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Predicting the Water Quality of Kodaikanal Lake Using Genetic Programming

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ABSTRACT: Lake has been an important surface water source from ages but since the past two centuries the quality of lake water has been altered drastically and undoubtedly human intervention has been the primary cause for the deterioration. With alteration in lake water quality the water scarcity issues have increased quite considerably. So, keeping in view the urgency to restore lake this study has been initiated. Since lakes are vast water bodies physical analysis of every parameter is practically complex hence modeling studies are adopted using Genetic Programming (GP) tool, which is based on Darwin's theory of survival of fittest. This paper predicts the water quality parameters and the stimulation model was developed which was based upon the testing of data using the tool Genetic Programming.

KEYWORDS: Genetic programming, lake water sampling, physico-chemical and ecological role.

I. INTRODUCTION

Lakes are an important feature of the Earth's landscape. They are extremely valuable ecosystems and provide a range of goods and services to humankind .The lakes and reservoirs, all over the country without exception, are in varying degrees of environmental degradation which is due to encroachments eutrophication (from domestic and industrial effluents) and silt. Limnology is the study of the biological, chemical and physical features of lakes and other bodies of fresh water .In Tamil Nadu State, under Monitoring of Indian National Aquatic Resources (MINARS) programme funded by Central Pollution Control Board (CPCB), the water quality of 8 major lakes such as Ooty, Kodaikanal, Yercaud, Pulicat, Poondi, Red Hills, Veeranam and Porur are monitored by Tamil Nadu Pollution Control Board (TNPCB) on monthly basis by collecting water samples.BOD was found to be more than the criteria level in Kodaikanal, Yercaud and Porur lakes. This is mainly due to mixing of sewage and contaminated surface-runoff into lakes. It is very important to predict the water quality which can enhance economic efficiency as a result. However water quality prediction becomes a very complicate issue due to the complexity and diversity. Genetic Programming is an evolutionary algorithm based on Darwinian theories of natural selection and survival of the fittest. The algorithm considers an initial population of randomly generated equations, derived from the random combination of input variables, random numbers and functions. The function can include arithmetic operators (plus, minus, multiply and divide), mathematical functions (sin, cos, exp, log) etc., which has to be chosen based on some understanding of the process. This population is then subjected to an evolutionary process and the fitness of the evolved programs are evaluated; individual programs that best fit the data are then selected from the initial population. The programs that best fit are selected to exchange part of the information between them to produce better program through 'crossover' and 'mutation'. The user must decide a number of GP parameters before applying the algorithm to the data. The program that fitted the data less well is discarded. This evolution process is repeated over successive generation and is driven towards finding symbolic expressions describing the data, which can be scientifically interpreted to derive knowledge about the process being modeled. Genetic Program writes computer programs from data given to it. These data are contained in "training data", "validation data" and "applied (or testing) data" that is provided in Genetic Programming. In order to emphasize the hydrological, ecological role of the Kodaikanal Lake and the restoration of the aesthetic appearance this study will enhance good solutions. This study also assesses the Physico-chemical and biological quality of the Kodaikanal lake and to check whether the lake requires bioremediation programme.

The remainder of this paper is organized as follows: section II overviews the related work. Section III gives a study area Section IV explains the methodology in detail. Section V presents the results and analysis and section VI covers the conclusion.

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II. RELATED WORK

Roberto Bertoni, et.al(2016) introduced a set of quantitative tools that can help in predicting current environmental challenges avoiding such restrictions is currently being researched and developed within the framework of ecological informatics. One of these approaches attempting to model the relationship between a set of inputs and known outputs is based on Genetic Algorithms (GA) and Genetic Programming (GP). This stochastic optimization tool is based on the process of evolution in natural systems and was inspired by a direct analogy to sexual reproduction and Charles Darwin's principle of natural selection. GP is an evolutionary algorithm that uses selection and recombination operators to generate a population of equation. Lake Maggiore (Northern Italy) is the ideal case study to test the predictive ability of GP. Testing of GP on the multi-year data series of this lake has allowed us to verify the forecasting efficacy of the models emerging from GP application[5].

