in spring and winter, whereas the accuracy of SRC in summer and autumn was better than ACO1. From these results, it can be concluded that GA1 for spring, SRC for summer and autumn and ACO1 for winter are good models for estimating suspended sediment using the seasonal method at Nodeh station. From the above-mentioned results, it can be concluded that the suspended sediment discharge had a good relationship with the current discharge for the ACO model and a good relationship with the current discharge and one-day previous discharge for the GA model, whereas there was a weak relationship between the two-day previous discharge and suspended sediment discharge for both ACO and GA. For the evolution of parameters **a** and **b** from SRC, GA1 and ACO1,

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their characteristics were explored using the monthly and seasonal methods.

Key world: suspended sediment estimation, rating curve, Ant colony optimization, Genetic Algorithm, Gorgan River, Iran

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Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGOPTIMUMAM KOLONI SEMUT DAN MODEL GENETIK ALGORITMA UNTUK MENGANGGAR PENGELUARAN SEDIMEN BEKU DI SUNGAI GORGAN, IRAN

Olah

OMOLBANI MOHAMMAD REZA POUR

2010

Pengerusi: Profesor Lee Teang Shui Ph.D.
Faculti: Kejurteraan

ABSTRAK

Suspended sedimen yang diangkut oleh sungai merupakan fenomena penting dalam ilmu sains berkaitan teknik sedimentasi di sungai. Hubungan secara empirikal, seperti lengkungan debit sedimen, adalah yang sering digunakan untuk menentukan hubungan antara debit dan beban sedimen tersuspensi. Jenis - jenis model seperti ini umumnya terlalu merendahkan atau terlaluu melebihi bilangan sedimen.

Terutamanya, pengukuran sedimen secara langsung adalah terlalu mahal untuk dilaksanakan. Berbagai model telah dibangunkan selama ini untuk mengenalpasti hubungan antara beban debit dan juga sedimen. Sebahagian besar model adalah berdasarkan kaedah regresi dan mempunyai beberapa andaian yang menyekat dan membantutkan perjalanan penyelidikan. Dalam beberapa tahun terakhir, beberapa model kotak hitam yang berdasarkan rangkaian saraf tiruan telah dibangunkan untuk

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mengatasi masalah ini. Oleh kerana itu, pembangunan model tersebut adalah lebih penting dan ia masih diperlukan untuk membangunkan model bagi hubungan debit-sedimen. Model baru yang didasarkan pada model kecerdasan buatan, iaitu; Ant Colony Optimization (ACO) dan Algoritma Genetik (GA) kini lebih sering digunakan untuk menyelesaikan masalah pengoptimuman. Oleh kerana itu, tujuan utama dari penelitian ini adalah untuk melaksanakan ACO dan GA untuk mengenalpasti hubungan antara debit aliran sungai dan debit sedimen layang untuk estimasi muatan sedimen untuk Stesen Nodeh di Sungai Gorgan di Iran. Dalam kajian ini, bagi mengenalpasti hubungan antara debit sedimen layang dan debit aliran bagi setiap model, sekitar 600 sampel debit sedimen tersuspensi dan tarikh debit aliran di Stesen Nodeh di Sungai Gorgan di Iran digunakan. Setelah mengenalpasti hubungan antara debit sedimen dan aliran ditangguhkan, debit aliran harian dari tahun 1978 hingga 2008 digunakan untuk estimasi muatan sedimentasi untuk stesen Nodeh. Latihan dan ujian data set dipilih berdasarkan kaedah K-kali ganda dari validasi silang untuk mencari klasifikasi optimum. Pada bahagian pertama kajian ini, data sampel, termasuklah debit sedimen tersuspensi dan debit aliran, digunakan sebagai masukkan kepada pengoptimuman Koloni semut dan model algoritma genetik untuk mengenalpasti hubungan antara debit sedimen layang dan debit aliran.Tiga kaedah berdasarkan penjagaan data yang digunakan dalam tempoh bulanan, bermusim dan tahunan pangkalan masa yang digunakan oleh untuk mengenal pasti hubungan antara debit sedimen layang dan debit aliran untuk menganggarkan sedimen tersuspensi. Kombinasi input yang berbeza antara ACO dan model GA (iaitu ACO1 dan GA1: anggaran sedimen tersuspensi berdasarkan debit saat ini; ACO2 dan GA2: estimasi sedimen tersuspensi berdasarkan saat ini dan satu hari sebelumnya debit, dan ACO3 dan GA3: sedimen tersuspensi berdasarkan

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anggaran saat ini, satu dan dua-hari (discharge dahulu) dipilih berdasarkan keperluan meteorologi sama dengan persamaan sedimen tersuspensi termasuk dalam kajian ini. Ketepatan model ACO dan GA juga dibandingkan dengan model empirik dari kurva rating sedimen teknik (SRC). Model tersebut berbanding berdasarkan kriteria statistik, iaitu; Koefisien regresi (R^2) dan Root Mean Square Error (RMSE). Hasil dari kaedah bulanan menunjukkan bahawa ACO model dengan masukkan debit arus (ACO1) model yang disediakan prestasi yang lebih baik berbanding dengan model ACO lain.

