Advances in Intelligent Systems and Computing 584

Millie Pant
Kanad Ray
Tarun K. Sharma
Sanyog Rawat
Anirban Bandyopadhyay *Editors*

Soft Computing: Theories and Applications

Proceedings of SoCTA 2016, Volume 2

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Preface

It is a matter of pride to introduce the first international conference in the series of "Soft Computing: Theories and Applications (SoCTA)", which is a joint effort of researchers from Machine Intelligence Lab, USA, and the researchers and Faculty members from Indian Institute of Technology, Roorkee; Amity University Rajasthan.

The maiden conference took place in the historic city of Jaipur at the campus of research-driven university, Amity University Rajasthan. The conference stimulated discussions on various emerging trends, innovation, practices, and applications in the field of Soft Computing.

This book that we wish to bring forth with great pleasure is an encapsulation of 149 research papers, presented during the three-day international conference. We hope that the initiative will be found informative and interesting to those who are keen to learn on technologies that address to the challenges of the exponentially growing information in the core and allied fields of Soft Computing.

We are thankful to the authors of the research papers for their valuable contribution in the conference and for bringing forth significant research and literature across the field of Soft Computing.

The editors also express their sincere gratitude to SoCTA 2016 Patron, Plenary Speakers, Keynote Speakers, Reviewers, Programme Committee Members, International Advisory Committee and Local Organizing Committee, Sponsors without whose support the support and quality of the conference could not be maintained.

We would like to express our sincere gratitude to Prof. Sanghamitra Bandyopadhyay, Director, ISI Kolkata, for gracing the occasion as the Chief Guest for the Inaugural Session and delivering a Plenary talk.

We would like to express our sincere gratitude to Dr. Anuj Saxena, Officer on Special Duty, Chief Minister's Advisory Council, Govt. of Rajasthan, for gracing the occasion as the Chief Guest for the Valedictory Session.

We would like to extend our heartfelt gratitude to Prof. Nirupam Chakraborti, Indian Institute of Technology, Kharagpur; Prof. Ujjwal Maulik, Jadavpur University; Prof. Kumkum Garg, Manipal University Jaipur; Dr. Eduardo Lugo,

Université de Montréal; Prof. Lalit Garg, University of Malta for delivering invited lectures.

We express our special thanks to Prof. Ajith Abraham, Director, MIR Labs, USA, for being a General Chair and finding time to come to Jaipur amid his very busy schedule.

We are grateful to Prof. W. Selvamurthy and Ambassador (Retd.) R.M. Aggarwal for their benign cooperation and support.

A special mention of thanks is due to our student volunteers for the spirit and enthusiasm they had shown throughout the duration of the event.

We express special thanks to Springer and its team for the valuable support in the publication of the proceedings.

With great fervor, we wish to bring together researchers and practitioners in the field of Soft Computing year after year to explore new avenues in the field.

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About the Editors

Dr. Millie Pant is an associate professor in the Department of Paper Technology, Indian Institute of Technology, Roorkee (IIT Roorkee) in India. A well-known figure in the field of swarm intelligence and evolutionary algorithms, she has published several research papers in respected national and international journals.

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Dr. Tarun K. Sharma has a Ph.D. in artificial intelligence as well as MCA and MBA degrees and is currently associated with the Amity University Rajasthan (AUR) in Jaipur. His research interests encompass swarm intelligence, nature-inspired algorithms, and their applications in software engineering, inventory systems, and image processing. He has published more than 60 research papers in international journals and conferences. He has over 13 years of teaching experience and has also been involved in organizing international conferences. He is a certified internal auditor and a member of the Machine Intelligence Research (MIR) Labs, WA, USA and Soft Computing Research Society, India.

Dr. Sanyog Rawat is presently associated with the Department of Electronics and Communication Engineering, SEEC, Manipal University Jaipur, Jaipur, India. He holds a B.E. in Electronics and Communication, an M.Tech. in Microwave Engineering and Ph.D. in Planar Antennas. Dr. Rawat has been involved in organizing various workshops on "LabVIEW" and antenna designs and simulations using FEKO. He has taught various subjects, including electrical science, circuits and system, communication system, microprocessor systems, microwave devices, antenna theory and design, advanced microwave engineering and digital circuits.