Carolina Dona, et.al(2016) described Lake eutrophication is a critical issue in the interplay of water supply, environmental management, and ecosystem conservation. Integrated sensing, monitoring, and modelling for a holistic lake water quality assessment with respect to multiple constituents is in acute need. The aim of this paper is to develop an integrated algorithm for data fusion and mining of satellite remote sensing images to generate daily estimates of some water quality parameters of interest, such as chlorophyll a concentrations and water transparency, to be applied for the assessment of the hypertrophic Albufera de Valencia. The Albufera de Valencia is the largest freshwater lake in Spain, which can often present values of chlorophyll a concentration over 200 mg•m -3 and values of transparency (Secchi Disk, SD)[4].

Bhoir Saurabh Hemant, et.al (2014) applied the mathematical models for the purpose of dates back to the initial studies of oxygen depletion due to organic waste pollution. Since then, models have been constantly refined and updated to meet new and emerging problems of surface water pollution, such as eutrophication, acute and chronic toxicity, etc. In order to handle the complex interactions caused by the increased influence of human activities in rivers. It is today mandatory to couple river water quality models with model describing emissions from the drainage and sewerage system. Special attention is given here to the modeling of convergence processes, but also the methods and tools to work with the models i.e. parameter estimation, software QUAL2E are discussed. In our project, we found out the parameters present in respective stretch and pollutant concentration[2].

Y.R. Ding, et.al (2014) proposed that it is very critical to establish a water quality prediction system. Combined Principal Component Analysis (PCA), Genetic Programming (GP) and Back Propagation Neural Network (BPNN), a hybrid intelligent algorithm is designed to predict river water quality. Firstly, PCA is used to reduce data dimensionality. 23 water quality index factors can be compressed into 15 aggregative indices. PCA improved effectively the training speed of follow-up algorithms. Then, GP optimizes the parameters of BPNN. The average prediction rates of non-polluted and polluted water quality are 88.9% and 93.1% respectively, the global prediction rate is approximately 91%. The water quality prediction system based on the combination of Neural Networks and Genetic Algorithms can accurately predict water quality and provide useful support for real-time early warning systems[8].

Yang, Likun,et.al(2014) proposed that the algorithm efficiency often limits their application in multi-parameter eutrophication models. In this study, a genetic algorithm was integrated into a Bayesian method to improve sampling performance during the parameter calibration process. An eutrophication model of an urban lake in north China (Tianjin) is established based on biological processes and external loads. A Markov chain Monte Carlo method coupled with a genetic algorithm (MCMC-GA) is developed to sample the posterior parameter distributions and calculate the simulation results. Then, the performances of the MCMC-GA and classical MCMC are compared and analyzed. Finally, a water quality assessment is conducted for eutrophication management. The results are as follows: (1)the MCMC-GA displays a better convergence efficiency during parameter sampling, higher Markov chain quality, and narrower 95% upper and lower confidence intervals than the classical MCMC method; and (2) rainwater runoff nutrient loading must be controlled for urban lake restoration. Shuming Liu,et.al(2007) made an attempt to calibrate a diffuse pollution model using a genetic programming (GP). Designed to simulate the export of phosphorus from diffuse sources(agricultural land) and point sources (human), the Phosphorus Indicators Tool (PIT) version 1.1, on which this paper is based, consisted of 78 parameters. Previous studies have indicated the difficulty of full range model calibration due to the number of parameters involved. In this paper, a GP was employed to carry out the model calibration in which all parameters were involved. A sensitivity analysis was also performed to investigate the impact of operators in the GP on its effectiveness

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Volume 5, Issue 3, March 2018

in optimum searching. The calibration yielded satisfactory results and required reasonable computing time. The application of the PIT model to the Windrush catchment with optimum parameter values was demonstrated. The annual P loss was predicted as 4.4 kg P/ha/yr, which showed a good fitness to the observed value[7].