Seperti yang dilihat dari keputusan untuk majoriti bulan berkaitan (abaut 10 bulan) yang ACO1 mempunyai RMSE terendah dan R^2 tertinggi. Dalam hal ini, misalnya, pada bulan Mei, nilai RMSE dan R^2 untuk model ACO1 adalah 28.98 dan 0.37, masing-masing. Di sisi lain, RMSE dan R^2 untuk model ACO2 adalah 50.48 dan 0,38, masing-masing, dan 31.80 dan 0.11, sesuai untuk model ACO3. Begitu juga, model GA2 lebih tepat dari model GA1 dan GA3 kerana dari hasil untuk sebahagian besar bulan berkaitan (sekitar 8 bulan) GA2 yang mengandungi RMSE terendah dan R^2 tertinggi. Misalnya di Aril, nilai-nilai RMSE dan R^2 untuk model GA1 adalah 117.83 dan 0.68, masing-masing. Di sisi lain, nilai-nilai RMSE dan R^2 untuk model GA2 adalah 86.93 dan 0.74, dan untuk model GA3, mereka 130.2 dan 0.63, Seiring penemuan kajian ini menunjukkan bahawa prestasi dari model GA lebih rendah daripada daripada ACO dan teknik SRC ketika memasukkan dari GA, ACO dan model rating kurva hanya terdiri debit saat ini. Seperti yang dilihat dari hasil, model ACO1 mendekati yang sesuai dari sedimen tersuspensi diamati nilai lebih baik dari kurva rating dan teknik GA2. GA2 juga dilakukan lebih baik berbanding dengan model SRC. Hal itu terlihat dari hasil yang baik nilai-nilai sedimen rendah dan tinggi

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dan pada umumnya bentuk keseluruhan dari time series sedimen yang erat didekati oleh ACO1 untuk kaedah bulanan.

The ACO1, GA1 dan model SRC yang tersirat untuk mengenalpasti hubungan antara debit sedimen layang dan debit aliran untuk setiap tahun dan bermusim kaedah. Untuk setiap kaedah hasilnya menunjukkan bahawa GA1 mempunyai prestasi yang baik berbanding dengan kurva sedimen rating dan teknik ACO1. Dalam hal ini nilai-nilai RMSE dan R^2 untuk model ACO1 adalah 14.06 dan 0.79, masing-masing. Di sisi lain, RMSE dan R^2 untuk model GA1 adalah 10.47 dan 0.79, masing-masing, dan 16.59 dan 0.73, sesuai untuk model SRC. Selain itu, seperti untuk hubungan bermusim antara debit sedimen layang dan debit aliran, boleh jelas dilihat dari hasil bahawa model ACO1 dilakukan jauh lebih baik daripada teknik kurva rating untuk musim semi dan musim dingin, sebaliknya model SRC digunakan ketika musim sejuk, musim panas dan musim luruh.

Tammbahan pula, apa yang dapat kita amati sekarang, jauh lebih baik dari ACO. Selain itu, dapat diamati dari hasil bahawa prestasi dari model ACO1 jauh lebih baik daripada GA1 teknik di musim panas dan musim dingin dan GA1 jauh lebih baik di musim semi dan musim luruh. Perbandingan antara model GA1 dan SRC menunjukkan model GA1 hanya untuk musim semi kerana mempunyai ketepatan lebih dari model SRC. Perbandingan antara model ACO1 dan SRC menunjukkan model ACO1 mempunyai ketepatan yang lebih di musim semi dan musim dingin, sebaliknya ketepatan SRC pada musim panas dan musim luruh adalah lebih baik daripada ACO1. Daripada hasil tersebut, dapat disimpulkan bahawa GA1 bersesuaian untuk musim semi, SRC untuk musim panas dan musim luruh dan

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musim sejuk ACO1 mempunyai prestasi yang baik untuk menganggarkan sedimen yang tersuspensi dalam kaedah bermusim di stesen Nodeh.

Kata Kunci: estimasi sedimen tersuspensi, kurva penilaian, pengoptimuman Ant tanah jajahan, Algoritma Genetik, Sungai Gorgan, Iran

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APROVAL

I certify that an Examination Committee has met on 31/March/2011 to conduct the final examination of Omolbani Mohammad Reza Pour on his Doctor of Philosophy thesis entitled "Ant Colony Optimization and Genetic Algorithm models for suspended sediment discharge estimation for Gorgan - River, Iran" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the Doctor of Philosophy. Members of the Examination Committee are as follows:

Chairman

Prof. Madya Dr. Abdul Halim Ghazali

Faculty of Engineering
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BUJANG KIM HUAT, PhD
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Date:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy.

The members of the Supervisory Committee were as follows:

Lee Teang Shui, PhD
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(Chairman)

Desa Bin Ahmad, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
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_____

HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at University Putra Malaysia or at any other institution.

OMOLBANI MOHAMMAD REZA POUR

Date: 31 March 2011

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