Dr. Anirban Bandyopadhyay is a Senior Scientist in the National Institute for Materials Science (NIMS), Tsukuba, Japan. Ph.D. from Indian Association for the Cultivation of Science (IACS), Kolkata 2005, on supramolecular electronics. During 2005–2008, he was selected as Independent Researcher, ICYS Research Fellow in the International Center for Young Scientists (ICYS), NIMS, Japan, he worked on brain-like bio-processor building. In 2007, he started as permanent Scientist in NIMS, working on the cavity resonator model of human brain and brain-like organic jelly. During 2013–2014, he was a visiting professor in Massachusetts Institute of Technology (MIT), USA. He has received many honors such as Hitachi Science and Technology award 2010, Inamori Foundation award 2011–2012, Kurata Foundation Award, Inamori Foundation Fellow (2011–), Sewa Society International member, Japan, etc.

Geometric phase space model of a human brain argues to replace Turing tape with a fractome tape and built a new geometric-musical language which is made to operate that tape. Built prime metric has to replace space–time metric. Designed and built multiple machines and technologies include: (1) angstrom probe for neuron signals, (2) dielectric imaging of neuron firing, (3) single protein and its complex structure's resonant imaging, and (4) fourth circuit element Hinductor. A new frequency fractal model is built to represent biological machines. His group has designed and synthesized several forms of organic brain jelly (programmable matter) that learns, programs, and solves problems by itself for futuristic robots during 2000–2014, also several software simulators that write complex codes by itself.

Designing ANFIS Model to Predict the Reliability of Component-Based System

Rajni Sehgal, Deepti Mehrotra and Manju Bala

Abstract Predicting reliability of any product is always a desire of quality-oriented industry. The fault-free working of products depends on large number of parameters, and designing a machine learning model that can predict the reliability considering these as input parameters will help to plan testing and maintenance of the product. In this paper, ANFIS approach is adopted to train a model that can predict reliability of component-based software system. The parameters considered for designing the model are standard design metrics which are evaluated for quality benchmarking during software development process.

Keywords FIS · ANFIS · Component-based system · Halstead fault

1 Introduction

There is a close dependency between the software reliability and the quality of a software system. Software reliability is defined as "the probability of failure-free operation of a computer program for a specified period occurring in a specified environment." Development of Software requires new technologies to deal with size and complexity that is increasing day by day [1]. The component-based software development approach has been established as viable solution to the above problem. The biggest advantage of component-based software engineering is that it supports the reuse of components. Reliability of a component-based system

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increases if the reliable component is reused. These emerged techniques can predict the reliability of component-based applications. The reliability of a system can be predicted either at the system level or component level. System-level reliability prediction is for the application as a whole, and component-based reliability prediction is by the reliability of the individual components and their interconnection mechanisms.

Many researchers have used traditional approaches like software testing to estimate the reliability. During the software test phase, only test data is used to model the software's interactions with the outside world neglecting the structure of software constructed from components as well as the reliability of individual components and is therefore unsuitable for modeling CBSS applications. In recent literature, soft computing techniques deal with uncertainty making it ideal for predicting CBSS reliability. Neural networks and fuzzy logic are the two primary soft computing techniques. This paper outlines an adaptive neuro-fuzzy inference system (ANFIS) model for the prediction of the reliability of CBSS. However, this is a relatively slow and prolonged process. The ANFIS model uses the combination of fuzzy logic and learning capabilities of neural networks to solve the problem making it more advantageous than an FIS model. The ANFIS yields an improvement over an FIS. This paper is divided into five sections. Existing literature is reviewed in Sect. 2. Section 3 describes the framework of proposed ANFIS approach, parameters taken in this study number of faults, cyclomatic complexity, coupling, and cohesion. In Sect. 4, experiment conducted is discussed, followed by result and conclusion in Sect. 5.