Egeman Aras, et.al (2007) described that Conventional mathematical programming methods, such as linear programming, non linear programming, dynamic programming and integer programming have been used to solve the cost optimization problem for regional wastewater treatment systems. In this study, a river water quality management model was developed through the integration of a genetic programming (GP). This model was applied to a river system contaminated by three determined discharge sources to achieve the water quality goals and wastewater treatment cost optimization in the river basin. The genetic algorithm solution, described the treatment plant efficiency, such that the cost of wastewater treatment for the entire river basin is minimized while the water quality constraints in each reach are satisfied. This study showed that genetic algorithm can be applied for river water quality modeling studies as an alternative to the present method[6].

Su-Young Park, et al(2006) proposed an integrated technique which uses a genetic programming (GP) and a geographic information system (GIS) for the design of an effective water quality monitoring network in a large river system. The criteria include the outline of a river system, compliance with water quality standards, supervision of water use, surveillance of pollution sources and examination of water quality changes. The fitness levels were obtained through a series of calculations of the fitness functions using GIS data. A sensitivity analysis was performed for major parameters such as the numbers of generations, population sizes and probability[3].

III. STUDY AREA

Kodaikanal lake is in Dindigul district of Tamilnadu situated at elevation of 2285meters having an Altitude of 2133 meters above sea level with an area of 21.45 Sq. Kms with Population of 32,931 (2001Census) Annual Rainfall of 165 Cm (average), heavy rain season is between October and December. The climate is salubrious with summer temperatures of 19.8°C (max) and 11.3°C (min) and winter temperatures of 17.3°C (max) and 8.3°C (min). Kodaikanal town is one of the best hill station of Tamilnadu and kodaikanal lake is the main attraction of tourists.kodaikanal lake has been formed during 1863 by then collector of Madurai district sir Venci henry Levin. The water spread area of the lake is 26.30 Hectares. Its maximum depth is 11.50 metre and average depth is 3 metre. The lake is situated at 10 deg 14' n latitude and 77 deg 28' longitude and it looks magnificent with star shaped glittering water, in the midst of evergreen lush slopes. An earthen dam was constructed to create the lake in a marshy where three streams flowed.

IV.METHODOLOGY

The samples are collected from 5 sampling sites of kodaikanal lake which was located in dindigul district of TamilNadu. The samples were analyzed, and characterized.

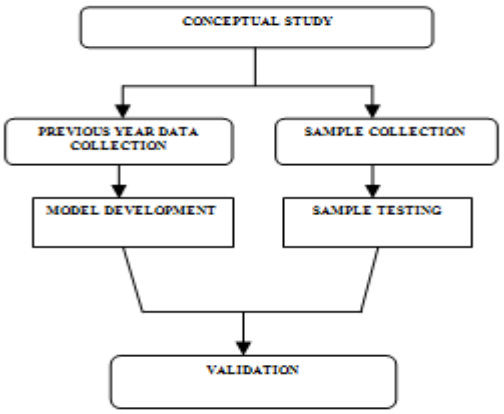

Fig1: Methodology flow chart

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Visit: www.ijmrsetm.com

Volume 5, Issue 3, March 2018

Lake water sampling

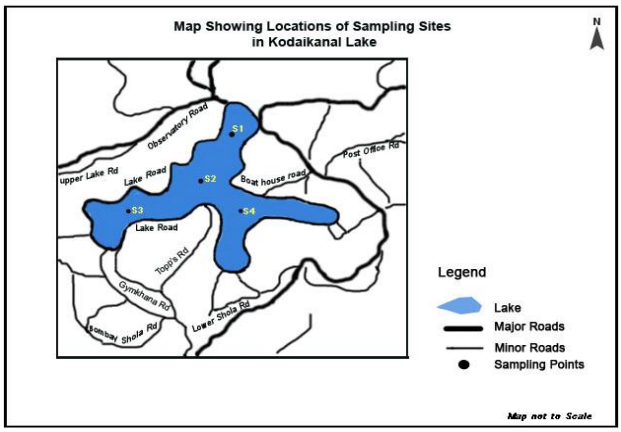

Fig 2: Sampling locations

The sampling sites are mentioned as S1,S2,S3 and S4.This map showing the locations of sampling sites in Kodaikanal lake.

Previous Water Quality Data of Kodaikanal Lake for Model development

The Previous year water quality data for the kodaikanal lake were collected and the parameters are given in the Table below.

S.NO	YEARS	PARAMETERS		
		PH	BOD	DO
1	2001	6.3	10.8	6.7
2	2002	6.8	5.7	6.6
3	2003	7.3	6.9	6.1
4	2004	6.1	7	7
5	2005	6.1	7.9	5.5
6	2006	6.4	2.7	6.4
7	2007	6.14	2.01	6.53
8	2008	7.05	4.9	6.2
9	2009	6.81	4.7	6.6
10	2010	6.51	7	6.06
11	2011	6.66	7.27	5.85
12	2012	6.51	9	6.36
13	2013	7.01	6	5.7
14	2014	7.88	4.83	5.03
15	2015	7.1	5	4

Table 1: Previous year water quality data for Kodaikanal Lake

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Testing data of samples

PARAMETERS	RESULTS				
	LOCATION1	LOCATION2	LOCATION3	LOCATION4	LOCATION5
PH	7.9	8.10	8.40	7.70	8.20
BOD	4.25	4.32	4.26	4.29	4.37
DO	5.70	5.30	5.40	5.10	5.30

Table 2: Testing data of samples

Out of 14 Data sets, 50% is used for Training, 30% is used for Testing and remaining 20% for Validation. The function set in GP training consists of arithmetic and trigonometric functions.GP is implemented using Disciplus software. The error measure is taken as Regression coefficient R

$$R^2 = 1 - \frac{\sum (y_t - \overline{y_t})^2}{\sum y_t^2 - \frac{\sum \overline{y_t}^2}{n}}$$

V. RESULTS AND ANALYSIS

Kodaikanal refers to a dense forest in Tamil language. The township was established by the British administrators in 1845 on a plateau in the upper Palani Hills (district Indigo) at 2133 m, between the Parappar and Gundar Valleys. A lake was created in 1863 by Vera Levinge, a former District Collector of Madurai by constructing a strong bund across the marshy land with several streams in the valley. The star-shaped Kodai lake in the midst of evergreen shola forest on the surrounding hills (2285m above sea level) is a major attraction of Kodaikanal which is a well known area for tourists. The lake has a water spread of only 25 ha and a maximum depth of 11.5 m which has declined to 9 m during the past 40 years. The average depth is only 3.0 m. The lake is surrounded by a 5 km road. The lake and its surroundings are extensively used by tourists for boating, sailing, angling, walking, cycling, horse riding and other leisure activities.The entire sewage generated from the Kodaikanal Municipality was allowed to enter into the lake without any treatment.The Government of India has sanctioned the proectof 'Revival of Kodaikanal lake ' at an estimated cost of Rs.10.43 crore.The works are to be commenced.Deweeding,aeration and bioremediation are to be carried out by the public works(PWD)at cost of Rs.2.41 crore.Based on the parameters the relationship and values of Ph Dataset,DO and BOD are represented.