2 Related Work

Predicting the reliability of any system is a critical task. Researchers consider different approaches for predicting the reliability. In this study, the focus is on prediction of reliability based on design metric and use of soft computing techniques for the prediction. Many authors conclude that design metrics can be suitably used for predicting the reliability of software [1]. Sehgal and Mehrotra [2] predict the faults before testing phase using the Halstead metric to improve the reliability of software. Tripathi [3] purposed a model for early reliability prediction based on reliability block diagram and found that the coupling is a parameter which affects the reliability of the system. Shatnawi and Li [4] found that software metrics such as CBO, RFC, WMC, DIT, and NOC metrics are efficient to find out the classes predisposed to error. Shin and Willams [5] perform the statistical analysis on different complexity metrics to find the impact of software complexity on security. Graylin [6] presents the high correlation between lines of code and cyclomatic complexity. Subramanyam and Krishan [7] utilize CK metrics suit to find out the fault in an early phase of software development in an object-oriented system. Lee et al. [8] identify that coupling and cohesion as two parameters for component identification for reusability. In a good component, the coupling should be weak, and cohesion should be high. Briand et al. [9] state that cohesion is a parameter to measure the quality of software system and is a degree which tells how firmly two elements belong to each other. Kumar et al. [10] suggest a new measure for the cohesion of class and called it the conceptual cohesion of classes (CCC). It is used to evaluate the strength of class relation to each other conceptually and capturing conceptual aspects of cohesion of classes. This new method measures the quality of the system. System having high cohesion implies high quality. Binkley and Schach [11] state that coupling is suitable quality measure. Yadav and Khan [12] state that higher cohesion decreases the complexity of the software making the system less fault-prone and more reliable. Chowdhury [13] considers complexity, coupling, and cohesion metrics to locate the code vulnerabilities.

Many researchers applied soft computing techniques to various domains such as hydraulic engineering, electrical engineering, flood forecasting [14–17]. ANFIS has gained importance in software engineering field. Nagpal et al. [18] identify relevant parameters of an educational Web site for evaluating the usability of the site using ANFIS. Kaur et al. [19] predict the software maintenance efforts and compare various soft computing techniques. Ardil and Sandhu [20] considered NASA data set and applied ANFIS to discover the severity of faults. Reliability is an important aspect of any software system. Tyagi and Sharma [21] used ANFIS to estimate the reliability by taking four parameters namely component dependency, operational profile, application complexity, and reusability of the component.

3 Framework for Proposed Model

In this paper, an automated reliability prediction model for component-based software system (CBSS) is proposed using ANFIS, which was proposed in 1992 by Jang [22]. Optimization of parameters of a given FIS can be done by ANFIS by mapping the relation between input and output data through a learning algorithm. In an ANFIS network, nodes and directional links and learning rules are associated. In this study, four important parameters of reliability of component-based software are considered, namely number of faults, cyclomatic complexity, cohesion, and coupling (Fig. 1).

3.1 Number of Faults

A fault is an incorrect step, human mistake in typing, in correct syntax, which causes a software program to work in an intended manner. When a fault executes, it leads to decrease in reliability of the software system. So reliability is inversely proportional to the number of faults. Halstead metric [23] is used to predict the fault before the system undergoes testing phase by evaluating number of operator and operand in a software program.

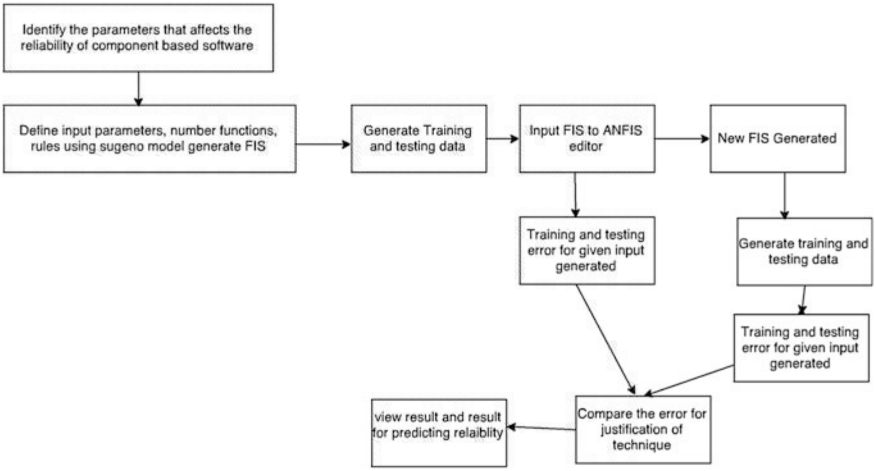

Fig. 1 Framework for proposed model

3.2 Cyclomatic Complexity

Mccabe cyclomatic complexity was developed by Thomas J. McCabe in 1976 to measure the complexity of a program by measuring the number of its decision point. It is a technique which works on the software code by measuring the number of linearly independent path in control graph. Control graph is made up of nodes and edges, whereas nodes represent the group of statements and edges represent the flow of that statement. Complexity of the program is closely related to the reliability of software system. A program number with high decision point will have higher complexity and will have higher probability of occurrence of error in the system.