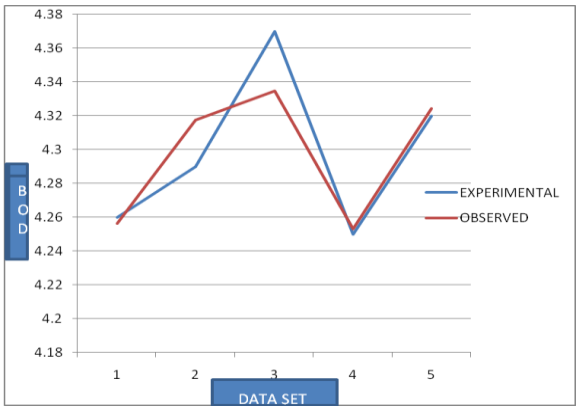

Fig 3: Relationship between BOD and Dataset

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Volume 5, Issue 3, March 2018

Table 3: values of experimental and observed

S.NO	EXPERIMENTAL VALUE OF BOD	OBSERVED VALUE OF BOD
1	4.26	4.256499
2	4.29	4.317306
3	4.37	4.33461
4	4.25	4.25316
5	4.32	4.32409

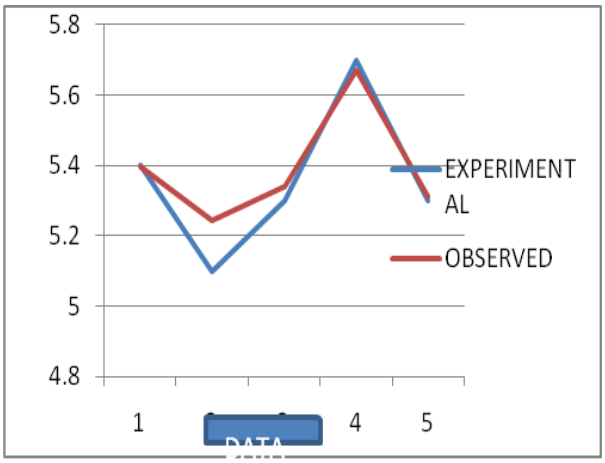

Fig4: Relationship between PH and Dataset

S.NO	EXPERIMENTAL VALUE OF PH	OBSERVED VALUE OF PH
1	8.4	8.325975
2	7.7	7.940563
3	8.2	8.260667
4	7.9	7.950247
5	8.1	8.10143

Table 4: values of experimental and observed

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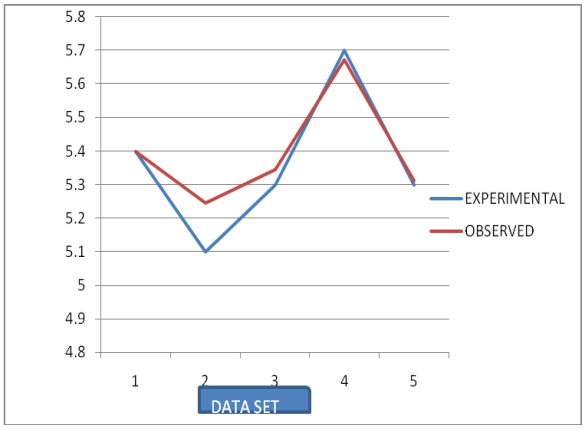

Fig 5: Relationship between DO and Dataset

S.NO	EXPERIMENTAL VALUE OF DO	OBSERVED VALUE OF DO
1	5.4	5.397108
2	5.1	5.244191
3	5.3	5.342861
4	5.7	5.671835
5`	5.3	5.311795

Table 5: values of experimental and observed

VI.CONCLUSION

From the results and discussion it is found that BoD level is continuously changing over the time whereas other parameters such as DO, PH are found to be within the acceptable limit. Kodaikanal town is the one of the best hill station of Tamilnadu and kodaikanal lake is the main attraction of tourists. In order to emphasize the hyrological, ecological role of the kodaikanal lake and the restoration of the aesthetic appearance this study will enhance good solutions. This paper also assesses the Physico-chemical and biological quality of the Kodaikanal lake and to check whether the lake requires bioremediation program.

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Volume 5, Issue 3, March 2018

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