3.3 Cohesion

Cohesion is a metric which is directly related to the reliability, i.e., higher the cohesion, higher the value of reliability. It measures the strength of the function within a module. Modules with high cohesion are not complex, and they are easy to maintain and can be reusable.

3.4 Coupling

Reliability of a software system is strongly dependent on coupling. Coupling is a metric which measures the interdependency of one module on to another module. If two modules are strongly coupled, then error in one module is propagated to another model thereby decreasing the reliability of software system. Modules which are strongly coupled are more complex, tough to maintain, and difficult to reuse.

4 Experimental Setup

In this paper, ANFIS approach is proposed for the prediction of reliability which depends on the four factors, namely number of faults, cyclomatic complexity, cohesion, and coupling. Intermediate value between conventional evaluations like true/false, yes/no, high/low can be defined with fuzzy logic which is a multi-valued logic [24]. Knowledge base is formed with the number of fuzzy rules (IF-THEN) in a fuzzy reasoning system. Decisions are made by decision-making unit based on this rule. An ANFIS approach combines the benefits of artificial neural network (ANN) and fuzzy logic. The model proposed in this paper is additive in nature.

To create the ANFIS model, fuzzy toolbox of MATLAB is considered. Following are the steps for implementing the ANFIS approach for predicting the reliability:

(i) Crisp values of parameters are provided as input.
(ii) For each parameter, membership functions (low, medium, high) are determined.
(iii) Rules are fired based on the input parameter and membership function.
(iv) Training and testing data for ANFIS editor are evaluated based on fuzzy rules.
(v) Error is evaluated using training and testing data in ANFIS editor.
(vi) To evaluate the network error, a new, trained FIS is created, and same procedure is applied again.

In this study, each input variable has three fuzzy linguistic set (low, medium, high). Fuzzification processes are done by using the triangular membership function (TMF). Values of the input parameter number of faults (NF), cyclomatic complexity (CC), coupling (CP), cohesion (CH) are normalized between [0, 3] for the fuzzification. Defuzzified values give the crisp values between the range [0, 1]. The ANFIS system provides 81 rules and is given in Fig. 2.

Rule set based on above-mentioned parameter for first-order Sugeno fuzzy model is as follows:

Number of faults = NF
Cyclomatic complexity = CC
Cohesion = CH
Coupling = CP
Rule 1
If NF is A_i and CC is B_i and CH is C_i and CP is $D_{i,}$ then

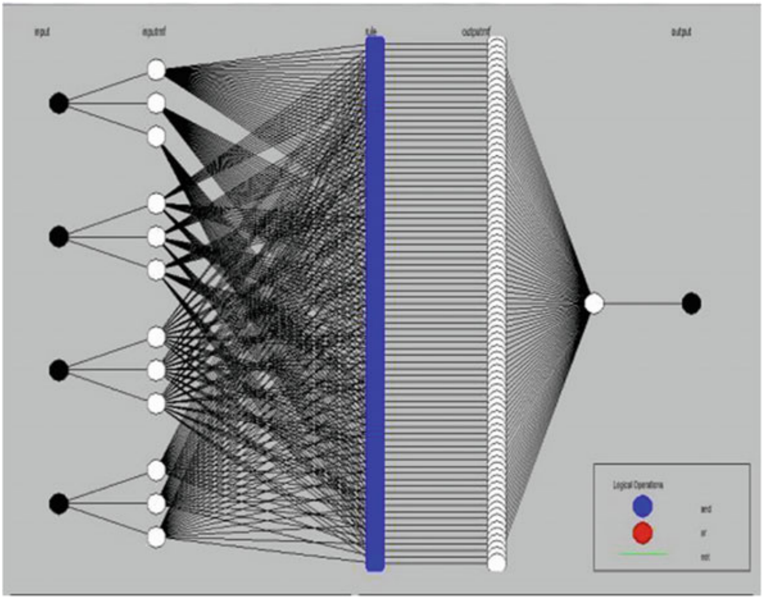

Fig. 2 Proposed architecture

$$F = p_i\mathrm{NF} + q_i\mathrm{CC} + r_i\mathrm{CH} + n_j\mathrm{CP} + m_i \quad (1)$$

Fuzzy sets are represented by A_i, B_i, C_i, and $D_{i,}$ respectively, and during the training process, parameters determined are p_i, $q_{i,}$ r_i, n_i, and $m_{i.}$

5 Results and Conclusion

Data generated is used to train and test the ANFIS. A total of 80% of the data is used for training and rest 20% for testing the network. A total of 81 rules were formed on the basis of the available data. The rules divide the input factors into three variables: low, medium, and high. The training data set was loaded to evaluate the proposed model. ANFIS was trained using the data set. The model is validated using the testing data set, and testing error is plotted as shown in Figs. 3 and 4.

Reliability values obtained by FIS and ANFIS for different input sets are compared after creating the ANFIS model. There is a significant difference in output obtained by FIS and ANFIS which is calculated by root mean square value (RMSE). Error obtained in results using FIS is 10.4%, while it is 1.4% using ANFIS, which shows that the ANFIS gives the better results than FIS as shown in Figs. 3 and 4. FIS is trained using the ANFIS on the basis of training data rules that are formed to produce the output of the trained model.

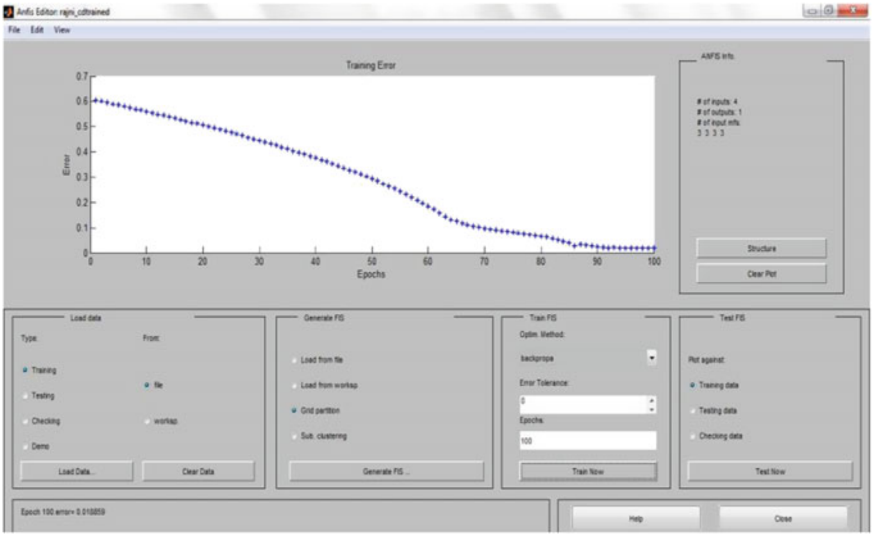

Fig. 3 Mapping original Sugeno FIS to ANFIS training error (1.2%)

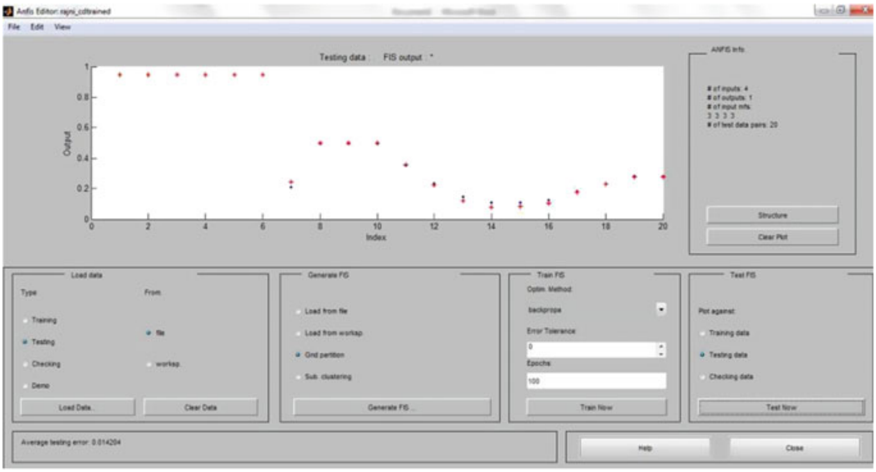

Fig. 4 Mapping original Sugeno FIS to ANFIS testing error (1.4%)

The reliability of component-based system depends on the constitute components and their interaction with each other. In this paper, the only reliability of individual component is predicted before testing phase. Halstead metric for fault prediction, McCabe complexity metrics for predicting complexity of design, coupling and cohesion metrics are used as input for ANFIS model is designed. These metrics can be measured during design and coding stage of software development.

This approach will help to identify which components are reliable and which components need more rigorous testing to achieve the desired level of reliability. To achieve this, firstly FIS model was designed which make more robust by applying artificial neural network principle. The error was reduced by 1.4% using ANFIS.

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